Southeast Fisheries Science Center Reference Document MMTD-2024-04

Abundance of Tamanend's Bottlenose Dolphins (*Tursiops erebennus*) along the U.S. Atlantic Coast from Aerial Surveys Conducted During Summer 2021

Lance P. Garrison[1], Laura Aichinger Dias[1,2]

[1]U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, FL 33149

[2]University of Miami
Cooperative Institute of Marine and Atmospheric Studies
4600 Rickenbacker Causeway
Miami, FL 33149

October 15, 2024

1. Background

Tamanend's bottlenose dolphins ("bottlenose dolphin", *Tursiops erebennus,* Costa et al. 2022) are present in estuarine, coastal, and continental shelf waters from Florida to Long Island, New York and overlap spatially on the outer continental shelf with the common bottlenose dolphin, *Tursiops truncatus*, in part of their range. Until recently, the two were considered the same species, and "coastal morphotype" bottlenose dolphins (i.e., *T. erebennus*) occurring in coastal and estuarine waters of the U.S. east coast have long been a focus of management due to mortality and serious injury in commercial fishing gear. Bottlenose dolphins occur in a complex mosaic of population stocks along the U.S. east coast. In waters over the U.S. continental shelf, there are five defined stocks: Northern Migratory (NM), Southern Migratory (SM), South Carolina/Georgia (SC/GA), Northern Florida (NFL), and Central Florida (CFL; Figure 1). At least two of these stocks (NM and SM) are thought to undertake large scale seasonal migrations and overlap spatially with other coastal and estuarine stocks during certain months of the year. However, during summer months, it is thought that the stocks are largely separated from each other and occupy discrete spatial ranges. There are significant uncertainties in the defined stock boundaries, and the boundaries of the SC/GA, NFL, and CFL stocks are based upon either state boundaries or evidence of separation between stocks in estuarine waters (Rosel et al. 2009). Finally, the region labeled "Southern North Carolina" (SNC, Figure 1) between the SC/GA and SM stocks is currently not included in the range of any stock during summer months. Adding to this complexity, *T. erebennus* and *T. truncatus* overlap spatially south of Cape Hatteras, North Carolina over the continental shelf in waters with bottom depths greater than 20 m (Torres et al. 2003, Rosel et al. 2009). To account for this, a logistic regression model based upon genetic analysis of tissue samples collected from each species is used to estimate the probability that an observed group is from *T. erebennus* based upon location and habitat features (Garrison et al. 2017).

Aerial line-transect surveys have been conducted by the Southeast and Northeast Fisheries Science Centers along the U.S. Atlantic coast since the early 1980s. Since 2002, surveys during summer months (July-August) have provided data to assess the abundance of bottlenose dolphins in waters over the continental shelf and have followed consistent methods. An analysis of surveys conducted in summer 2002, 2004, 2010, 2011, and 2016 is described in Garrison et al. (2017).

That report included abundance estimates for the defined coastal stocks (i.e., *T. erebennus*) and an assessment of population trends. At the stock level, high uncertainty in the estimates combined with the uncertainty in the spatial boundaries of each stock makes it difficult to evaluate and interpret observed trends. However, several stocks included statistically significant declines between the 2011 and 2016 surveys. When aggregating coastwide across stocks, there was a statistically significant decline in the coastwide population size between 2010-2011 ($\hat{N}$ = 49,039 [95% Confidence Interval (CI: 31,562 – 76,194]) and 2016 ($\hat{N}$ = 19,470 [95% CI: 12,574 – 30,149], Garrison et al. 2017). This apparent decline corresponded to a large Unusual Mortality Event caused by a morbillivirus outbreak during 2013-2015 along the U.S. east coast (Morris et al. 2015).

The objective of the current analysis is to estimate the abundance of the five defined Tamanend's bottlenose dolphin stocks along the U.S. Atlantic coast based on an aerial line-transect survey conducted during the summer of 2021. This analysis follows a similar approach to that described in Garrison et al. (2017) and includes the partitioning of sightings in deeper waters over the continental shelf between the two species (formerly described as the coastal and offshore morphotypes of *Tursiops truncatus*). The study provides a current abundance estimate for Tamanend's bottlenose dolphin stocks, and we compare these findings to previous estimates to assess population trends.

2. Methods

2.1. Aerial Survey Data Collection

A DeHavilland DHC-6 Twin Otter was used to conduct the aerial survey between June 18 and September 14, 2021 (Aichinger Dias et al. 2022, Figure 1). Transects were flown at an airspeed of 185 km/hr at a survey altitude of 182 m. The aircraft position was recorded at 10 second intervals, and environmental parameters were recorded including weather conditions, visibility, water color, water turbidity, sea state, and glare. Surveys were typically flown during favorable sighting conditions at sea states less than or equal to 4 on the Beaufort scale (surface winds <12 knots). Visual observers searched for marine mammals and sea turtles from directly beneath the aircraft out to a perpendicular distance of approximately 500 m from the trackline. Upon sighting a sea turtle or marine mammal, the observer measured the angle from the vertical to the animal (or group). This sighting angle, θ, was converted to the perpendicular sighting distance from the trackline (PSD) by PSD = tan(θ) x Altitude.

A two-team configuration was used that allowed estimation of perception bias at the trackline (i.e., the likelihood of detecting an animal or group on the trackline given that it is at the surface and available for detection by both survey teams). In this case, the forward team consisted of observers stationed in bubble windows on either side of the aircraft. The aft team consisted of a belly window observer and an observer stationed at a large bubble window on the right side of the aircraft. Because of this configuration, sightings at angles greater than 40° from the trackline on the left side of the plane were not visible to the aft survey team. Both teams had independent data recorders and did not communicate with each other while actively surveying. Upon observation of a marine mammal sighting, the forward observer would allow the airplane to pass over the group allowing the aft team the opportunity to see the group. Once the group passed the rear of the airplane, the pilots were notified, and the group was circled to verify species identification and group size. For each marine mammal sighting, it was determined if the sighting had been seen by the forward team only, the aft team only, or both teams at the time of data entry.

2.2. Detection Probability – Distance Sampling Analysis

The summer 2021 survey data were analyzed within the framework of distance sampling line-transect analysis with incomplete detection on the trackline (referenced in Buckland et al. 2001, Laake and Borchers 2004, Thomas et al. 2010). Standard line-transect analysis assumes that detection probability on the trackline [p(0)] is equal to 1. However, detection on the trackline is less than 1 [p(0) < 1] because some animals at the surface may be missed by the observers (i.e., perception bias) and/or some animals may be beneath the surface and hence not available to be detected by the survey (i.e., availability bias). Detection probability on the trackline was estimated using the independent-observer approach described in Laake and Borchers (2004). The high speed of the aircraft and the resulting short viewing interval for each group means that sightings are available to both teams at the same time. Thus, p(0) in this case is an estimate of the likelihood of at least one team on the survey detecting the marine mammal group conditional on its being at the surface (or subsurface but visible) at the time the aircraft passed over its location. This is described as Mark-Recapture Distance Sampling (MRDS; Laake and Borchers 2004) as implemented in the MRDS package of the R statistical language (version 2.3.0, Laake et al. 2023). The approach includes a mark-recapture (MR) component that uses sightings by each team (and the “point independence” assumption that detection probability between the teams is independent at the trackline) to estimate detection probability at zero distance and a distance-sampling (DS) component that estimates detection probability within the surveyed strip. The likelihood that animals are beneath the surface is not estimated; however, we expect this probability to be small since bottlenose dolphins have short dive-surface intervals and occur in groups where it is likely that at least one animal in group will be visible to the survey platform.

