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ABSTRACT

Mortality and serious injury from bycatch of common bottlenose dolphins *(Tursiops truncatus*) in gillnet fisheries along the US Mid-Atlantic coast has been documented by US federal fishery observer programs operating from Maine to North Carolina. This bycatch, while biologically important, consists of statistically rare events that are further complicated by the spatial and temporal overlap of 4 coastal bottlenose dolphin stocks in North Carolina (NC) where stock affiliation is uncertain. To assess the impact on dolphin stocks from observed gillnet bycatch, mean annual minimum and maximum bycatch were calculated by stock and compared to the stock's Potential Biological Removal (PBR) level. A matrix of spatial and temporal stock boundaries was applied to both sampled and total gillnet effort to assign documented bycatch to dolphin stock(s), and a model-averaging approach was used to estimate bycatch for the 4 dolphin stocks. From 2007-2015, 4 bycatch events resulting in mortality were documented by fishery observers, and 1 event resulted in an animal being released alive and not seriously injured. Estimated minimum mean annual bycatch between 2011-2015 was 6.11 (CV = 0.32) for the Northern migratory stocks and 0 or unknown for the remaining 3 stocks. Estimated maximum mean annual bycatch increased between 2011-2015 compared to 2007-2011 for both coastal migratory stocks and the Northern NC estuarine stock. Mean annual maximum bycatch between 2011-2015 was 16.42 (CV = 0.22) for the Northern NC estuarine stock, 12.47 (CV = 0.32) for the Southern migratory stock, and 12.23 (CV = 0.22) for the Northern migratory stock. The recent bycatch estimate for the Northern NC stock is 210% of its PBR. In contrast, recent bycatch estimates for both migratory stocks are below their PBR levels. Stranding data may be a useful indicator to detect bycatch events for the Southern NC Estuarine stock where observer coverage is too low to detect a bycatch event. Fisheries observer monitoring of bottlenose dolphin bycatch should continue to be directed to nearshore coastal waters, particularly in regions adjacent to the coast of North Carolina.

INTRODUCTION

The bycatch of marine mammals in commercial fishing gear is a global conservation issue (Hall et al. 2000; Lewison et al. 2004; Read et al. 2006). Bycatch resulting in serious injury or mortality can result in less than optimal sustainable population (i.e., stock) sizes by causing the population to decline. US laws protecting marine mammals such as the Marine Mammal Protection Act (MMPA; 16 U.S.C 1387) are designed to prevent this level of decline. The MMPA mandates monitoring marine mammal stocks by determining stock structure, estimating the abundance of the stock, and estimating the level of human-induced serious injuries and mortalities. The status of the stock is determined by comparing the level of human-induced serious injuries and mortalities to the Potential Biological Removal (PBR) level (MMPA, 16 U.S.C. 1362 [20]; Barlow et al. 1995; NMFSPD 2012; Wade and Angliss 1997). PBR is derived from the best abundance estimate and its level of uncertainty. When the level of human-induced serious injuries and mortalities caused from bycatch in commercial fisheries (hereafter "bycatch") exceeds PBR, the stock is designated as "strategic." When this occurs, the MMPA requires multi-stakeholder groups called Take Reduction Teams (TRT) to provide regulatory agencies with recommendations of ways to reduce the stock's bycatch to levels below its PBR. To adequately monitor bycatch in commercial fisheries and effectiveness of mitigation measures to reduce bycatch, estimates of bycatch in commercial fisheries per stock are needed. This paper documents bycatch of Northwest Atlantic coastal bottlenose dolphins (*Tursiops truncatus*) in US Mid-Atlantic gillnet fisheries between 2007 – 2015 and focuses on the factors that contributed to the uncertainty in the estimated bycatch: stock definition, statistical methods, fishing effort patterns and observer coverage.

Genetic analyses have been informative to define bottlenose dolphin stocks in the Northwest Atlantic, but presently cannot be used definitively to assign bycatch events to individual coastal stocks (Rosel 2009; Louis et al. 2014). The current state of knowledge about stock structure, range, and movements for the Northwest Atlantic coastal bottlenose dolphin has been informed by a combination of satellite telemetry, photo-identification, stable isotopes, and genetic studies (Garrison et al. 2017a; Mead and Potter 1995; Waring et al. 2014, 2016). Based on these data sources, at least 4 coastal bottlenose dolphin stocks overlap in waters from New Jersey to North Carolina: the Northern Migratory (NM), Southern Migratory (SM), Northern North Carolina Estuarine (NN), and Southern North Carolina Estuarine (SN) stocks (Waring et al. 2016). The 4 stocks have shown differences in geographic movements and habitat usage of estuarine (internal state waters) and oceanic coastal nearshore waters (including state and federal waters). To further complicate the stock structure, there are varying degrees of temporal and spatial habitat overlap among the 4 stocks (Waring et al. 2016; Table 1). The minimum population estimates of abundance for these stocks vary from the larger migratory stocks (8,620 for NM and 6,326 for SM) to smaller estuarine stocks (782 for NN) to currently unknown abundance for the SN stock. More information on the abundance estimates and resulting PBRs are reported in Waring et al. (2016).

When it comes to documenting bycatch events, independent fisheries observers are among the most reliable and accurate source of bycatch data where systematic, design-based sampling programs allow for the estimation of total bycatch attributable to the observed fishery (Brooke 2012; ICES 2011; Lewison et al. 2004; Wigley et al. 2007). Of the known sources of bycatch, passive gillnet gear is considered one of the largest known contributors to bycatch of protected species (Lewison et al. 2014; Moore et al. 2009; Reeves et al. 2013). Marine mammal bycatch involves statistically rare events, but these can be biologically important for stocks with limited population sizes (Cunningham and Lindenmayer 2005; Lewison et al. 2014), such as some stocks of bottlenose dolphins. Complicating factors that limit the ability to collect or analyze the data needed to calculate bycatch estimates for these stocks include: poorly defined stock identification, unreliable estimates of stock size, inconsistent and limited commercial gillnet fishery effort statistics, low levels of observer coverage of the fishery and other logistic constraints. In the past, when bottlenose dolphin bycatch attributed to gillnet fishing gear was more frequent, a generalized linear model (GLM) approach was used to estimate bycatch (Palka and Rossman 2001). As the frequency of observed bycatch events declined, less data demanding methods (i.e. stratified ratio-estimated bycatch rates) and stranding data have been used to estimate bycatch and document bycatch patterns (Byrd et al. 2008, 2014; Lyssikatos 2015; NMFS 2013; Byrd and Hohn 2017).

Historically, some stocks of bottlenose dolphins were designated as strategic because fishery-related serious injury and mortality exceeded PBR (Palka and Rossman 2001; Waring et al. 2016). As a result, the Bottlenose Dolphin Take Reduction Team (BDTRT) was formed in 2001. The BDTRT is a stakeholder group composed of fishermen, conservation groups, state and federal fishery managers, and academic experts who are tasked with recommending mitigation actions to reduce bycatch to levels below PBR. These recommendations formed the basis of the Bottlenose Dolphin Take Reduction Plan (BDTRP), which was implemented in May 2006 and subsequently amended in 2012 (US Dept. Comm. 2006a, 2012). In June 2013, the BDTRT accepted results from the analytical approach described below which evaluates the status of coastal bottlenose dolphin mortality between 2007-2011 caused by commercial gillnet fishing in the US Mid-Atlantic region. These results formed the basis for additional regulatory action necessary to mitigate future mortality, with a focus on vulnerable estuarine stocks off the coast of North Carolina (NCDMF 2014).

The primary purpose of this report is to (1) document the magnitude of impact to the bottlenose dolphin stocks caused by bycatch from gillnet fishing between 2007-2011 that was presented to the BDTRT in June 2013; (2) extend the analysis to include bycatch estimates between 2012-2015; and (3) evaluate observer coverage by stock and water bodies occupied by the 4 coastal stocks. The bycatch estimates for the 4 stocks of bottlenose dolphins account for uncertainties in stock identification, inconsistent and limited commercial gillnet fishery effort statistics, and varying levels of observer coverage of the Mid-Atlantic gillnet fishery. As required by the Stock Assessment Reports (Waring et al. 2016), 5 year mean annual bycatch estimates for each stock were compared to each respective stock's PBR, and levels of fishery observer coverage were investigated.

DATA AND METHODS

The data used to estimate bycatch included (a) observer data collected from a sample of the fishing fleet by the federal Northeast and Southeast Fisheries Observer Programs (NEFOP and SEFOP, respectively) and (b) commercial fishery trip data collected by 3 main sources: vessel trip reports and both North Carolina and Virginia trip tickets, described below.

Study Area

The latitudinal limits of the study area ranged from coastal waters of New Jersey (40.3° N) southward to the North Carolina (NC)/South Carolina (SC) border (33.4° N), including Delaware and Chesapeake Bay estuaries and North Carolina bays, sounds, and estuaries (Figure 1). The offshore extent of the spatial range was limited to estuarine and nearshore, ocean-side habitats occupied by the bottlenose dolphins, which generally extended out to 12 km from shore north of Oregon Inlet, NC, and 27 km from shore south of Oregon Inlet, NC (Figure 1). This study area has a mixture of finfish gillnet fisheries with consistent, broad-scale, annual sampling by fisheries observers (Steve et al. 2001; Kolkemeyer et al. 2009; Waring et al. 2016).

Assigning Observed Bycatch Events to Stocks

Assigning observed bycatch events to individual stocks is fundamental to quantifying potential impact of bycatch and developing future monitoring plans to minimize such impact and meet conservation plan goals (US Dept. Comm. 2006a). Because stocks overlap, observed bycaught bottlenose dolphins can be assigned to more than 1 stock in certain times and areas. To assist with the assignment of bycatch events to individual stocks, a matrix of 6 bimonthly periods and 16 geographic regions (hereafter "bimonthly regional strata") was developed based on the best information available to define stock boundaries (Waring et al. 2016; Table 1).

Estimating Minimum and Maximum Bycatch

Because it was not possible to assign all bycaught bottlenose dolphins to a single stock within some of the bimonthly regional strata, a strategy was developed to bound the bycatch estimate by developing a minimum and maximum range for each stock. For minimum bycatch estimates, stock identification was considered known if an observed bycaught animal was either genetically identified to be affiliated with 1 stock or was taken in a specific bimonthly regional stratum known to be occupied by only 1 stock (hereafter "pure stock"). In contrast, maximum bycatch estimates were based on observed bycatch animals with known stock identification described above plus observed bycaught animals that were taken in bimonthly regions occupied by more than 1 stock. In the latter condition, stock identification is generally unknown, and hence a bycaught animal can be assigned to more than 1 stock (Table 1). As a result, bycatch estimates, observed, and total trips are not additive across the 4 stocks.

Fisheries Observer Data

Data from commercial gillnet fishing trips sampled in the study area by the NEFOP and SEFOP were combined and used to summarize the number of observed bycaught bottlenose dolphins and number of observed gillnet trips (NOAA Fisheries 2011, 2016). NEFOP collected data from 2007-2015. Prior to 2008, the SEFOP did not consistently collect data from gillnet trips in the study area, and thus SEFOP data include only years 2008-2015 (Figure 2).

The state of North Carolina also has an observer program in internal waters of Pamlico Sound that began in 2010 with an emphasis on observing sea turtle interactions (US Dept. Comm. 2013). These data were not included in this analysis because the data are not compatible with the federal NEFOP/SEFOP observer data collection programs because of their differences in data collection and sampling protocols.

Observed gillnet gear in this analysis included anchored and unanchored gear but not run-around gillnets. This gear was fished in all portions of the water column (bottom, mid-water, or surface nets) from traditional and alternative platforms (Kolkmeyer et al. 2007, 2009; NOAA Fisheries 2014).

Because of the low number of federal NEFOP/SEFOP trips observed inside internal waters relative to total gillnet effort (i.e. Pamlico Sound Estuary [PSE] and its adjacent rivers and sounds, Bogue Sound, New River, and Cape Fear River), the sampled trips do not provide an accurate representation of gillnet fishing practices in these areas. As a result, they were not included in the estimation of observed bycatch rates and total bycatch for the NN stock.