Model development and selection for abundance estimation proceeded in three steps. First, a histogram of the distribution of sighting distances (Figure 2) was inspected to identify a “right-truncation” distance or the maximum distance from the trackline used in the analysis. A right truncation distance of 325m from the trackline was selected, resulting in the removal of 2 dolphin groups from the analysis. As noted in prior surveys with this platform (see Garrison et al. 2017), there was a decline in the number of detections near the trackline, violating the expectation of a monotonically decreasing detection probability with increased distance. Groups were therefore “left-truncated” at 75m from the trackline (following Buckland et al. 2001). Sighting distances were recalculated by subtracting the left truncation distance for the remainder of the analyses. Second, the form of the detection function (hazard rate vs. half-normal) and covariates were selected for the DS portion of the model. Covariates considered for inclusion in the DS model were entered as factors and included sea state, glare, and cloud cover. All combinations of potential covariates were evaluated, and the subset of included variables was selected from among the candidate models based on the lowest Akaike’s Information Criterion (AIC). Finally, all combinations of covariates along with observer and observer x distance effects and log of group size were evaluated for inclusion in the MR model. The best model was again selected using the lowest AIC value. The fit of the final selected model was evaluated using the Cramer von Mises Goodness of Fit statistic and by inspection of a QQ-plot.

2.3. Abundance Estimation

To estimate stock-specific abundance estimates, effort (km of trackline) and sightings from each survey were post-stratified into 12 strata (Figure 1). The latitudinal boundaries correspond to defined stock boundaries for Tamanend’s bottlenose dolphins along the Atlantic coast. Effort was also stratified into a 0-20m depth strata and a 20-200m depth strata within each stock area (Figure 1). Within each stratum, the sightings and survey effort were summarized to calculate animal density following a Horvitz-Thompson like estimator (Thomas et al. 2010). The estimated number of bottlenose dolphins occurring within the surveyed strip, $\widehat{N_c}$, corrected for the probability of detection is calculated as:

$$(1)\ \widehat{N_c} = \sum_{i=1}^{n} \frac{s_i}{\widehat{p_i}\,\widehat{p(0)_i}},$$

where n is the number of sightings, s_i is the size of group i, $\widehat{p_i}$ is the estimated detection probability within the survey strip and $\widehat{p(0)_i}$ is the detection probability at zero distance (i.e., the left truncation distance). The latter two probabilities are estimated using the MRDS model described above. The total abundance of bottlenose dolphins, $\widehat{N_s}$, within a given stratum, s, is calculated as:

$$(2)\ \widehat{N_s} = A_s \cdot \frac{\widehat{N_{cs}}}{2L_s w},$$

where L_s is the total survey effort in the stratum, A_s is the area of the stratum, and w is width of the surveyed strip (Thomas et al. 2010).

The estimate in equation 2 is for all bottlenose dolphins occurring within a given stratum. However, the goal of this analysis is to estimate the abundance of only *T. erebennus*. Therefore, for each bottlenose dolphin sighting, the probability that it was from *T. erebennus* was estimated from a logistic regression model (Garrison et al. 2017) based upon the depth and latitude at which it was observed. The proportion of observed animals predicted to be from *T. erebennus* for each stratum was calculated and multiplied by the stratum abundance. This approach assumes that the detection probability is the same for the two species. Stratum specific estimates were summed to derive estimates for each stock. The variance of the estimates was calculated using the Delta method (Buckland et al. 2001) to incorporate uncertainty in both the distance sampling based abundance estimate and the logistic regression model. Uncertainty in the abundance estimates therefore arises from three sources: 1) uncertainty in the detection probability model, 2) sampling variability among the line-transects, and 3) uncertainty in the assignment of observed groups to species associated with uncertainty in the logistic regression model.

2.4. Assessment of Trends

We assessed potential interannual trends in abundance for each stock using a generalized linear model (GLM) weighting by the inverse of the variance of each annual estimate. We defined a factor, "period", to group the available estimates into four time periods: 2002-2004, 2010-2011, 2016 and 2021. This factor, a factor variable for stock, and their interaction term were explanatory factors in a weighted GLM to examine potential trends in stock abundance over time. Pairwise contrasts were used to examine differences between the four defined periods for each stock.

The coastwide trend in the total abundance of *T. erebennus* was examined in a separate GLM. In this case, we were interested in evaluating the change in the annual trend between each period. Therefore, we used a linear model with the total abundance in each year as the response variable (with estimates weighted by the inverse of their variance) and an interaction term between year and period (3 periods: {2002-2004 and 2010-2011}, 2016, and 2021) as the explanatory variable. This term tests for differences in slope (i.e., year effect) in each period.

3. Results and Discussion

A total of 9,319 km of trackline were surveyed on effort (Figure 1). Survey conditions were generally good with the daily average sea state ranging between 1.7 and 3.6 (mean 2.5). A total of 139 bottlenose dolphin groups were observed while on effort including a total of 1,194 individuals (Table 1). North of Cape Hatteras, North Carolina there was apparent separation between the two species with high numbers of sightings near the coastline and on the outer continental shelf with few sightings in between. South of Cape Hatteras, there was no apparent separation between the species (Figure 1). This is consistent with spatial patterns observed in previous studies (e.g., Garrison et al. 2017, Torres et al. 2003). There were relatively few sightings in the SNC inshore stratum and an apparent gap in distribution of bottlenose dolphins in shallow waters between Cape Fear, North Carolina and Cape Hatteras, North Carolina. However, there were three groups sighted north of the boundary between the SCGA and SNC regions near Cape Lookout, North Carolina, including two large groups of 91 and 26 animals. Consistent with previous analyses, the resulting abundance from these sightings is not included in any of the defined stocks.

The selected MRDS model included a half-normal function with no selected covariates in the DS component of the model and included sea state, observer (i.e., forward vs. aft station), the interaction between observer and distance, and the log of group size in the MR component (Table 2). The model fit to the data was adequate (Cramer-von Mises Test, p-value = 0.5894), and there were no substantial deviations from a straight line in a q-q plot of the fitted vs. empirical cdf (Figure 3). The resulting detection functions are shown in Figure 4. The resulting estimates of detection probability are shown in Table 3. The detection probability (combined across both survey teams) at distance zero (the left-truncation distance) for the survey was 0.950 (CV = 0.034). The overall average detection probability was 0.6048 (CV = 0.100; Table 3).

The resulting abundance estimates of all bottlenose dolphins (*T. erebennus* and *T. truncatus*) for each stratum are shown in Table 4. The uncertainty of these estimates is generally high with coefficients of variation ranging between 0.319 and 0.940 which reflects a high level of variability in the encounter rate within each stratum. The probability that observed groups are from *T. erebennus,* is shown in Figure 5. South of Cape Hatteras, this probability is typically greater than 0.6 in the inshore (0-20 m depth) strata and is typically <0.3 in the offshore (20-200 m depth) strata. North of Cape Hatteras where both past biopsy data and the discontinuity in sightings indicate no spatial overlap between the species, all sightings within the inshore strata were assigned as *T. erebennus,* and all sightings in the offshore strata were assigned to *T. truncatus*. The mean probability that a dolphin would be a *T. erebennus* is shown in Table 4 along with the stratum specific estimates for the species.

The best estimates of the abundance of each *T. erebennus* stock is shown in Table 5. As noted above, animals observed in the SNC stratum are not included in any stock, but are considered in the coastwide (total) estimate. Sources of uncertainty in these estimates include uncertainty in the detection probability, uncertainty in the encounter rate, and uncertainty in the assignment of observed dolphin groups to species.

The estimates from summer 2021 are compared to those from prior year surveys (Garrison et al. 2017) in Table 6 and Figure 6. There is limited power to assess trends in stock size over time given the high uncertainty in individual estimates and high variability between years. The only stock for which there are significant interannual trends is the SM stock with higher abundances in the 2002-2004 period and significantly lower abundance in subsequent years (Figure 6; Appendix 1). While the differences were not significant, all stocks (other than

SM) showed a decline in population size between 2010-2011 and 2016 and a subsequent increase in population size between 2016 and 2021 (Figure 6). Combining across all stocks (and the SNC stratum), there was a statistically significant ($p = 0.0280$; Appendix 2) change in the slope (year effect) in the total abundance of dolphins coastwide between 2010-2011 and 2016 indicating a significant decline (Figure 7). Comparing the 2021 coastwide estimate (35,523, 95% CI: 20,896 – 50,619) to the 2016 estimate (19,471, 95% CI: 12,572 – 30,156; Table 6) suggests partial recovery from the impacts of the 2013-2015 UME (unusual mortality event), and the coastwide abundance estimate is consistent with that of prior years.

The major source of unquantified uncertainty in these estimates results from the assumption of static geographic ranges for each stock. In addition, the analysis assumes that the detection probability for animals occurring water depths greater than 20 m (i.e., predominantly *T. truncatus*) is the same as that for animals in nearshore waters. Violation of this assumption could result in biased estimates of abundance and the associated uncertainty. We have accounted for the primary source of negative bias associated with incomplete detection of animals available at or near the surface at zero distance (i.e., the left-truncation distance). Because bottlenose dolphins have relatively short dive-surface intervals and occur in groups, the bias due to groups being submerged, and therefore unavailable to observers, is likely small. The stock specific abundance estimates (Table 5) represent the most recent and best available abundance estimates to be used for calculation of the potential biological removal metric in MMPA mandated stock assessment reports.

4. Acknowledgements

The authors thank the visual observers who participated in these surveys, C. Accardo, R. DiGiovanni, R. Hardee, R. Holt, N. Metheny, P. Nagelkirk, and J. Wicker. We also thank the pilots and the NOAA Office of Marine and Aircraft Operations for their support and expertise. The survey was conducted under MMPA research permit 21938 to the Southeast Fisheries Science Center. The work was funded as part of a cooperative project with the US Department of the Interior, Bureau of Ocean Energy Management Environmental Studies Program through Interagency Agreement M14PG00005 and the US Department of Commerce, National Oceanic and Atmospheric Administration.

5. Literature Cited

Aichinger Dias, L., Palka, D., Wicker, J., Martinez, A., Garrison, L., Reid, J., Soldevilla, M., DeAngelis, A., Wallace, J., Broughton, E., Walsh, H., Jech, M., Cholewiak, D., Haas, H., Sasso, C., Westell, A., Davis, G., Chavez-Rosales, S., Sigourney, D., Josephson, E., Orphanides, C. 2022. 2021 Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in US waters of the Western North Atlantic Ocean – AMAPPS III. Northeast Fisheries Science Center (U.S.); Southeast Fisheries Science Center (U.S.). https://doi.org/10.25923/jazw-5467

Buckland, S. T., D. R. Andersen, K. P. Burnham, J. L. Laake, D. L. Borchers and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. Oxford University Press, New York, 432 pp

Costa, A., W. McFee, L. Wilcox, F. Archer, and P. Rosel. 2022. The common bottlenose dolphin (*Tursiops truncatus*) ecotypes of the western North Atlantic revisited: an integrative taxonomic investigation supports the presence of distinct species. Zool. J. Linn. Soc. 196:1608–1636.

Garrison, L.P., K. Barry, and W. Hoggard. 2017a. The abundance of coastal morphotype bottlenose dolphins on the U.S. east coast: 2002-2016. Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, 75 Virginia Beach Dr., Miami, FL 33140. PRBD Contribution # PRBD-2017-01, 37 pp.

Laake, J.L. and D.L. Borchers. 2004. Methods for incomplete detection at distance zero. pp. 108-189. *In:* S.T. Buckland, D.R. Andersen, K.P. Burnham, J.L. Laake and L. Thomas (eds.) Advanced distance sampling. Oxford University Press, New York.

Laake, J., Borchers, D., Thomas, L., Miller, D., Bishop, J., and J. McArthur. 2023. _mrds: Mark-Recapture Distance Sampling_. R package version 2.3.0, <https://CRAN.R-project.org/package=mrds

Morris, S.E., J.L. Zelner, D.A. Fauquier, T.K. Rowles, P.E. Rosel, F. Gulland and B.T. Grenfell. 2015. Partially observed epidemics in wildlife hosts: Modelling an outbreak of dolphin morbillivirus in the northwestern Atlantic, June 2013–2014. J. R. Soc. Interface 12:20150676.

Rosel, P.E., L. Hansen and A.A. Hohn. 2009. Restricted dispersal in a continuously distributed marine species: Common bottlenose dolphins *Tursiops truncatus* in coastal waters of the western North Atlantic. Mol. Ecol. 18: 5030–5045.

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A., and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. J. of Appl. Ecol. 47:5-14. https://doi.org/10.1111/j.1365-2664.2009.01737.x

Torres, L. G., P. E. Rosel, C. D'Agrosa and A. J. Read. 2003. Improving management of overlapping bottlenose dolphin ecotypes through spatial analysis and genetics. Mar. Mamm. Sci. 19:502-514.

6. Tables

Table 1. Survey effort and sightings in each stratum.

Stratum	Depth	Stock	Area (km^2)	Effort (km)	Groups	Individuals
CFL-IN	0-20	CFL	6,250	472	7	49
CFL-OFF	20-200	CFL	11,217	643	11	84
NFL-IN	0-20	NFL	6,192	285	10	122
NFL-OFF	20-200	NFL	7,426	454	7	30
NM-IN	0-20	NM	5,345	318	10	186
NM-OFF	20-200	NM	34,798	1,919	17	53
SCGA-IN	0-20	SCGA	19,364	905	25	212
SCGA-OFF	20-200	SCGA	33,100	1,484	16	41
SM-IN	0-20	SM	8,341	423	8	60
SM-OFF	20-200	SM	24,615	1,429	10	176
SNC-IN	0-20	SNC	5,587	230	3	121
SNC-OFF	20-200	SNC	15,861	757	15	60

Table 2. Parameters included in the detection probability function (DS = distance sampling component, MR = mark-recapture component)

Model	Parameter	Estimate	Standard Error
DS	Scale Coefficient (Half-Normal Key Function)	4.9123	0.1329
MR	Intercept	2.5128	1.121
MR	Distance	-0.009	0.009
MR	Observer	-0.9368	0.5857
MR	Sea State (factor)	-0.7248	0.5022
MR	log(Group Size)	0.8026	0.4540
MR	Distance x Observer	-0.002	0.0048

Table 3. Estimated detection probability within the surveyed strip. p(0) is the estimated detection probability at the left-truncation distance (i.e., 75 m from the trackline).