Commercial Gillnet Fishing Effort

Data on commercial gillnet fishing effort came from 3 main sources: Vessel Trip Reports (VTR) from New Jersey to Virginia; Virginia Marine Resources Commission (VMRC) trip tickets from internal and state ocean waters; and North Carolina Division of Marine Fisheries (NCDMF) trip tickets from internal, state, and ocean federal waters (NCDMF 2013b; VMRC 2015). Self-reporting of commercial fishing effort is mandatory on VTRs for federally permitted commercial fishing vessels that harvest federally regulated species (NOAA Fisheries 2014). The VTRs include date and location (latitude/longitude coordinates) of fishing trips, type of gear used, target species and weight landed, gear characteristics, water depth, and additional effort variables (http://www.greateratlantic.fisheries.noaa.gov/aps/evtr/doc/vtr_inst.pdf).

A large fraction of the bottlenose dolphins stocks' habitat and a significant portion of the commercial gillnet effort occur in state waters adjacent to Virginia and North Carolina, but this region is not fully captured by the VTR data. To estimate total gillnet trips in this habitat, the VMRC trip ticket program was used to quantify the number of gillnet trips by state registered vessels that primarily harvest nonfederally managed species in internal and state waters. In addition, data from the NCDMF trip ticket program were also used to quantify the number of gillnet trips by state and federally registered vessels harvesting both state and federally managed species in internal, state, and federal waters.

Unlike VTR data that include average trip location latitude and longitude coordinates, commercial trips from the VMRC and NCDMF only include temporal (year and month) and broad spatial characteristics (county or water body) for use in assigning fishing trips to the bimonthly regional strata defined in Table 1. VTR data included in the analysis were from state and federal water bodies within coastal bottlenose dolphin habitat adjacent to the states of New Jersey, Delaware, Maryland, and federal waters of Virginia. VMRC state water bodies included in the analysis were from Chesapeake Bay (upper and lower east side, upper and lower west side), state ocean waters off Virginia Beach, and state ocean waters off the Eastern Shore. NCDMF trips were included from 16 internal, state, and federal ocean water bodies representing > 93% of reported gillnet trips for the state of North Carolina (Albemarle Sound, Bogue Sound, Cape Fear River, Core Sound, Croatan Sound, Currituck Sound, Neuse River, New River, Pamlico River, Pamlico Sound, Pungo River, Roanoke Sound, ocean 0-3 mi N. of Cape Hatteras, ocean 0-3 mi S. of Cape Hatteras, ocean >3 mi N. of Cape Hatteras, ocean >3 mi S. of Cape Hatteras). NCDMF trips from internal water bodies were used only to compute observer coverage by water body. They were not used in the calculation of estuarine stock mortality estimates and observer coverage in time and areas occupied by the 2 estuarine stocks because of insufficient observer coverage in NC internal waters.

A fishing trip is the only measure of fishing effort consistently reported and available among the observer, VTR, VMRC, and NCDMF data. As a result, trips were used as the unit of effort to estimate (1) bycatch rates of bottlenose dolphins; (2) total bycatch by the commercial gillnet fleet; and (3) observer coverage, by water body and stock.

Model Averaging of Estimated Mortality from Observer Data

Two approaches using a simple expansion method were used to estimate total bycatch mortality of bottlenose dolphins based on annual trips (annual ratio method [ARM]) and trips pooled over multiple years (pooled ratio method [PRM]) (Cochran 1977). The 2 methods resulted in bycatch rate estimates that then were multiplied by total number of commercial gillnet fishing trips to estimate total bycatch mortality for each stock where:

(1) ARM: $M_{ys} = R_{ys} * E_{ys}$ and (2) PRM: $M_{ys} = R_s * E_{ys}$

(2) $R_{ys} = \sum t_{yis} / \sum n_{ys}$ and (2a) $R_s = \sum t_{is} / \sum n_s$

where

M is the estimated total gillnet bycatch mortality;

R is the mean observed bycatch rate;

E is the number of commercial gillnet trips;

t is the number of observed takes;

n is the number of observed trips;

i is trip;

y is year;

s is the combinations of bimonthly time periods and spatial strata occupied by a stock;

The final average estimate of bycatch (for both minimum bycatch and maximum bycatch) is the average of the 5 year mean mortality estimate from both the ARM and PRM, which was weighted by the inverse of the coefficient of variance (CV); thus, giving more weight to the estimate with greater precision.

(3) $$\overline{M}_{s\omega} = (\overline{M}_{s1} \cdot \omega_1 + \overline{M}_{s2} \cdot \omega_2) \cdot CV_{\overline{M}_{sw}}$$

where

$\overline{M}_{s\omega}$ = 5 year weighted mean mortality estimate by stock;

$\overline{M}_{s}$ = 5 year mean mortality by stock; *1* = ARM; *2* = PRM;

ω = Inverse of the CV from 5 year mean mortality estimate; *1* = ARM; *2*= PRM;

(4) $$CV_{\overline{M}_{sw}} = 1/(\omega_1 + \omega_2)$$

Coefficients of variation (CVs) for the annual bycatch estimates (eq. 1-2) were calculated with a bootstrap procedure where observed trips were resampled, generating 1000 mean bycatch rates per method. It was assumed there was no uncertainty in the total effort (number of gillnet trips).

The standard error of the 1000 bootstrapped mean ARM or PRM bycatch rates were divided by the respective observed bycatch rate to estimate the CVs. The composite CVs for the 5 year (2007-2011; 2011-2015) mean mortality estimates (eq. 3) per method were calculated following marine mammal stock assessment guidelines (Wade and Angliss 1997).

Observer Coverage

Using ArcMap (vs.10.3.1) software, all observed gillnet trips and trips from VTR effort data were assigned to bimonthly regional strata (Table 1) based on the date and location of each trip. NCDMF county and month level trip data and VMRC monthly trip data from state waters were assigned to the bimonthly regional strata based on counties and water bodies with boundaries adjacent to the spatial strata defined in Table 1. Then the percent coverage of total commercial gillnet fleet trips by water body and stock was estimated. Water bodies were defined as the following: internal (bays, sounds, estuaries); ocean state waters (0-5.6 km from shore); and ocean federal waters (5.6-370.4 km from shore). Stock regions are defined by the bimonthly regional strata in Table 1.

RESULTS

Observed Fishery Interactions

Between 2007 and 2015, 5 bottlenose dolphin takes were documented by fisheries observers (Table 2). Three of the 5 observed takes occurred inside the nearshore coastal region adjacent to Dare and Hyde counties (Table 1; Figure 1-2). Two of the 5 takes occurred during the January/February bimonthly period, 2 during September/October bimonthly period, and 1 during July/August bimonthly period (Tables 1-2). Three of the 5 observed takes occurred in small mesh (< = 5”) and 2 in medium mesh (>5” <7”) gillnet gear. Four of the 5 observed takes occurred in gillnets with soak durations < 6 hours and 1 with soak duration = 24 hours. Two of the takes were observed in the Spanish mackerel (*Scomber scombrus*) fishery and 3 in dogfish fisheries (Table 2).

One dolphin observed in 2013 in February (small mesh and < 1 hour soak duration) was released alive and hence not included in the bycatch analysis described in this report (Wenzel et al. 2015). Of the 4 remaining observed mortalities, 2 were observed by the SEFOP, and 2 were observed by the NEFOP.

The October 2009 take observed by the SEFOP off North Carolina north of Oregon Inlet was 1.1 km from shore. This location indicates the animal would be assigned to the NM and SM stocks but is only 0.1 km outside the 1-km spatial boundary for the NN stock (Table 2; Figure 2). Given the close proximity to NN habitat, this take was also assigned to NN in addition to NM and SM stocks (Tables 1-2). Out of the 4 observed mortalities, 3 were assigned to NN, 0 to SN, 2 to SM, and 3 to NM. Because of month and location variability, only 1 out of the 4 observed mortalities could be purely assigned to one stock – NM (Table 2; Figure 2). Between 2011-2015 the majority of observed bycatch events occurred in stratum 7, where the NN stock overlapped with the NM during the Jan/Feb bimonthly period and with the SM stock during the Sep/Oct bimonthly period (Table 1-2).

Commercial Gillnet Trips and Observer Coverage

Overall magnitude of commercial effort (number of trips) between 2007-2015 ranged from 25,584 in 2015 to 45,261 trips in 2007. Trips in internal waters have consistently contributed greater than 70% of effort during the time series, followed by trips in state waters and then federal waters (Table 3; Figure 3). Mean annual commercial gillnet fishing effort decreased from 39,811 trips between 2007-2011 to 32,925 between 2011-2015 (Table 3).

The number of observed trips between 2007-2015 ranged from 205 in 2011 (<1% coverage) to 547 trips in 2015 (2% coverage; Table 3). Total observer coverage steadily declined from 2007 to 2011 and subsequently increased steadily to 2015 (Table 3). Observer coverage was lowest in internal waters (<1% on average, range 40-130 trips), higher in state waters (nearly 3% on average, range 89-270 trips), and highest in federal waters (averaging 5%-9%, range 71-149 trips; Table 3 and Figure 3). Observer coverage in the state and federal waters of the coastal bottlenose dolphin habitat averaged 4% between 2007-2011 compared to 3% between 2011-2015 (Table 3).

Total trips and observer coverage (excluding NC internal waters) were also evaluated by stock region (Figure 4). Total trip effort was highest in NM stock region followed by NN and SM, each with similar magnitude of effort, and lowest in the SN region (Figure 4). Mean annual coverage in the NN region increased from 1.7% between 2007-2011 to 2.3% between 2011-2015. This contrasts with the SN region, where coverage decreased from 3.0% to 1.1% across the 2 time periods. In recent years mean annual observer coverage was highest (3%) and lowest (1%) in water bodies occupied by the NM and SN stocks, respectively (Figure 4).

Estimated minimum and maximum gillnet mortality

There was only 1 minimum estimate for any of the stocks between 2007-2015 since there was only 1 take that was able to be identified/assigned confidently to just 1 stock, which was for NM. This estimate led to a weighted mean annual minimum bycatch for NM of 6.11 animals (CV = 0.32) between 2011-2015. The weighted mean annual maximum bycatch averaged across years and methods (ARM and PRM) for 2007-2011 was 12.60 (CV = 0.30) for the NN stock, 8.20 (CV = 0.32) for the NM stock, and 10.94 (CV = 0.30) for the SM stock (Table 4). For 2011-2015 the weighted mean annual maximum estimates increased to 16.42 (CV = 0.22) for the NN stock, 12.23 (CV = 0.22) for the NM stock, and 12.47 (CV = 0.31) for the SM stock (Table 5). There were no observed takes from regions occupied by the SN stock, however observer coverage was too low to detect a bycatch event (Figure 5 further described below). Consequently, the bycatch estimate for the SN stock is unknown.

During both 5 year time periods, mean maximum annual estimated bycatch was less than PBR for both NM and SM stocks (Tables 4 and 5). Mean maximum annual estimated bycatch for the NN stock increased from 161% of PBR between 2007-2011 to 210% of PBR between 2011-2015 (Table 5). Abundance is presently unknown for the SN stock. Consequently, PBR is also unknown for the SN stock.

DISCUSSION

Between 2007 and 2015 (9 years), only 5 bottlenose takes were observed in Mid-Atlantic commercial gillnet fisheries. Three of the 5 (60%) observed takes were observed in stratum #7, the coastal region ranging from NC Oregon Inlet to Hatteras Inlet (Table 2; Figures 1-2). Patterns in gillnet fishing trip effort in state and federal water bodies were largely consistent over the entire time series, while effort in internal waters declined (Figure 3). On average, trips from internal waters represented nearly 80% of total trips, with the remaining 15% and 5% from state and federal waters, respectively (Table 3; Figure 3). On the other hand, there was an inverse pattern in observer coverage. Coverage on average was lowest in internal waters (<1%), moderate in state waters (3%), and highest in federal waters (>5%; Table 3, Figure 3). Annual observer coverage in state waters incrementally increased from a low of 0.62% in 2011 to a high of 4.74% in 2015, contributing to increased detections of observed bycatch events during the 2011-2015 time period.