Parameter	Estimate	Standard Error	Coefficient of Variation
Detection probability	0.6366	0.0600	0.0944
Forward Team p(0)	0.8528	0.0722	0.1214
Aft Team p(0)	0.7020	0.0852	0.1213
Combined p(0)	0.9500	0.0322	0.0339
Overall Avg. Detection Prob.	0.6048	0.0061	0.1003

Table 4. Abundance estimates of bottlenose dolphins (BND) and the average probability that they are Tamanend's bottlenose dolphin by stratum. CV = coefficient of variation

Stratum	Total BND	CV Total	Mean Prob. Tamanend's	CV Prob Tamanend's	Tamanend's BND	CV Tamanend's BND
CFL-IN	1,857	0.569	0.627	0.159	1,413	0.591
CFL-OFF	3,186	0.592	0.432	0.183	1,562	0.619
NFL-IN	4,979	0.414	0.668	0.068	3,324	0.420
NFL-OFF	1,523	0.527	0.194	0.186	295	0.559
NM-IN	10,244	0.501	1.000	NA	10,244	0.501
NM-OFF	2,686	0.576	0.000	NA	0	NA
SCGA-IN	10,846	0.319	0.761	0.031	8,258	0.321
SCGA-OFF	2,825	0.422	0.306	0.091	863	0.432
SM-IN	2,626	0.739	1.000	NA	2,626	0.739
SM-OFF	5,963	0.458	0.000	NA	0	NA
SNC-IN	7,281	0.940	0.557	0.094	4,055	0.945
SNC-OFF	3,591	0.538	0.089	0.324	318	0.628

Table 5. Abundance estimates of Tamanend's bottlenose dolphin stocks for summer 2021.

Stock	Abundance	Standard Error	Coefficient of Variation	95% Confidence Interval
CFL	2,541	1,165	0.458	1,080 – 5,980
NFL	3,619	1,278	0.353	1,848 – 7,087
NM	10,244	5,137	0.501	4,049 – 25,918
SCGA	9,121	2,518	0.276	5,362 – 15,514
SM	2,626	1,939	0.739	721 – 9,569
SNC	4,373	2,915	0.667	1,332 – 14,351
Coastwide	32,523	7,435	0.229	20,896 – 50,619

Table 6. Abundance estimates by stock of Tamanend's bottlenose dolphins from summer aerial surveys conducted between 2002 and 2021.

Stock	Year	Abundance Estimate	Coefficient of Variation	95% Confidence Interval
CFL	2002	1,148	0.478	472-2793
CFL	2004	8,992	0.438	3956-20439
CFL	2010	18,221	0.741	4982-66635
CFL	2011	4,814	0.481	1969-11772
CFL	2016	1,218	0.352	623-2380
CFL	2021	2,541	0.458	1080 - 5980
NFL	2002	299	0.839	71-1250
NFL	2004	2,320	0.389	1112-4842
NFL	2010	4,355	0.448	1883-10070
NFL	2011	8,619	0.828	2091-35524
NFL	2016	877	0.485	356-2159
NFL	2021	3,619	0.353	1848-7087
NM	2002	20,200	0.580	7030-58040
NM	2004	5,823	0.481	2381-14239
NM	2010	14,314	0.738	3931-52125
NM	2011	15,630	0.293	8906-27431
NM	2016	6,639	0.411	3061-14401
NM	2021	10,243	0.501	4,049-25,918

Stock	Year	Abundance Estimate	Coefficient of Variation	95% Confidence Interval
SCGA	2002	21,940	0.274	12948-37176
SCGA	2004	4,894	0.445	2127-11259
SCGA	2010	11,274	0.274	6654-19103
SCGA	2011	7,406	0.529	2797-19607
SCGA	2016	6,027	0.338	3163-11483
SCGA	2021	9,120	0.276	5362-15514
SM	2002	19,316	0.314	10590-35232
SM	2004	29,535	0.334	15614-55868
SM	2010	9,217	0.511	3586-23691
SM	2011	4,988	0.638	1587-15680
SM	2016	3,751	0.599	1267-11104
SM	2021	2,625	0.739	721 - 9569
SNC	2002	3,941	0.513	1528-10163
SNC	2004	4,286	0.492	1721-10675
SNC	2010	4,281	0.585	1478-12398
SNC	2011	9,561	0.901	2110-43324
SNC	2016	2,524	0.598	854-7460
SNC	2021	4,373	0.667	1332 - 14351
Coastwide	2002	63,310	0.260	38350-104515

Stock	Year	Abundance Estimate	Coefficient of Variation	95% Confidence Interval
Coastwide	2004	51,669	0.236	32738-81546
Coastwide	2010	57,381	0.331	30500-107952
Coastwide	2011	41,457	0.301	23276-73838
Coastwide	2016	19,471	0.226	12572-30156
Coastwide	2021	32,523	0.229	20896 - 50619

7. Figures

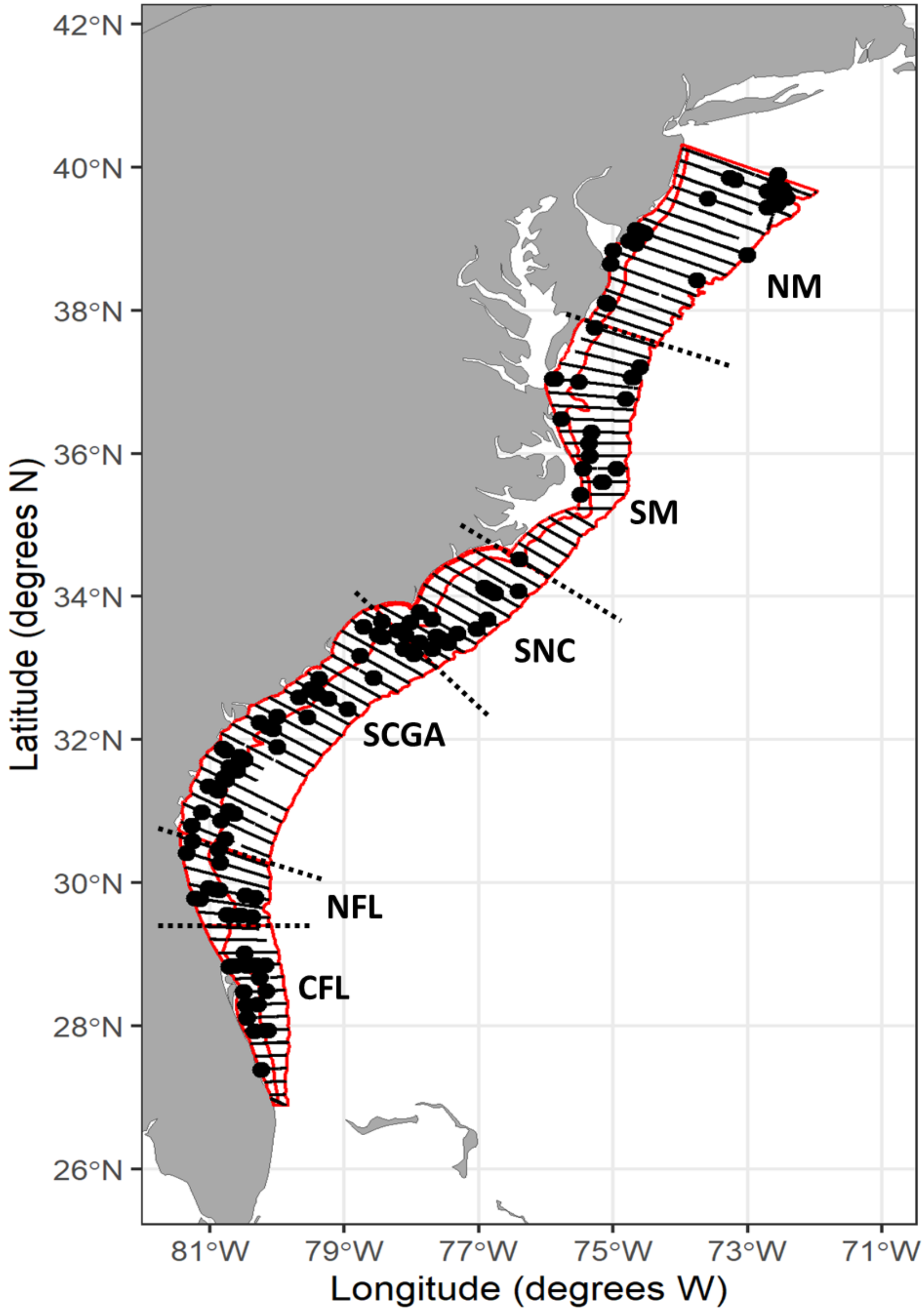

Figure 1: Surveyed strata, dolphin stocks, tracklines and sightings of bottlenose dolphins during summer 2021.

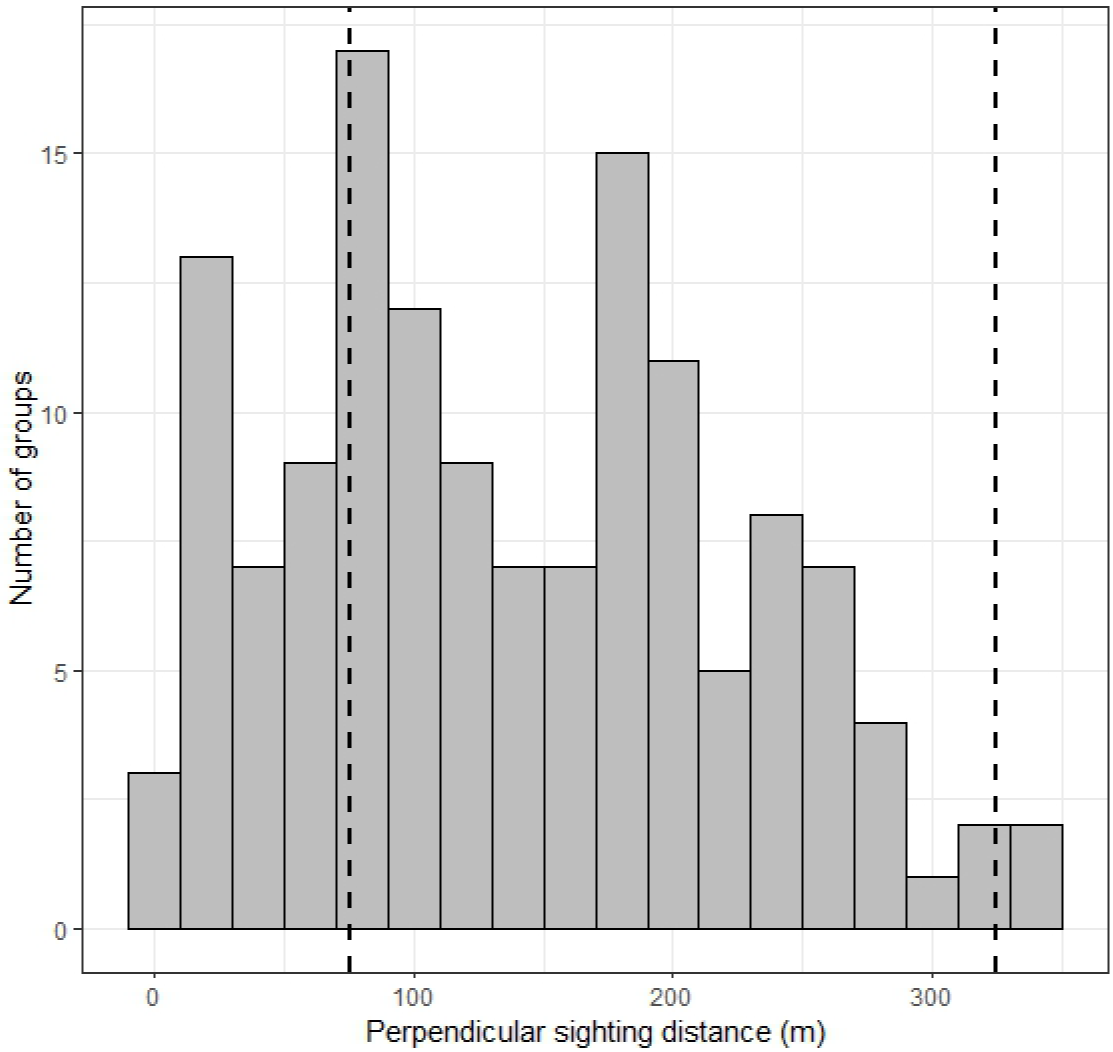

Figure 2: Histogram of perpendicular sighting distances (PSD) for observed dolphin groups. Dashed lines indicate the selected left truncation distance at 75m and the right truncation distance at 325 m.