The pattern in total trip effort by stock was also consistent over the time series within the regions occupied by the 4 stocks (Figure 4). Total trip effort in regions occupied by the NM, SM, and NN stock showed consistent trends because several of the stocks overlap in space and time (Table 1; Figure 1). For example, 28% (9 out of 32) spatial/temporal strata are known to be occupied by both the SM and NN stocks (Table 1). That means that 28% of trip effort is coming from the same spatial/strata for these 2 stocks. Total trip effort in the SN region was several orders of magnitude lower than the other stock regions. Average observer coverage by stock region between 2011-2015 ranged from approximately 1% in the SN region to 3% in the NM region. Average observer coverage declined in both SN and SM stock regions but increased for both the NM and NN stock regions (Figure 4).

Observed bycatch rates and mean maximum coastal bottlenose dolphin gillnet bycatch increased between 2011-2015 for NN, SM, and NM relative to the previous 5 year time period (2007-2011; Table 6, Figure 6). However, these increases resulted in an unsustainable take level only for the NN stock (210% of its PBR; Table 5). In contrast, the mean maximum bycatch levels for the NM and SM stocks ranged from 24% and 46% of their respective PBRs and SN bycatch is unknown.

Because of the disparity in population size among all 4 stocks, there is a differential impact of bycatch mortality among stocks when weighed against the stocks' PBRs (Waring et al. 2016). Bycatch estimates from fishery observer data show NN is subject to the highest level of bycatch mortality relative to its PBR. The SN stock is also particularly vulnerable because, although PBR is unknown and bycatch has not been observed, the observer coverage is too low to detect bycatch events in southern coastal waters of NC (Figure 5). Stranding data also indicate that bycatch is occurring in times and areas occupied by the SN stock. For example, Byrd et al. (2008) discusses the presence of strandings with evidence of fishery interactions associated with the small-mesh spot (*Leiostomus Xanthurus)* fishery in southern coastal waters of NC in the absence of observed bycatch events. Consequently, stranding data are now playing a more central role in monitoring the impact of gillnet fishery bycatch on the stocks of coastal bottlenose dolphins in the Mid-Atlantic region of the United States (Waring et al. 2014; NMFS 2013). Although the coastal NM and SM stocks are below their respective PBRs, in light of a recent bottlenose dolphin unusual mortality event (UME), these stocks should continue to be monitored for interactions with commercial fisheries. A bottlenose dolphin UME was declared by NOAA Fisheries for the Mid-Atlantic region between 2013-2015. During this time 1,827 dolphins stranded, and cause of death is preliminarily associated with cetacean morbillivirus and Brucella sp. bacteria (NOAA Fisheries 2015).

Several factors contributed varying degrees of uncertainty into the estimated bycatch of bottlenose dolphins in Mid-Atlantic fisheries: stock definition, statistical methods, fishing effort patterns, and observer coverage. Each factor is discussed below.

Assigning observed takes to a stock

The limited ability to differentiate observed takes among unique stocks is a large source of uncertainty in this analysis. Out of 96 bimonthly spatial strata, 28 (29%) are occupied by 2 or more stocks (Table 1). Based on month and spatial location, only 1 of the 4 observed mortalities could be considered "pure" and was uniquely assigned to the NM stock (Tables 1-2, 5). Assigning the remaining 3 observed takes to more than 1 stock because of their spatial and temporal overlap among stocks is an analytical approach that allows for comparisons among the stocks to evaluate relative impact to the populations' PBR (NMFS 2016). However, estimating both minimum and maximum bycatch adds an additional layer of complexity by presenting 2 extreme scenarios: the minimum considers only bycatch events that are certain to involve each stock (i.e., pure stock ID assignments), and the maximum considers all observed takes that could possibly involve each stock, thus resulting in 2 quite different estimates. An alternative approach, considered by the Atlantic Scientific Review Group during its 2017 meeting (NOAA Fisheries 2017), could be to apportion observed bycaught animal(s) to a stock when given estimates of relative proportions of each stock in each bimonthly regional stratum based on available stock identification data. This approach would avoid the complexity with maximum bycatch estimates that are not additive across stocks, but it introduces the stock identification uncertainty into the singular bycatch estimate (i.e., the uncertainty in stock proportions). This approach should be evaluated and compared to other analytical approaches (see next section on Statistical Methods below).

Given the current state of knowledge on stock distribution, the largest degree of temporal stock overlap occurs in strata where at least 3 stocks can be present (Table 1). During the Sep/Oct timeframe the NM, SM, and NN stocks may inhabit waters of Chesapeake Bay and adjacent coastal waters of Virginia (strata 3 and 4; Table 1, Figure 1). During the Mar/Apr timeframe the same 3 stocks may also co-occur in North Carolina coastal waters adjacent to Carteret County (stratum 9). During the Sep-Oct time period farther south in North Carolina, the SM, SN, and NN stocks may co-occur in coastal waters between Cape Lookout and New River Inlet (stratum 12; Table 1, Figure 1).

Statistical Methods

Palka and Rossman (2001) used a Generalized Linear Model to estimate bottlenose dolphin bycatch rates during a time period (1996-2000) when takes were more frequent, bottlenose dolphins were not managed by stock, and there was no take reduction plan. Estimating marine mammal bycatch rates in a modeling framework generally provides increased precision, thereby reducing statistical uncertainty bounding the model based estimates (Carretta et al. 2017; Orphanides 2009).

Since 2002 bottlenose dolphin bycatch events became increasingly rare with changes in fishing conditions relative to the earlier time period (Figure 7). For example, during the same time the first BDTRT was convened in 2001, the medium-mesh, spiny dogfish fishery was closed down, a fishery shown to have relatively high bottlenose dolphin bycatch rates and mortality estimates (Byrd et al. 2008; NMFS 2005; Palka and Rossman 2001; US Dept. Comm. 2006b). Fishing practices such as long soak durations were subsequently restricted for medium-mesh fisheries in 2006 with the implementation of the BDTRP (US Dept. Comm. 2006a).

The resulting rarity in observed bycatch events limited the utility of the GLM approach, so it was dropped in favor a simple stratified ratio estimate of bycatch to effort described in this report (Waring et al. 2016). Further exploratory analyses could be undertaken to determine if an appropriate data set from the historical time series can support more advanced statistical methods for estimating future bottlenose dolphin bycatch (e.g., GLM, generalized additive model [GAM], regression trees, Bayesian model frameworks, or mixture models) with the aim of better characterizing and minimizing uncertainty around annual bottlenose dolphin bycatch estimates. It is important to note that no statistical method can overcome the data collection program shortcomings that plague bottlenose dolphin bycatch analysis in the US Mid-Atlantic region (i.e., limited sample sizes, limited biological samples to support stock assignments, inconsistent reporting of effort, and limited spatial resolution across data sources).

The ratio of observed bycatch to the sampling unit (trip) provides an unbiased mean bycatch rate for bottlenose dolphins stratified by stock (Cochrane 1977). However, the ARM and PRM expansion methods each have their own statistical advantages and disadvantages. An ARM can exhibit extreme interannual variability, low precision (because of rare events, small sample size, and over stratification). The ARM also results in deflated annual estimates and inflated variance from years with no observed bycatch when there was insufficient observer coverage to detect these rare bycatch events and surrounded by years with observed bycatch. However, the ARM approach is not vulnerable to overlooking small interannual changes in fishing practices that could potentially have an important effect on bottlenose dolphin bycatch rates. This method contrasts with the PRM that exhibits less interannual variability because there are not any annual estimates equal to zero, and higher precision from larger sample sizes as a result of more positive events from pooling data over multiple years. When ignoring the year effect, pooling assumes that fishing practices were consistent among the years being pooled.

It is uncertain whether small changes in fishing practices in addition to increased observer coverage between 2011-2015 contributed to an increase in observed bycatch (Table 2, 6; Figure 4). For example, overall good compliance with fishing practices regulated by the BDTRP resulted in consistent fishing practices between 2007-2011 (NMFS 2013). Comparatively, Figure 8 provides a closer look at some of the more subtle changes in fishing practices in the NN stock region between 2011-2015 (e.g., small increases in medium-mesh soak duration and total gear length), even though overall recent fishing practices demonstrate conditions still largely within the confines of BDTRP regulations (compliance ranging from 72-100%). This is in spite of a >50% increase in landings of medium-mesh spiny dogfish in Northern NC between 2011-2015 (Table 7; Figure 9).Concurrently, coverage of the NN stock region decreased from 2007 to 2011 and subsequently increased from 2011-2015. Thus, making inferences from more than one method, such as averaging the results from both the ARM and PRM, provides more robust results by taking into account uncertainty and conditions between these two methods (Burnham and Anderson 2002).

Observer Coverage

Low sampling in the internal and state waters relative to federal waters contributes to uncertainty in estimating dolphin bycatch particularly for the North Carolina estuarine stocks (Table 3 and Figure 3). Internal and coastal waters of North Carolina and Virginia are inhabited by the NN and SN estuarine stocks (Waring et al. 2016) that are considered the most vulnerable because of their low or unknown population sizes. An evaluation of sample sizes required to observe at least one bycatch event in 2015 showed a near 50% chance of observing bycatch in regions occupied by the NM and NN stocks, given the 2015 level of observer coverage and recent mean maximum mortality estimates (Figures 10-11). The same analysis indicated that there was only a 25% chance of observing a bycatch event in the SM stock region (Figure 12).

Observer coverage in regions occupied by the SN stock would need to be greater than 10% to approach a 50% probability of observing at least 1 bycatch event if mean annual mortality is expected to be near the last reported PBR of 1.6 for this stock (Waring et al. 2014; Figure 5).

Stranding data are commonly used to highlight areas and timing of bycatch mortality where observer coverage may be absent or limited (Byrd et al 2008, 2014, 2017; Friedlaender et al. 2001; Carretta et al. 2015). Although the shoreline outlining the Pamlico Sound portion of internal North Carolina waters is largely inaccessible and not conducive to opportunistic reporting of stranded carcasses, a state-run observer program of primarily medium-mesh gillnets has not reported any dolphin bycatch (Byrd et al. 2014; Wells 2015; NCDMF 2013a). This reporting is in addition to the NEFOP coverage of predominantly small-mesh gillnets that also has not reported any dolphin bycatch. Given the high fishing effort in internal waters of Pamlico Sound, NEFOP coverage is likely too low to detect rare bycatch events, which could be a reason why bycatch has never been observed in this habitat. Alternatively, it is also possible that fishing practices inside PSE and other internal water bodies are different from coastal state waters, resulting in reduced interactions with dolphins. Further information is needed to determine if and why the bycatch level of dolphins could be lower in internal waters than coastal waters in North Carolina. Also, it is not clear how important internal waters of Delaware and Chesapeake Bay are to the NM and SM and estuarine stocks (Waring et al. 2014).

In some cases stranding data may be a more consistent indicator of spatial/temporal bycatch patterns and relative levels of bycatch than dedicated observer programs with inconsistent or low coverage. There are efforts to scale stranding data to account for the percentage of dead dolphins that do not reach the shore (Peltier et al. 2012; Carretta et al. 2015). However, stranding data are not a perfect substitution for fisheries observer data and can vary depending on regional habitat characteristics. Bycatch events documented by fisheries observers provide further clues as to predictors of bycatch (e.g., mesh size, soak times, target species) that can lead to the identification of potential mitigation measures to reduce bycatch (Palka and Rossman 2001). As such, given the uncertainty in stock identification and limited observer coverage in habitat important to the estuarine stocks, stranding data and observer data are best used together to supplement our understanding on potential bycatch hot-spots by comparing observed bycatch with stranding events in time and space (Waring et al. 2016).

The most striking finding of the analysis of fishing and observed trips by water body was the inverse relationship between the 2. Mean observer coverage was highest in federal waters where total gillnet effort was lowest. This pattern has negative implications for observing and estimating total bycatch of coastal bottlenose dolphins because all 4 stocks occur primarily in the nearshore coastal (< 3 miles) waters. The discovery of the inverse relationship between fishing trips and observer coverage suggests the need for future adjustments of the spatial distribution of observer coverage which should improve the accuracy and precision of future bycatch estimates. With the onset of significant changes in commercial gillnet fishing regulations and implementation of the Bottlenose Dolphin Take Reduction Plan (BDTRP) to mitigate future bycatch, declining gillnet bycatch events will become more difficult to detect with status quo sampling rates in coastal state and federal waters ranging from 3% to 5% on average (Byrd et al. 2008; NCMFC 2002; NMFS 2005; US Dep. Comm. 2000, 2002, 2006; Waring et al. 2014). Statistical power tests have shown that cost prohibitive and impractical observer coverage levels would be required in the estuarine stock regions to detect small but biologically significant reductions in bycatch with a high degree of confidence. Large increases to the implementation of the NEFOP observer sea days are not feasible because of funding and work-force capacity limitations and other logistical constraints related to commercial gillnet fleet dynamics, particularly for the regions adjacent to the state of NC (Rossman 2007).