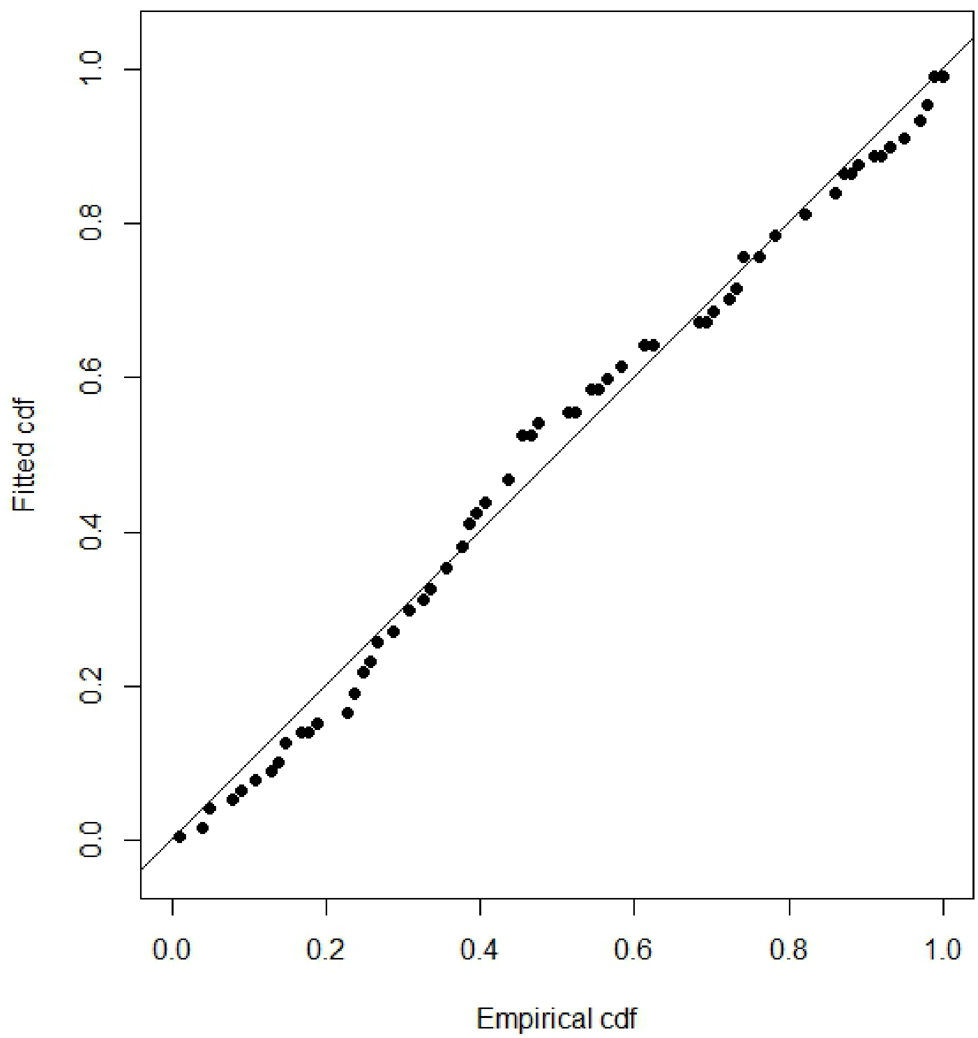

Figure 3: MRDS detection function Q-Q plot (cdf = cumulative distribution function).

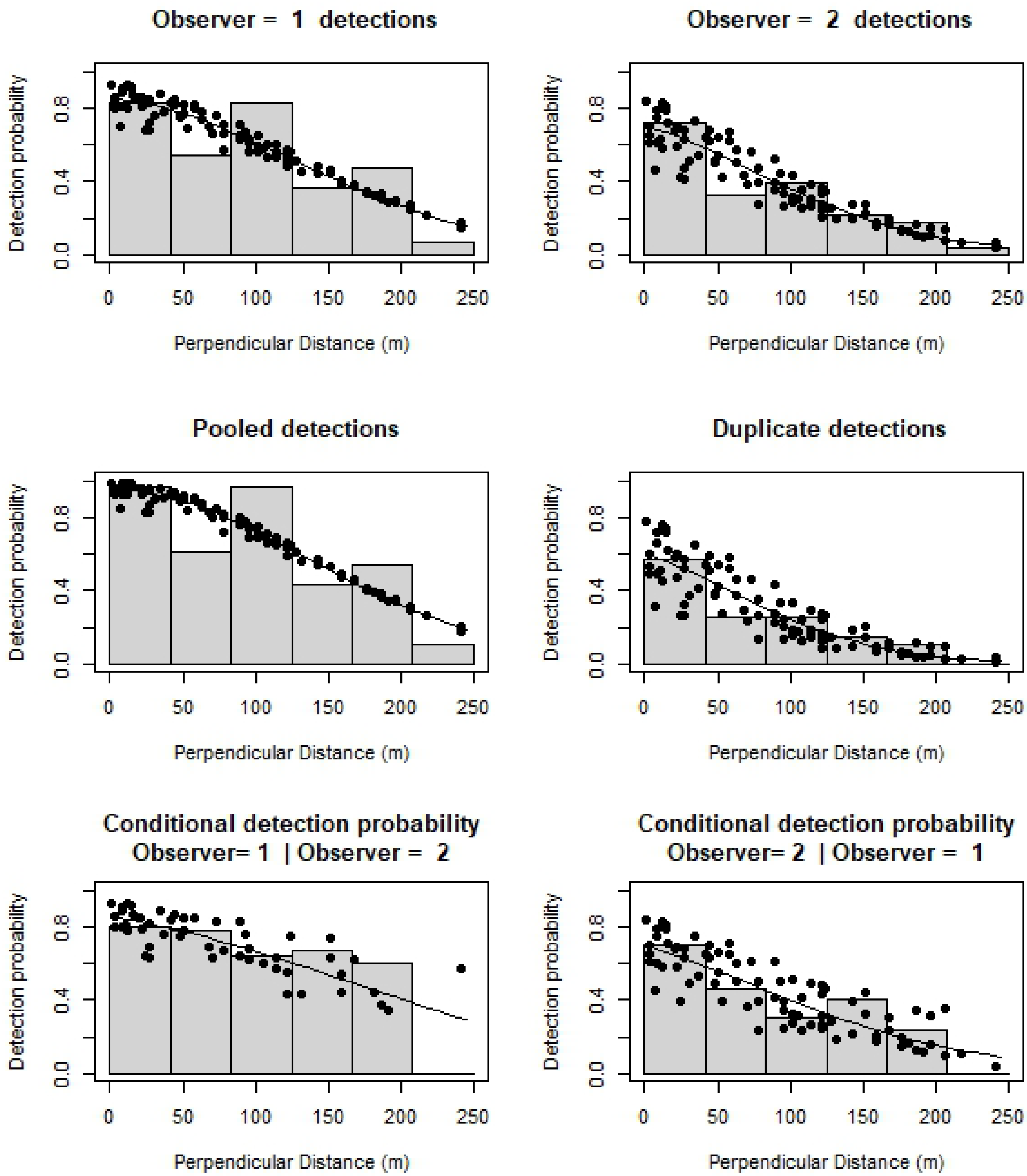

Figure 4: Detection function showing the relationship between detection probability and perpendicular sighting distance. Points indicate detection probabilities for different combinations of explanatory variables.