For internal waters of NC, the NCDMF is required by the NMFS to obtain 7% coverage of gillnet trips for gillnets with a mesh size of $\geq$ 10.2 cm stretch mesh (“large mesh”) and 1% coverage for gillnets with a mesh size of < 10.2 cm stretch mesh (“small mesh”) (NCDMF 2013a). NC state observer effort is directed at documenting sea turtle and other protected species bycatch in estuarine gillnets. Given the state’s resources dedicated to $\geq$ 7% observer effort, it would be more economical and efficient to redirect the limited resources to monitoring bycatch in nearshore coastal waters only.

Gillnet Effort Data

The term “gillnet trips” has been used interchangeably with the term “effort” throughout this report. However, trips are not a true measure of effort, such as the quantity of gear and the amount of time the gear has been fished (e.g., total soak hours, product of number of nets fished and soak hours, product of number of nets, and length of nets and soak hours). The absence of a measure of true fishing effort is a consequence of not having total number of nets, net length, or total soak hours available across the 3 commercial fishery databases. Hence, bycatch rates are not a function of true effort in this analysis. The bycatch rates are simply a mean estimate of observed bycatch events, considered to be unbiased because the denominator is the sampling unit that is monitored by an observer (Table 6).

Unlike VTR data, the VMRC and NCDMF only include broad spatial characteristics (i.e., statistical area, county, and water body) for assigning fishing trips to spatial strata. Consequently, the Virginia and North Carolina counties and water bodies identified in their trip ticket programs do not perfectly align with spatial stock structure strata that are adjacent to these states (Table 1). As a result, gillnet trips fishing in spatial strata 4-16 may be over or underestimated. The degree and direction of bias is undetermined.

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Table 1. Matrix depicting temporal and spatial distribution and overlap of 4 coastal bottlenose dolphin (*Tursiops truncatus*) stocks (NM = gray, SM = pink, NN = blue, SN = yellow, stock overlap = cross hatched) based on bimonthly periods and 16 geographic regions (Figure 1). The 16 strata were developed by using telemetry, biopsy, and stable isotope data (Waring et al. 2016). Cells that include characters t, u, v, w identify all gillnet takes that were observed between 2007-2015 which are further described in Table 2 and shown in Figure 2.

Geographic Region	Stratum Type	Stratum No.	Jan/ Feb	Mar/ Apr	May/ Jun	Jul/ Aug	Sep/ Oct	Nov/ Dec
Delaware	Estuary (Delaware Bay)	1						
New Jersey, Delaware, Maryland	Coastal & Offshore	2				x		
Maryland & Virginia	Estuary (Chesapeake Bay)	3						
Virginia & North Carolina	Coastal	4					t	
Virginia & North Carolina	Offshore	5					t, t	
North Carolina	Estuary (Pamlico Sound)	6						
North Carolina – Dare & Hyde Counties	Coastal	7	*u,w*, *u,w*				v, v	
North Carolina – Dare & Hyde Counties	Offshore	8						
North Carolina – Carteret County	Coastal	9						
North Carolina – Carteret County	Offshore	10						
North Carolina – Onslow County	Estuary (Bogue Sound & New River)	11						
North Carolina – Onslow County	Coastal	12						
North Carolina – Onslow County	Offshore	13						
North Carolina – Pender, New Hanover, Brunswick Counties	Estuary (Cape Fear River)	14						
North Carolina – Pender, New Hanover, Brunswick Counties	Coastal	15						
North Carolina – Pender, New Hanover, Brunswick Counties	Offshore	16						

Table 2. Descriptive characteristics for observed takes of coastal bottlenose dolphin (*Tursiops truncatus*) from 2007 to 2015.

Key [1]	Yr	Mo	Obs Prog [2]	Target Species	NEFSC Tag Number	Sample status [3]	Stock (O/C) [4]	State	County	Depth (m)	Coastal Habitat	Mesh Size (inches)	Soak Time (hrs)	Twine Size (mm)	String Length (feet)	Stock ID	Stratum # [1]	Comments
t	2009	10	*SE*	Spanish Mackerel (*Scomber scombrus*)	no tag	NA	unk	NC	Dare	12.2	state	3.8	5.9	unk	1200	SM or NM or NN	4 or 5	released dead- distance from shore = 1.1km
u	2013	2	NE	Spiny Dogfish (*Squalus acanthius*)	*released alive*	NA	unk	NC	Hyde	5.5	state	3.8	0.6	0.90	1200	NM or NN	7	released alive - not seriously injured[5]. Distance from shore = 1.8km
v	2014	9	*SE*	Spanish Mackerel (*Scombero morous maculatus*)	no tag	NA	unk	NC	Hyde	11.5	state	3.3	2.1	0.52	900	SM or NN	7	released dead- distance from shore = 0.9km
w	2015	1	NE	Spiny Dogfish (*Squalus acanthius*)	DO5666	C	tbd	NC	Hatteras	3.6	state	5.8	2.5	0.81	900	NM or NN	7	released dead- distance from shore = 0.23km
x	2015	8	NE	Smooth Dogfish (*Mustelus canis*)	no tag	NA	unk	NJ	Ocean	21.9	state	6.0	24.0	0.90	300	NM	2	released dead- distance from shore = 5.4km

[1] Key letter and stratum number correspond with ArcMap shapefiles that delineate temporal and spatial habitat regions occupied by coastal bottlenose dolphins- see Table 1 and Figure 1.

[2] Takes observed by the Southeast (SE) or Northeast (NE) observer program.

[3] Sample status NA = no sample was collected; C = collected

[4] Stock = Offshore (O) or Coastal (C) determined by genetic analysis. If no sample collected then stock affiliation cannot be confirmed by genetic analysis. All unknowns (unk) are presumed to be coastal animals based on the time of year (i.e., month) and location of take (i.e., region). TBD = to be determined.

[5] Wenzel et al. 2015.

Table 3. Summary table of total and observed gillnet trips by year and water body. Mean annual calculations are provided for two 5 year time periods: 2007-2011 and 2011-2015. Water bodies considered part of coastal bottlenose dolphin (*Tursiops truncatus*) habitat: Internal = bays, sounds, and estuaries; State = 0-5.6 km from shore; Federal (Fed) >5.6 km from shore and within bottlenose dolphin habitat (<12-27 km from shore, Figure 1).

Year	Water Body	Total Trips	Observed Trips	Coverage (%)	Coastal (State & Fed) Coverage only
2007	Internal	36783	90	0.24	
	State	7520	303	4.03	
	Fed	958	145	15.14	
	Total	45261	538	1.19	5.28
2008	Internal	35735	101	0.28	
	State	5991	197	3.29	
	Fed	834	102	12.23	
	Total	42560	400	0.94	4.38
2009	Internal	36315	100	0.28	
	State	5543	161	2.90	
	Fed	950	71	7.47	
	Total	42808	332	0.78	3.57
2010	Internal	28561	130	0.46	
	State	5607	162	2.89	
	Fed	1043	110	10.55	
	Total	35211	402	1.14	4.09
2011	Internal	24845	40	0.16	
	State	6287	89	1.42	
	Fed	2082	76	3.65	
	Total	33214	205	0.62	1.97
2012	Internal	25407	42	0.17	
	State	6454	122	1.89	
	Fed	2223	106	4.77	
	Total	34084	270	0.79	2.63
2013	Internal	30239	75	0.25	
	State	6199	148	2.39	
	Fed	1985	105	5.29	
	Total	38423	328	0.85	3.09
2014	Internal	24039	44	0.18	
	State	7042	216	3.07	
	Fed	2237	115	5.14	
	Total	33318	375	1.13	3.57
2015	Internal	18144	128	0.71	
	State	5696	270	4.74	
	Fed	1744	149	8.54	
	Total	25584	547	2.14	5.63
Five Year Mean 2007-2011	Internal	32447.8	92.2	0.28	
	State	6189.6	182.4	2.95	
	Fed	1173.4	100.8	8.59	
	Total	39810.8	375.4	0.94	3.86
Five Year Mean 2011-2015	Internal	24534.8	65.8	0.27	
	State	6335.6	169.0	2.67	
	Fed	2054.2	110.2	5.36	
	Total	32924.6	345.0	1.05	3.38

Table 4. For the years (2007-2011), the minimum (pure stock identification: when observed bycaught animal was either genetically identified to be affiliated with 1 stock or was taken in a specific bimonthly regional stratum known to be occupied by only 1stock) and maximum (pure + mixed stock identification when observed bycaught animals were taken in bimonthly regions occupied by more than 1 stock) mean gillnet bycatch mortality and coefficient of variation (CV) by stock (NM = Northern Migratory, SM = Southern Migratory, NN = Northern North Carolina Estuarine,) and method (ARM = Annual Ratio, PRM = Pooled Ratio). Note, observer coverage was too low to detect a bycatch event in the Southern North Carolina Estuarine (SN) stock region (Figure 6). Consequently, mean mortality is unknown and not reported for this stock. CI = 95% Confidence Interval, PBR = potential biological removal level (% is relative to maximum mortality estimate).

	NM				SM				NN			
	Min		Max		Min		Max		Min		Max	
Year	ARM	PRM	ARM	PRM	ARM	PRM	ARM	PRM	ARM	PRM	ARM	PRM
2007	0.00 (NA)	0.00 (NA)	0.00 (NA)	8.45 (1.08)	0.00 (NA)	0.00 (NA)	0.00 (NA)	12.01 (0.97)	0.00 (NA)	0.00 (NA)	0.00 (NA)	14.35 (0.95)
2008	0.00 (NA)	0.00 (NA)	0.00 (NA)	7.48 (1.08)	0.00 (NA)	0.00 (NA)	0.00 (NA)	10.54 (0.97)	0.00 (NA)	0.00 (NA)	0.00 (NA)	10.72 (0.95)
2009	0.00 (NA)	0.00 (NA)	47.6 (0.95)	7.55 (1.08)	0.00 (NA)	0.00 (NA)	64.18 (0.99)	11.04 (0.97)	0.00 (NA)	0.00 (NA)	69.48 (0.98)	12.24 (0.95)
2010	0.00 (NA)	0.00 (NA)	0.00 (NA)	6.36 (1.08)	0.00 (NA)	0.00 (NA)	0.00 (NA)	8.23 (0.97)	0.00 (NA)	0.00 (NA)	0.00 (NA)	10.56 (0.95)
2011	0.00 (NA)	0.00 (NA)	0.00 (NA)	7.82 (1.08)	0.00 (NA)	0.00 (NA)	0.00 (NA)	8.67 (0.97)	0.00 (NA)	0.00 (NA)	0.00 (NA)	12.26 (0.95)
Mean	0.00 (NA)	0.00 (NA)	9.52 (0.95)	7.53 (0.48)	0.00 (NA)	0.00 (NA)	12.84 (0.99)	10.10 (0.44)	0.00 (NA)	0.00 (NA)	13.90 (0.98)	12.03 (0.43)
Weighted Mean Mortality Estimate	0.00 CV = NA 95% CI = NA		8.20 CV = 0.32 95% CI = 3.07-13.32		0.00 CV = NA 95% CI = NA		10.94 CV = 0.30 95% CI = 4.41-17.48		0.00 CV = NA 95% CI = NA		12.60 CV = 0.30 95% CI = 5.22-19.97	
PBR	48 (17% PBR)				23 (48% PBR)				7.8 (161% PBR)			

Table 5. For the years (20011-2015), the minimum (pure stock identification: when observed bycaught animal was either genetically identified to be affiliated with 1 stock or was taken in a specific bimonthly regional stratum known to be occupied by only 1stock) and maximum (pure + mixed stock identification when observed bycaught animals were taken in bimonthly regions occupied by more than 1 stock) mean gillnet bycatch mortality and coefficient of variation (CV) by stock (NM = Northern Migratory, SM = Southern Migratory, NN = Northern North Carolina Estuarine,), and method (ARM = Annual Ratio, PRM=Pooled Ratio). Note, observer coverage was too low to detect a bycatch event in the Southern North Carolina Estuarine (SN) stock region (Figure 6). Consequently, mean mortality is unknown and not reported for this stock. CI = 95% Confidence Interval, PBR = potential biological removal level (% is relative to maximum mortality estimate)