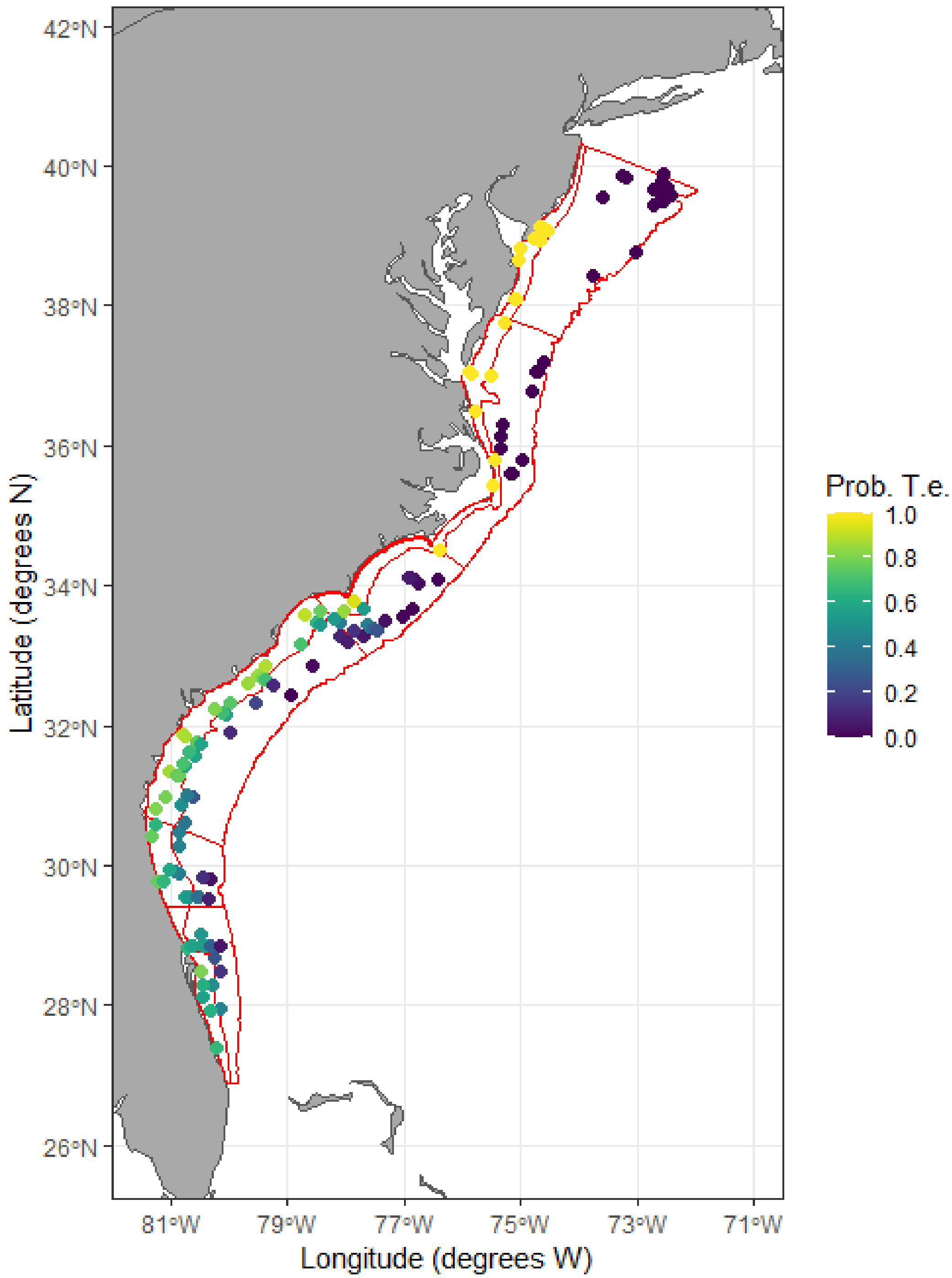

Figure 5: Predicted probability that observed groups of bottlenose dolphin are of *T. erebennus*.

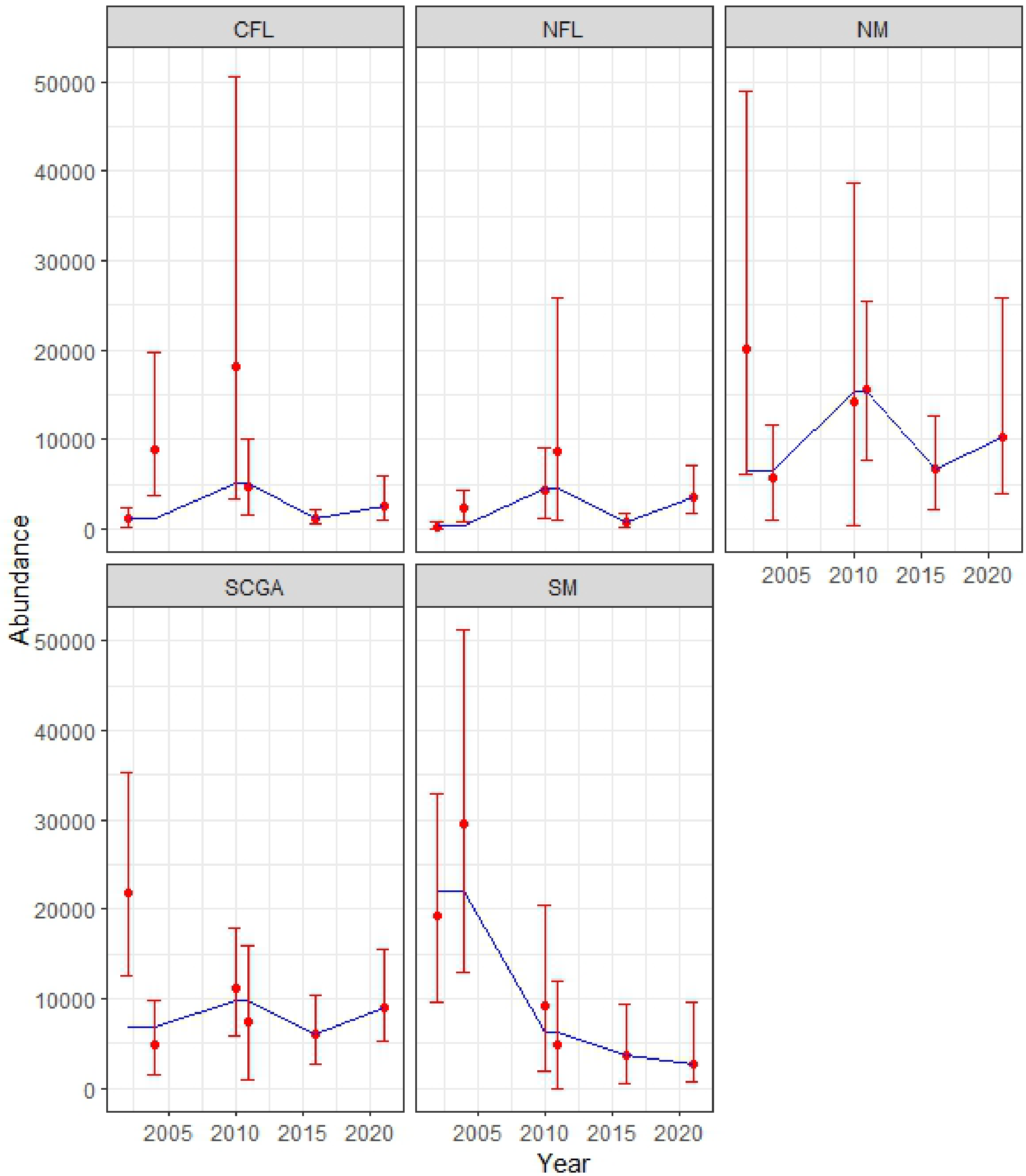

Figure 6: Trends in abundance estimates by stock. Error bars indicated 95% confidence intervals.