	NM				SM				NN			
	Min		Max		Min		Max		Min		Max	
Year	ARM	PRM	ARM	PRM	ARM	PRM	ARM	PRM	ARM	PRM	ARM	PRM
2011	0.00 (NA)	8.19 (1.02)	0.00 (NA)	16.38 (0.69)	0.00 (NA)	0.00 (NA)	0.00 (NA)	11.68 (1.01)	0.00 (NA)	0.00 (NA)	0.00 (NA)	18.32 (0.71)
2012	0.00 (NA)	7.16 (1.02)	0.00 (NA)	14.33 (0.69)	0.00 (NA)	0.00 (NA)	0.00 (NA)	12.29 (1.01)	0.00 (NA)	0.00 (NA)	0.00 (NA)	17.92 (0.71)
2013	0.00 (NA)	6.72 (1.02)	0.00 (NA)	13.44 (0.69)	0.00 (NA)	0.00 (NA)	0.00 (NA)	11.75 (1.01)	0.00 (NA)	0.00 (NA)	0.00 (NA)	16.85 (0.71)
2014	0.00 (NA)	8.01 (1.02)	0.00 (NA)	16.02 (0.69)	0.00 (NA)	0.00 (NA)	64.35 (1.00)	15.82 (1.01)	0.00 (NA)	0.00 (NA)	39.56 (1.00)	21.19 (0.71)
2015	18.32 (1.03)	5.93 (1.02)	36.65 (0.70)	11.86 (0.69)	0.00 (NA)	0.00 (NA)	0.00 (NA)	9.89 (1.01)	0.00 (NA)	0.00 (NA)	27.05 (1.00)	14.73 (0.71)
Mean	3.66 (1.03)	7.20 (0.46)	7.33 (0.70)	14.41 (0.31)	0.00 (NA)	0.00 (NA)	12.87 (1.00)	12.29 (0.46)	0.00 (NA)	0.00 (NA)	13.32 (0.72)	17.80 (0.32)
Weighted Mean Mortality Estimate	6.11 CV = 0.32 95% CI = 2.31-9.91		12.23 CV = 0.22 95% CI = 7.07-17.39		0.00 CV = NA 95% CI = NA		12.47 CV = 0.31 95% CI = 4.80-20.14		0.00 CV = NA 95% CI = NA		16.42 CV = 0.22 95% CI = 9.24-24.01	
PBR	48 (25% PBR)				23 (54% PBR)				7.8 (210% PBR)			

Table 6. Annual ratio method (ARM) and pooled ratio method (PRM) maximum observed (Obs) bycatch (resulting in mortality), trips and rates (coefficient of variation in parentheses) used to estimate total mortality by stock (Northern Migratory (NM), Southern Migratory (SM), and Northern North Carolina Estuarine (NN). NM had one pure stock assignment (minimum estimate) not included in the table below.

		NM			SM			NN		
Method	**Year**	**Obs Bycatch**	**Obs Trips**	**Bycatch Rate**	**Obs Bycatch**	**Obs Trips**	**Bycatch Rate**	**Obs Bycatch**	**Obs Trips**	**Bycatch Rate**
ARM	2007	0	392		0	132		0	151	
	2008	0	258		0	166		0	120	
	2009	1	195	0.0051. (0.95)	1	97	0.0103 (0.99)	1	89	0.0112 (0.98)
	2010	0	253		0	117		0	86	
	2011	0	131		0	52		0	59	
	2012	0	203		0	49		0	114	
	2013	0	208		0	103		0	138	
	2014	0	252		1	103	0.0097 (1.00)	1	181	0.0055 (1.00)
	2015	2	380	0.0053 (0.70)	0	112		1	184	0.0054 (1.00)
PRM	Total 2007-2011	1	1229	0.0008 (1.08)	1	564	0.0018 (0.97)	1	505	0.0020 (0.95)
	Total 2011-2014	2	1174	0.0017 (0.69)	1	419	0.0024 (1.01)	2	676	0.0029 (0.71)

Table. 7. Commercial fish species commonly caught in coastal state waters by North Carolina gillnet vessels, summarized by mesh size category as defined by the Bottlenose Dolphin Take Reduction Plan (US Dep. Comm. 2006a).

Small (<= 5 in)	Medium (> 5in <7in)	Large (>= 7 in)
Atlantic Croaker (*Micropogonias undulates*) Bluefish (*Pomatomus saltatrix*) Kingfish spp. (*Menticirrhus spp*.) King Mackerel (*Scomberomorus cavalla*) Spot (*Leiostomus xanthurus*) Southern Kingfish (*Menticirrhus americanus*) Spanish Mackerel (*Scomberomorous maculatus)* Spotted Sea Trout (*Cynoscion nebulosus)* Weakfish (*Cynoscion regalis*) Striped Mullet (*Mugil cephalus*)	Atlantic Bonito (*Sarda sarda*) False Albacore (*Euthynnus alletteratus*) Sharks (*Selachii spp*.) Smooth Dogfish (*Mustelus canis)* Spiny Dogfish (*Squalus acanthius*) Southern Flounder (*Paralichthys lethostigma*) Summer Flounder (*Paralichthys dentatus*)	No large mesh fishing in state waters

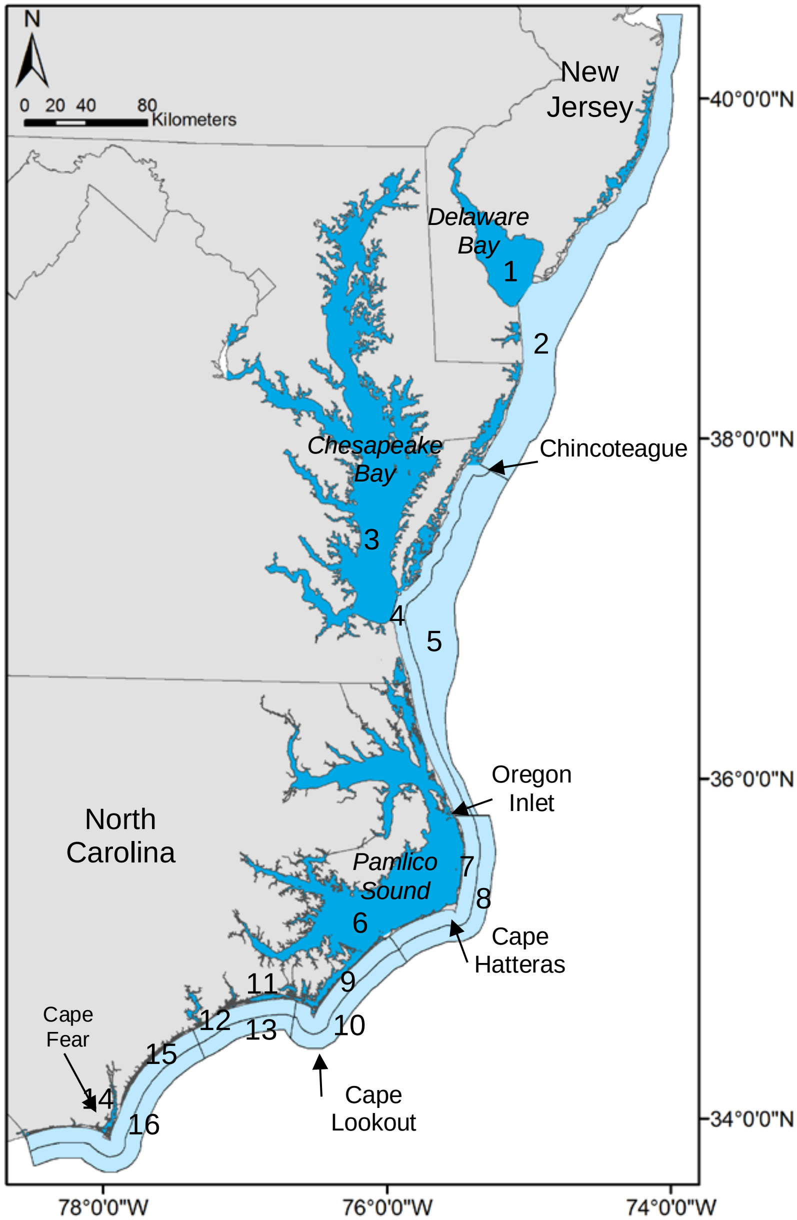
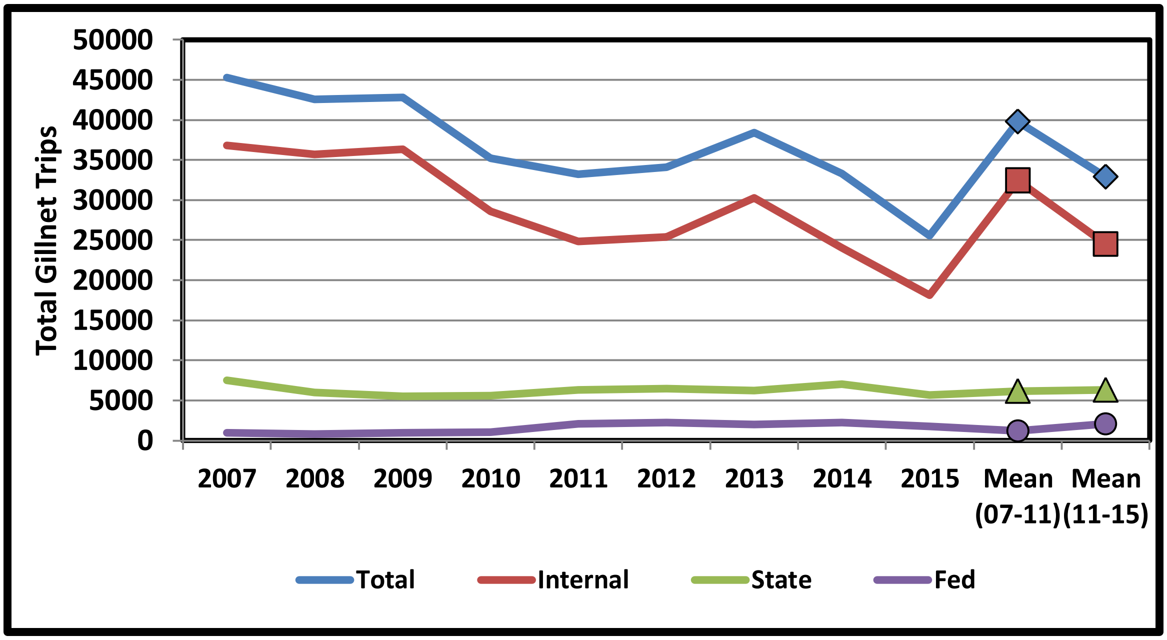


Figure 1. Range of coastal bottlenose dolphin (*Tursiops truncatus*) habitat from New Jersey to North Carolina, including estuarine (royal blue) and ocean waters (light blue). The range is divided into 16 geographic regions (see Table 1) where dolphins are assigned to stock(s) based on bimonthly periods. Note: for visual purposes, the ocean regions directly adjacent to shore south of Chincoteague, VA were artificially stretched to 10-km wide from 3-km south of Oregon Inlet and 1-km north of Oregon Inlet so they could be seen on the map.

Figure 2. Spatial distribution of gillnet hauls and takes observed within bottlenose dolphin habitat by the Southeast (SEFOP) and Northeast Fisheries Observer Programs (NEFOP) from 2008-2015 and 2007-2015, respectively. Colored circles represent individual gillnet haul locations from observed trips. Colored star symbols show locations of the 5 bottlenose dolphin (*Tursiops truncatus*) takes observed between 2007 and 2015.



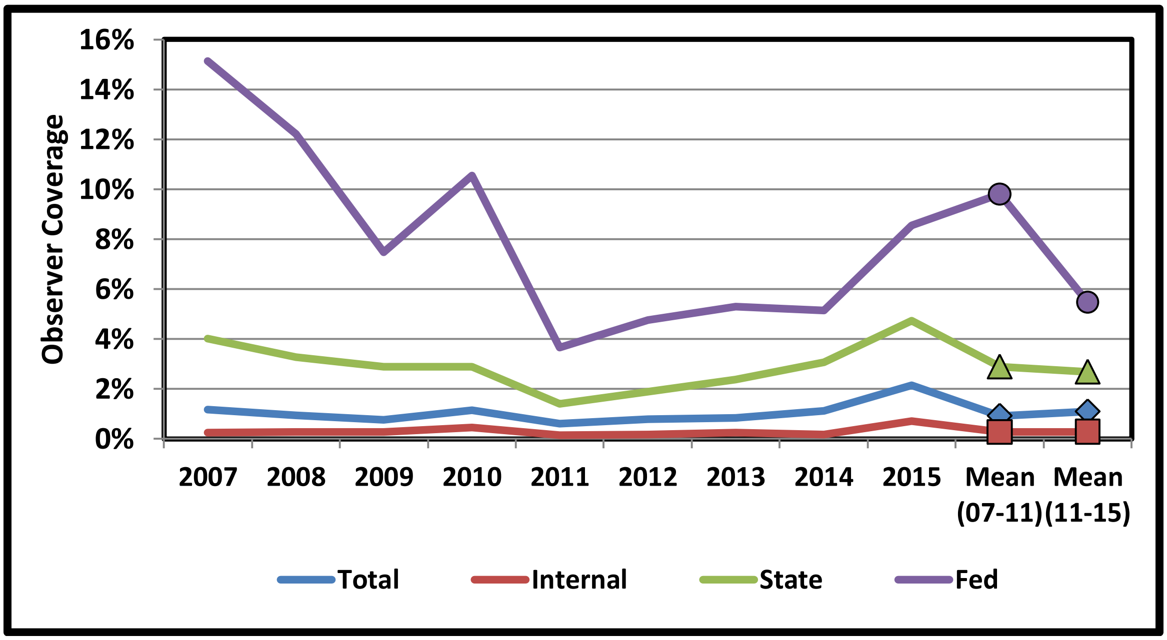
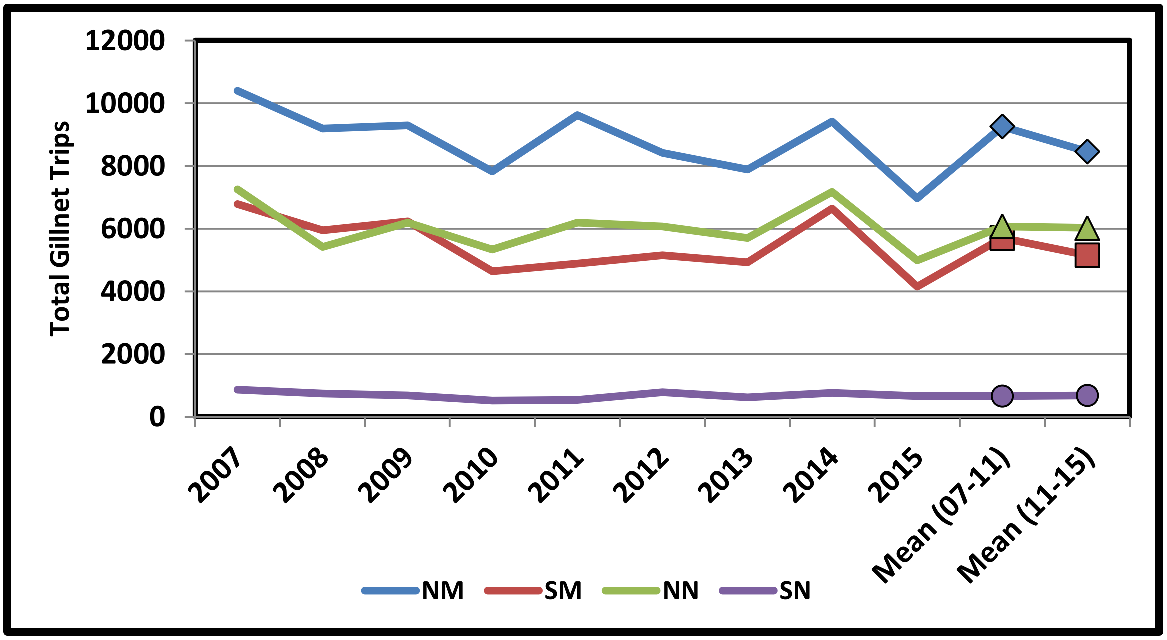


Figure 3. Total and mean annual commercial gillnet fishing trips (top) and percent observer coverage (bottom) between 2007-2015 by water body (internal = bays, sounds, estuaries; state = 0.56 km from shore; federal = 5.6-370.4 km from shore.



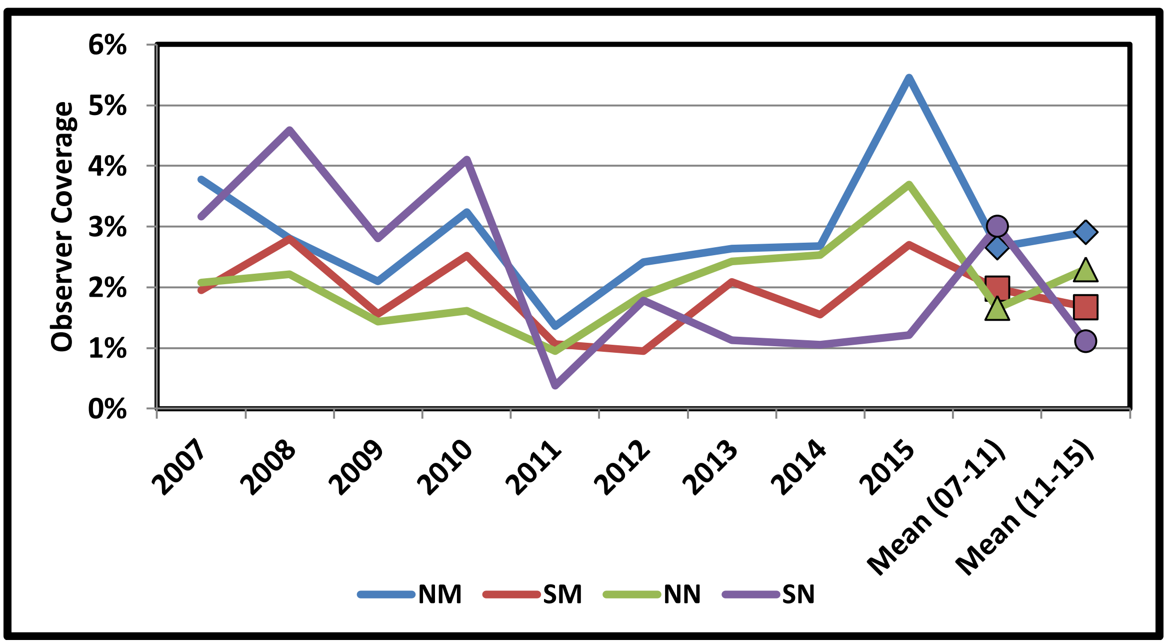


Figure 4. Total and mean annual commercial gillnet fishing trips (top) and percent observer coverage (bottom) between 2007-2015 by stock (NM = Northern migratory, SM = Southern migratory, NN = Northern North Carolina Estuarine, SN = Southern North Carolina Estuarine), excluding North Carolina internal waters.

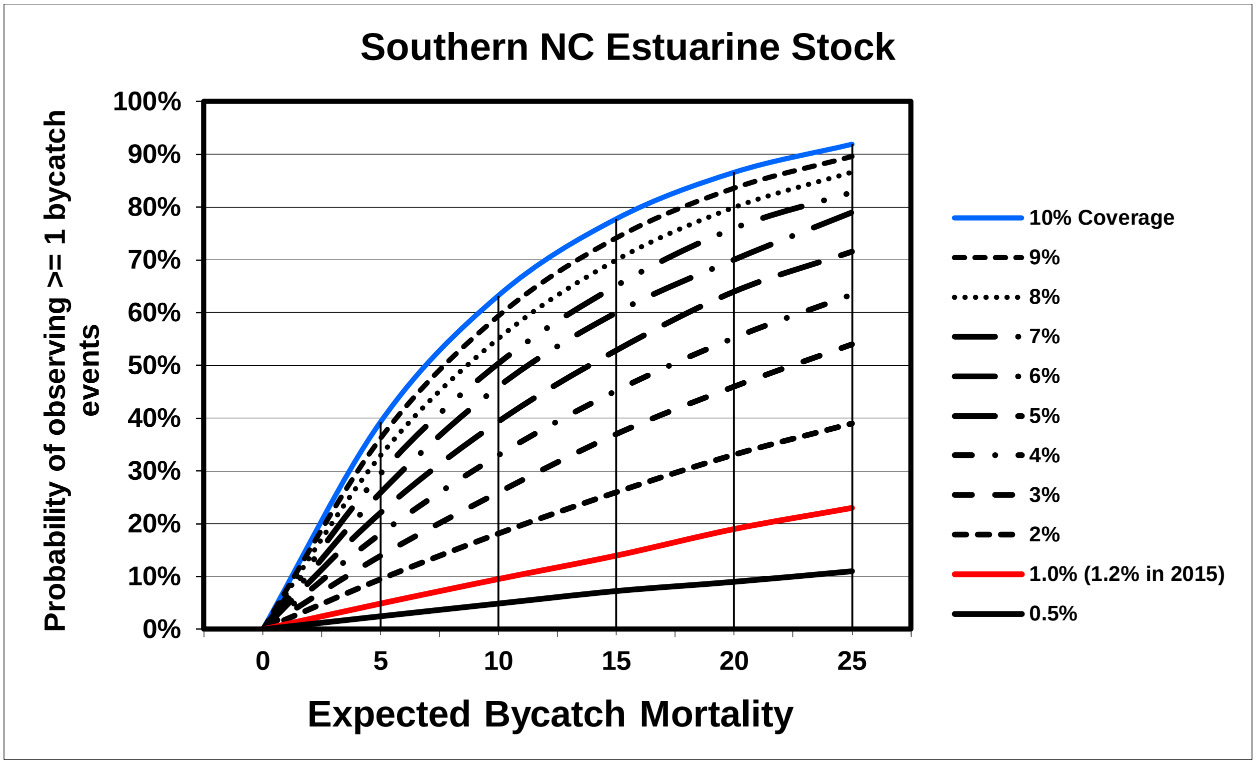


Figure 5. Probability of observing at least 1 bycatch event in the habitat occupied by Southern North Carolina estuarine (SN) animals as a function of 2015 effort from the SN stock range (excluding NC internal waters), expected mortality estimates, and varying levels of observer coverage.

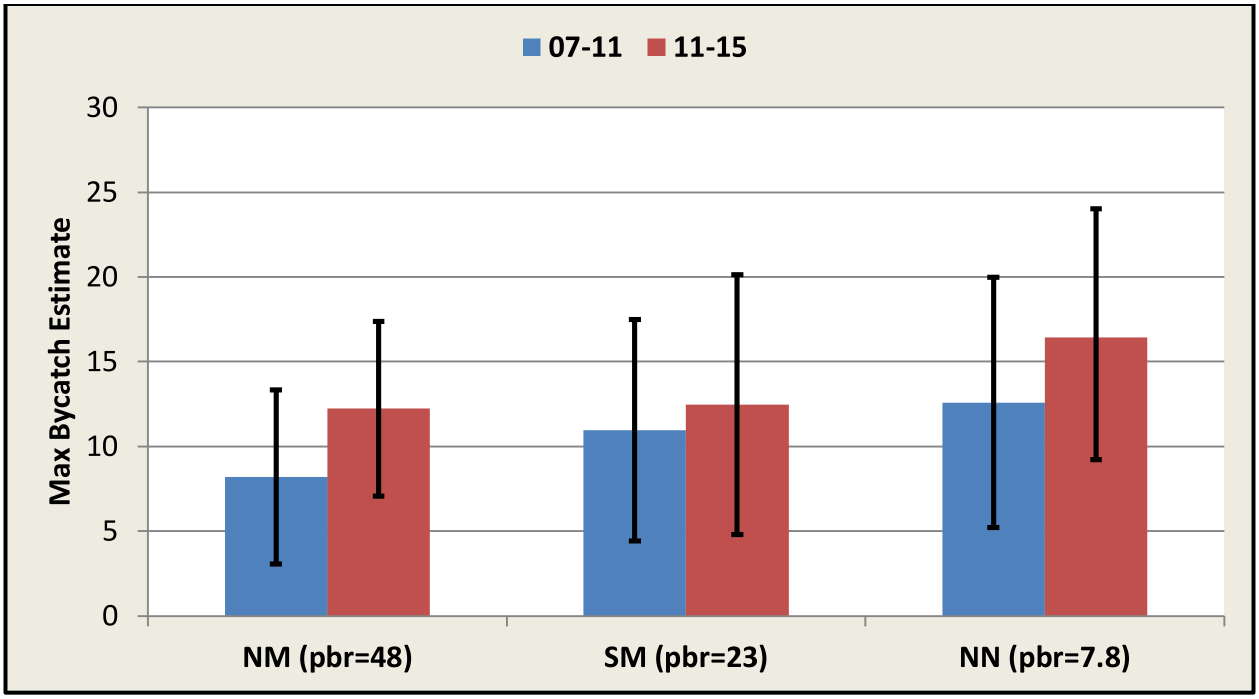


Figure 6. Mean maximum coastal bottlenose dolphin (*Tursiops truncatus*) bycatch estimates (95% Confidence Interval) by stock: Northern Migratory (NM), Southern Migratory (SM), Northern NC estuarine stock (NN) and time period: 2007-2011(07-11) and 2011-2015 (11-15). PBR=Potential Biological Removal.