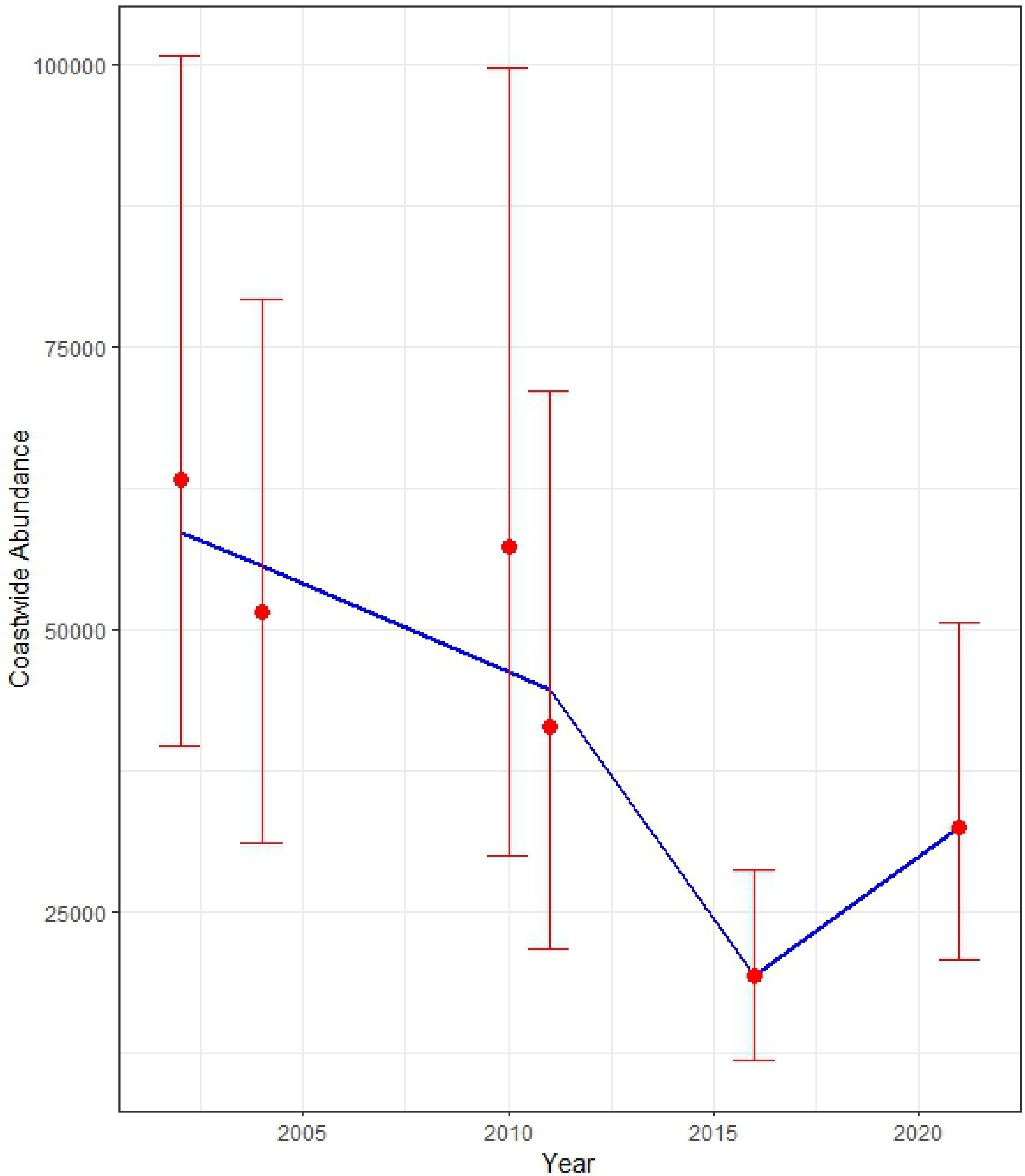

Figure 7: Trends in the coast wide abundance of *T. erebennus*. Error bars indicate 95% confidence intervals.

8. Appendix 1: Generalized linear model to assess changes in population size for each stock (fstrata) in four periods (fperiod): fperiod 1 = 2002-2004, fperiod 2 = 2010-2011, fperiod 3 = 2016, fperiod 4 = 2021.

```
Call:
lm(formula = N ~ fStrata + fperiod + fStrata:fperiod, data = bnd.stock,
    weights = 1/VAR)

Weighted Residuals:
    Min      1Q  Median      3Q     Max
-0.9107 -0.1620  0.0000  0.5371  2.5082

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)
(Intercept)            1298.0      775.2   1.674   0.1250
fStrataNFL             -853.1      848.5  -1.005   0.3384
fStrataNM              5302.3     3959.5   1.339   0.2102
fStrataSCGA            5581.3     3023.7   1.846   0.0947 .
fStrataSM             20820.8     7408.3   2.810   0.0185 *
fperiod2               3899.5     3347.0   1.165   0.2710
fperiod3                -79.7      986.9  -0.081   0.9372
fperiod4               1243.2     1832.9   0.678   0.5130
fStrataNFL:fperiod2     306.9     4302.8   0.071   0.9445
fStrataNM:fperiod2     4922.2     7886.1   0.624   0.5465
fStrataSCGA:fperiod2   -989.2     5631.6  -0.176   0.8641
fStrataSM:fperiod2   -19702.6     8923.8  -2.208   0.0517 .
fStrataNFL:fperiod3     511.8     1208.9   0.423   0.6810
fStrataNM:fperiod3      118.7     5587.5   0.021   0.9835
fStrataSCGA:fperiod3   -772.3     4237.9  -0.182   0.8590
fStrataSM:fperiod3   -18287.8     8094.7  -2.259   0.0474 *
fStrataNFL:fperiod4    1930.7     2608.2   0.740   0.4762
fStrataNM:fperiod4     2400.5     8491.6   0.283   0.7832
fStrataSCGA:fperiod4    998.5     4979.7   0.201   0.8451
fStrataSM:fperiod4   -20736.2     8080.2  -2.566   0.0281 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.426 on 10 degrees of freedom
Multiple R-squared:  0.8336,   Adjusted R-squared:  0.5173
F-statistic: 2.636 on 19 and 10 DF,  p-value: 0.0594
```

9. Appendix 2: Generalized linear model to assess changing trend (year effect) in three periods (fy2016): fy20160 = 2002-2004 and 2010-2011, fy20161 = 2016, and fy20162= 2021.

```
Call:
lm(formula = N ~ year:fy2016, data = bnd.total, weights = 1/VAR)

Weighted Residuals:
         1          2          3          4          5          6 
 2.816e-01 -3.211e-01  5.816e-01 -2.664e-01 -1.665e-16  1.388e-17 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)  
(Intercept)   58669.2     6256.8   9.377   0.0112 *
year:fy20160  -1542.9     1029.5  -1.499   0.2727  
year:fy20161  -2799.9      478.5  -5.852   0.0280 *
year:fy20162  -1376.1      392.1  -3.510   0.0725 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.5439 on 2 degrees of freedom
Multiple R-squared:  0.9629,  Adjusted R-squared:  0.9072 
F-statistic: 17.29 on 3 and 2 DF,  p-value: 0.05517
```