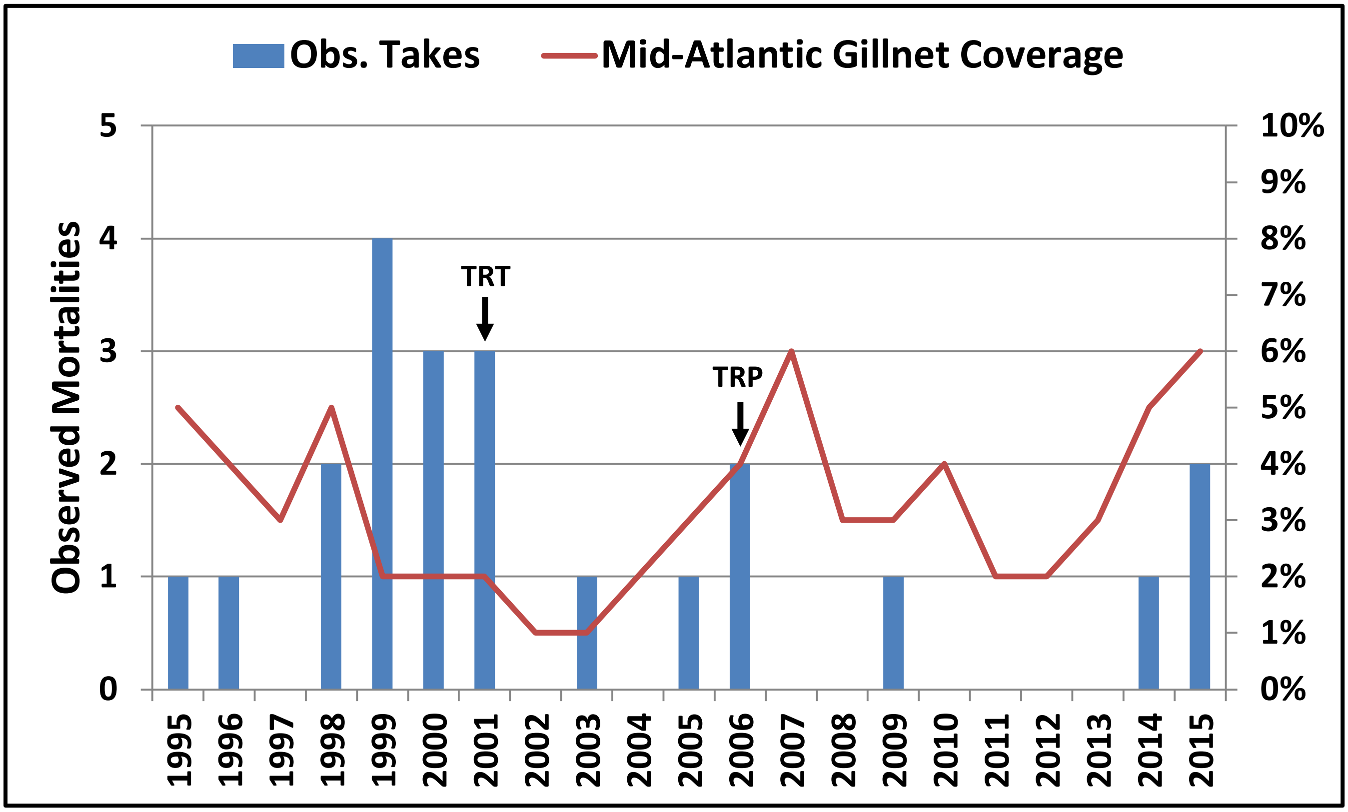


Figure 7. Coastal bottlenose dolphin (*Tursiops truncatus*) observed bycatch events and Mid-Atlantic observer coverage, 1995-2015. The first official Take Reduction Team (TRT) meeting was convened in 2001, and the Take Reduction Plan (TRP) was implemented in June 2006. Coverage is defined as the ratio of observed kept catch to total landed catch (metric tons) by the Mid-Atlantic gillnet fleet (excluding internal waters) sourced from the Northwest Atlantic and Gulf of Mexico Marine Mammal Stock Assessment Reports http://www.nmfs.noaa.gov/pr/sars/species.htm.

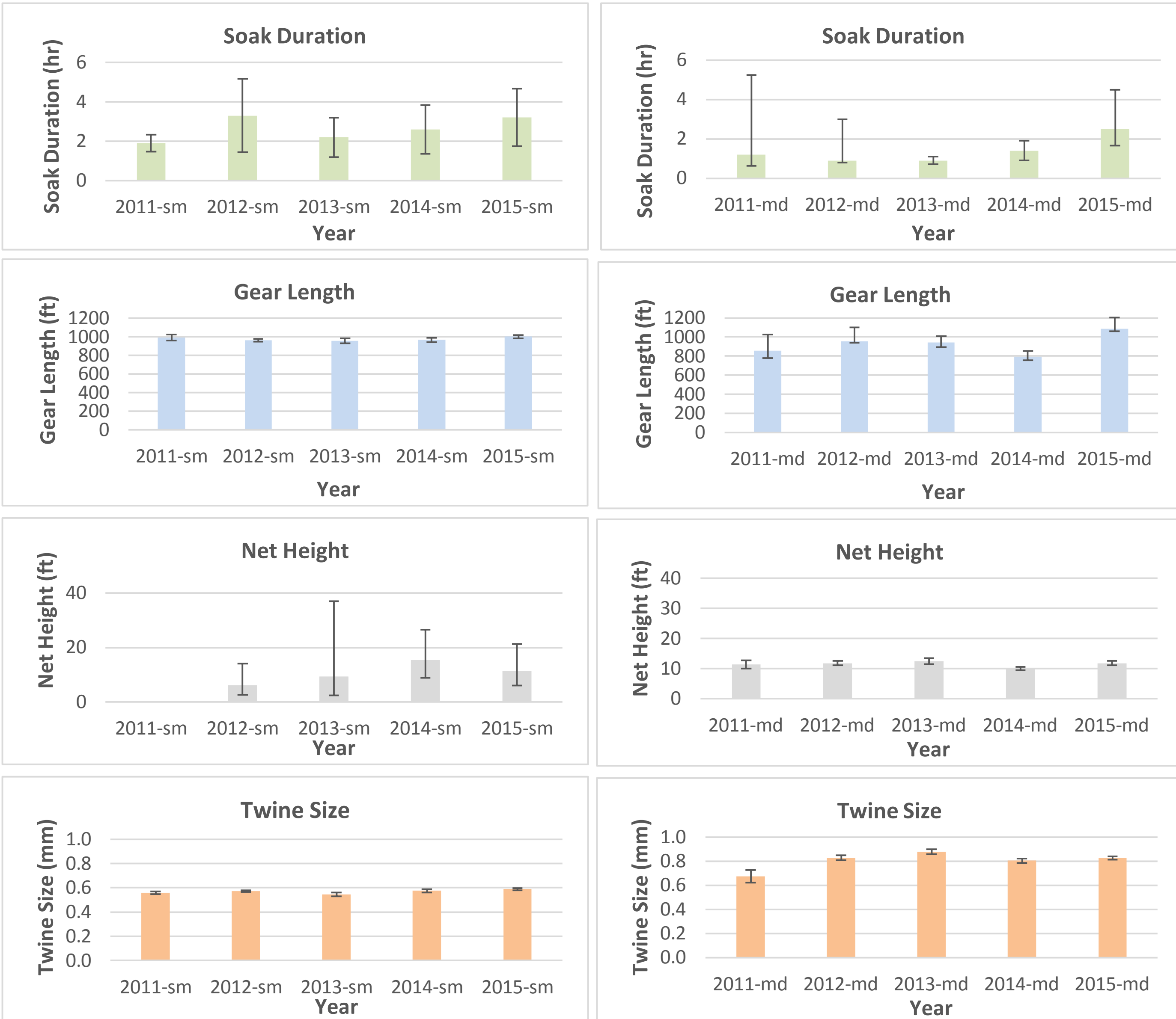


Figure 8. Mean observed fishing practices by mesh size category (defined by the Bottlenose Dolphin Take Reduction Plan (BDTRP: small <= 5in; medium >5 in < 7 in) where 75% of observed dolphin bycatch occurred between 2011-2015 (Stratum #7; Table 1). Medium-mesh soak duration and small-mesh total gear length are regulated by the BDTRP. Mean gear length, twine size, and medium-mesh net height are bound by normal 95% confidence intervals. Mean soak duration and small-mesh net height are bound by 95% lognormal confidence intervals.

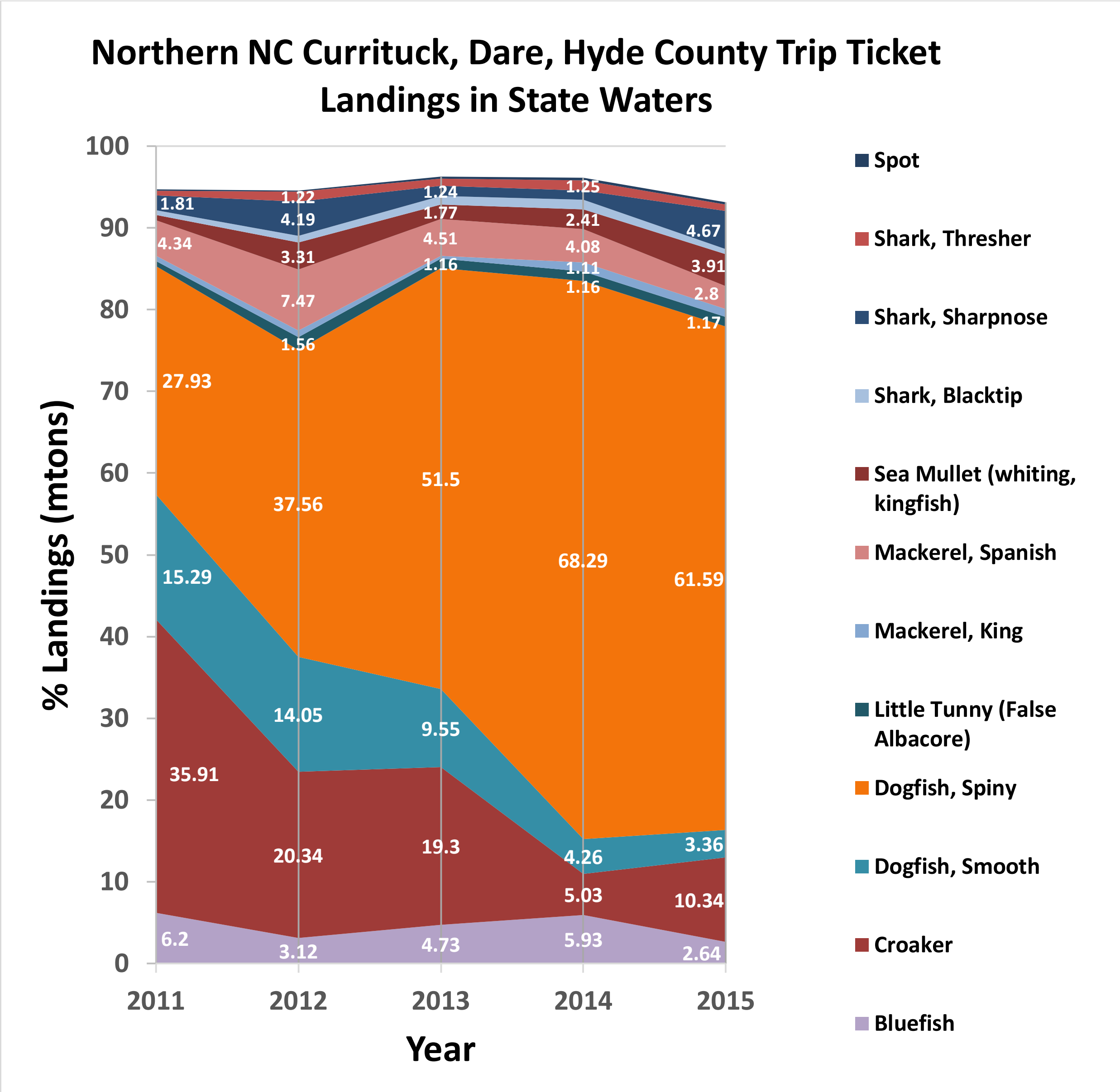


Figure 9. North Carolina (NC) trip ticket program landings from state waters reported from Currituck, Dare, and Hyde counties. These counties are adjacent to stratum #7 where 75% of observed dolphin bycatch was observed between 2011-2015. Landings shown by species as a proportion by weight (metric tons) to total weight landed. Species contributing less than 1% to total landings are not shown. Species include bluefish (*Pomatomus saltatrix*), croaker (*Micropogonias undulates*), smooth dogfish (*Mustelis canis*), spiny dogfish (*Squalus acanthius*), little tunny (*Euthynnus alletteratus*), king mackerel (*Scomberomorus cavalla*), spanish mackerel (*Scomberomorus maculatus*), sea mullet (*Menticirrhus spp.*), blacktip shark (*Carcharhinus limbatus*), sharpnose shark (*Rhizoprionodon terraenovae*), thresher shark (*Alopias vulpinus*), spot (*Leiostomus xanthurus*).

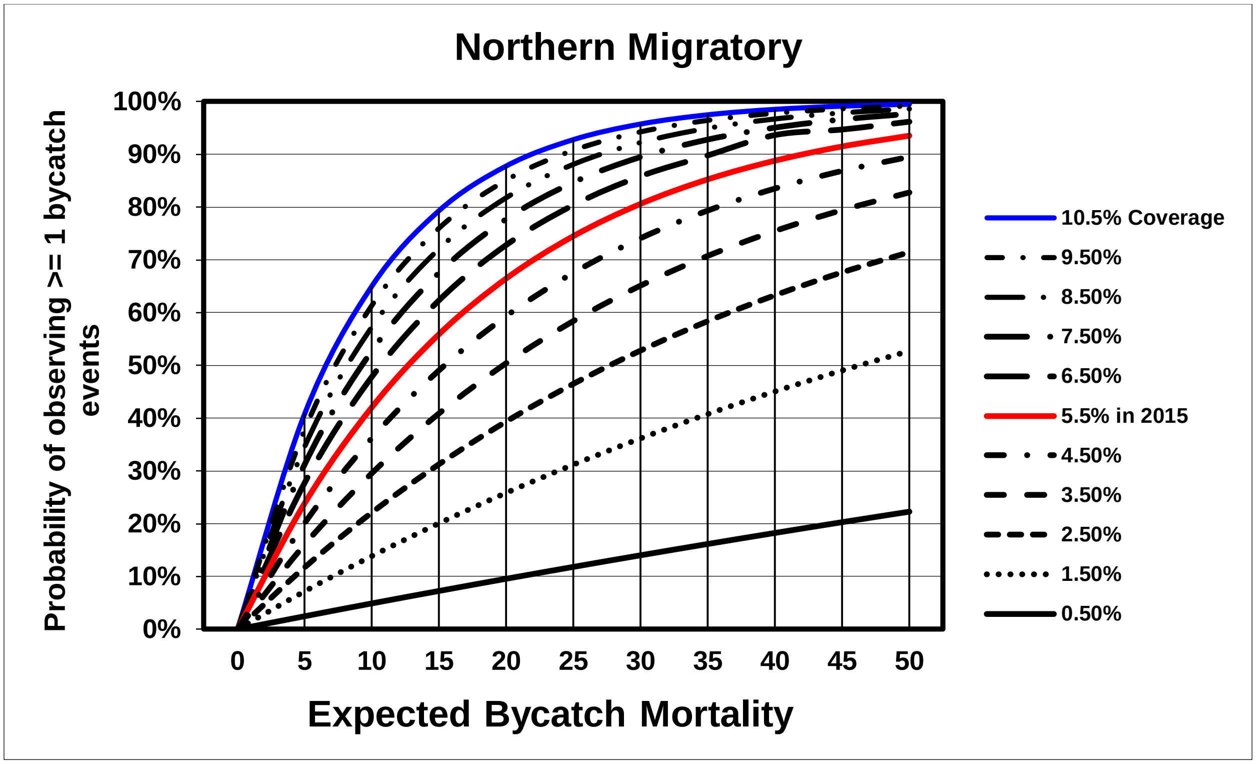


Figure 10. Probability of observing at least 1 bycatch event in the habitat occupied by Northern Migratory (NM) animals as a function of 2015 effort (trips) from the NM stock range, expected mortality estimates, and varying levels of observer coverage.

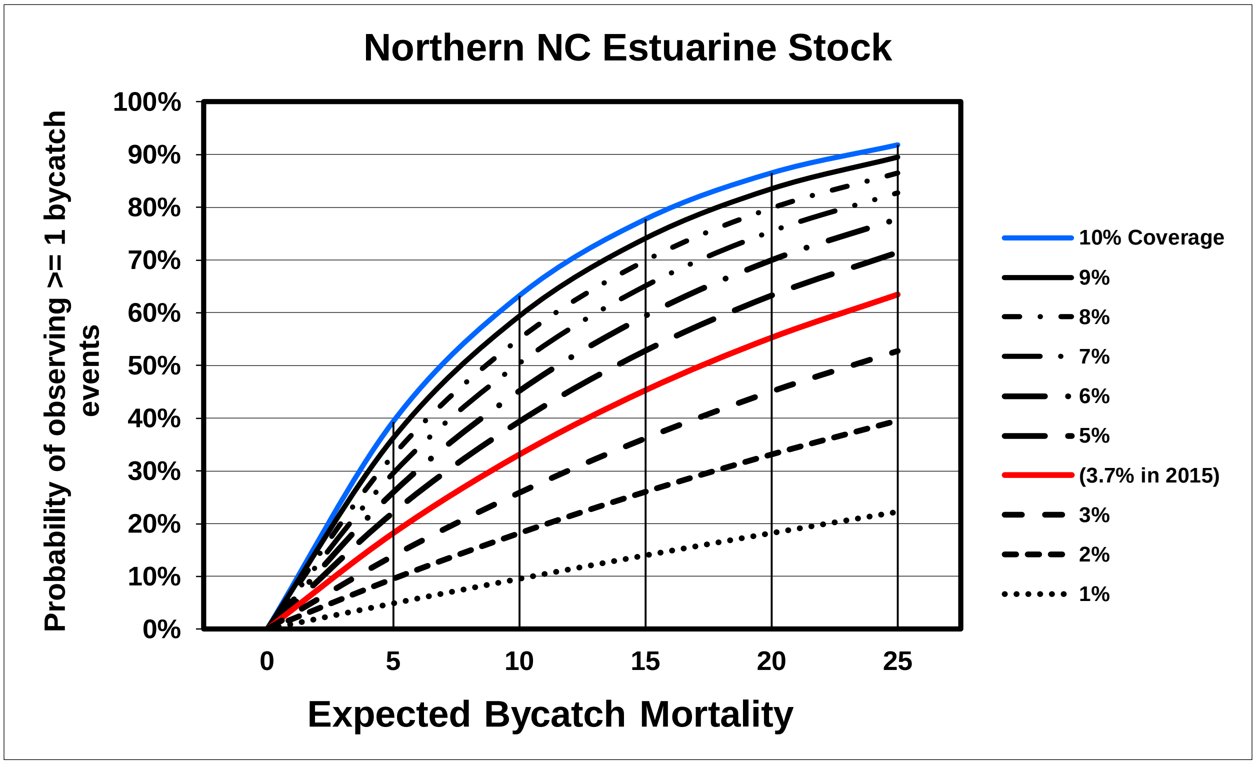


Figure 11. Probability of observing at least 1 bycatch event in the habitat occupied by Northern North Carolina estuarine (NN) animals as a function of 2015 effort from the NN stock range (excluding NC internal waters), expected mortality estimates, and varying levels of observer coverage.

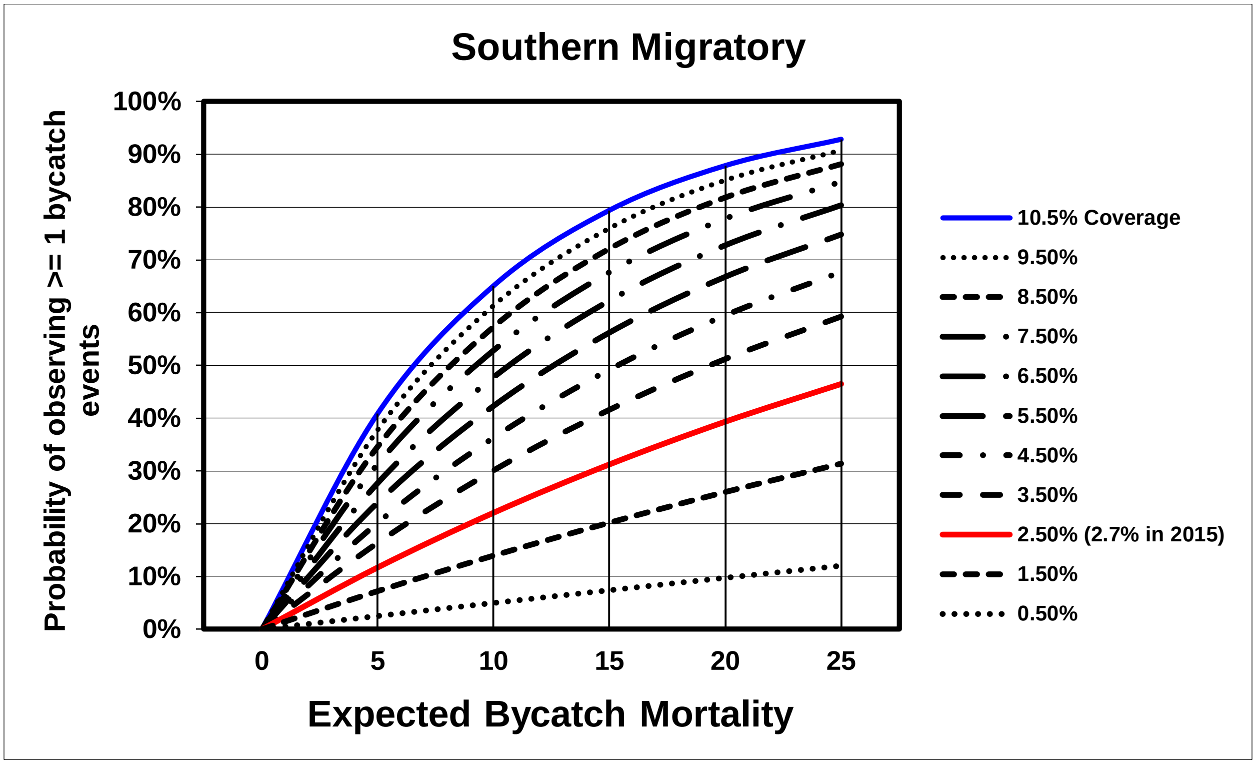


Figure 12. Probability of observing at least 1 bycatch event in the habitat occupied by Southern Migratory (SM) animals as a function of 2015 effort from the SM stock range (excluding NC internal waters), expected mortality estimates, and varying levels of observer coverage.

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