Southeast Fisheries Science Center Reference Document PRDB-2016-08

Abundance of marine mammals in waters of the U.S. east coast during the summer 2011

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JUNE 2016

1. BACKGROUND AND STUDY OBJECTIVES

In this report, we describe the results of a large vessel, visual line-transect survey conducted by the NMFS, Southeast Fisheries Science Center along the U.S. Atlantic coast during the summer of 2011. The primary objective of the survey was to collect data and samples to support assessment of the abundance, habitats, and spatial distribution of cetaceans within U.S. waters. The survey was conducted as part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS). The AMAPPS program is a comprehensive effort conducted jointly by the Bureau of Ocean Energy Management (BOEM), the U.S. Fish and Wildlife Service, and NOAA Fisheries' Northeast and Southeast Fisheries Science Centers, and its primary objective is to produce spatially explicit maps of marine mammal, sea turtle and sea bird density to support environmental impact assessments and planning. These data and resulting abundance estimates will also improve the assessment of marine mammal stocks as required under the Marine Mammal Protection Act (MMPA) The MMPA requires that stocks of marine mammal species in U.S. waters be maintained at or above their optimum sustainable population level (OSP), defined as the number of animals which results in the maximum net productivity. To meet this requirement, the National Marine Fisheries Service (NMFS) conducts research to define stock structure, and for each stock, estimates annual human-caused mortality and potential biological removal (PBR), the maximum number of animals that may be removed from a stock due to human activities (*e.g.*, fisheries bycatch) while allowing the stock to reach or maintain its OSP. PBR is calculated following specific criteria using the estimated minimum abundance of the stock, its maximum net productivity rate (theoretical or estimated), and a recovery factor (Barlow *et al*., 1995; Wade and Angliss, 1997). The NMFS is required to prepare an annual Stock Assessment Report (SAR) for each stock to update abundance, stock structure, maximum net productivity, human-caused mortality, PBR, and status (*e.g.*, Waring *et al.*, 2016). This study describes the results of the summer 2011 survey and resulting abundance estimates for U.S. Atlantic oceanic stocks of marine mammals.

2. METHODS

2.1. Survey Methods

The survey was conducted aboard the NOAA Ship *Gordon Gunter*, a 68-m (length) oceanographic research vessel, in waters off the southeast Atlantic coast of the U.S. The survey was conducted along "zig-zag" tracklines between central Florida and the Maryland/Delaware border and included shelf-break and inner continental slope waters within the U.S. EEZ. A small portion of the survey effort was conducted along the outer margin of the Blake Plateau at the border between U.S. and Bahamian waters (Figure 1). Survey effort was stratified into four geographic strata reflecting regional differences in hydrographic and bathymetric structure and spatial variation in the density and occurrence of different cetacean species.

Visual cetacean surveys were conducted from 19 June to 1 August 2011. Standard ship-based, line-transect survey methods for cetaceans, similar to those used in the Pacific Ocean, Atlantic Ocean, and Gulf of Mexico, were used (*e.g.*, Barlow, 1995; Mullin and Fulling, 2003). The survey employed the "independent observer" methodology to improve estimates of sighting probability. This approach was similar to that used during the summer of 2004 (Garrison *et al*., 2011). The two observer teams were stationed on the flying bridge (height above water = 13.7 m) and the bridge wings (height above water = 11.0 m). The two teams were isolated from one another to avoid "cueing" each other to the presence of marine mammals. Both teams consisted of four observers rotating through two positions at 30 min. intervals. A recorder position stationed on the bridge maintained communication with both teams and recorded data on sightings by each team using a computerized data entry program interfaced with a global positioning system (GPS) receiver. For each team, at least one observer experienced in ship-based, line-transect methods and identification of cetaceans was present on the flying bridge or bridge wings at all times. The left and right side observers searched to the horizon in the arc from 10° right and left of the ship's bow to the left and right beams (90°), respectively, using 25x "bigeye" binoculars. Survey speed was usually 18 km hr^{-1} (~10 kt) but varied with sea conditions. The effectiveness of visual line transect survey effort is severely limited during high sea state and poor visibility conditions (e.g., fog, haze, rain). Survey effort was therefore suspended during heavy seas (Beaufort sea state > 5) and rain.

For each cetacean sighting, time, position, bearing and reticle (a measure of radial distance) of the sighting, species, group-size, behavior, bottom depth, sea surface temperature, and associated animals (e.g., seabirds, fish) were recorded. The bearing and radial distance for groups sighted without 25x binoculars and close to the ship were estimated. Survey effort data were automatically recorded every 2 min and included the ship's position and heading, effort status, observer positions, and environmental conditions which could affect the observers' ability to sight animals (e.g., Beaufort sea state, trackline glare, etc.). Typically, if a sighting was within a 3.0 nm strip on either side of the ship, the ship was diverted from the trackline to approach the group to identify species and estimate group-size. Cetaceans were identified to the lowest taxonomic level possible.

2.2. Analytical Methods

Abundance estimates were derived using the independent observer approach assuming point independence (Laake and Borchers, 2004) as implemented in the Distance computer program (Thomas *et al*., 2009). Briefly, this approach is an extension of standard line-transect distance analysis that includes direct estimation of sighting probability on the trackline. The probability of sighting a particular group is the product of two probability components. The first probability corresponds to the “standard” sighting function such that the probability of detection declines with increasing distance from the trackline following a known functional form (typically the half-normal or hazard function). The second component is the likelihood of detection on the trackline, which is modeled using a logistic regression approach and the “capture histories” of each sighting (i.e. seen by one or both teams). The logistic model can include factors that may affect the probability of detection such as viewing or weather conditions. Details on the derivation, assumptions, and implementation of the estimation approach are provided in Laake and Borchers (2004).

Sighting probability was estimated separately for five groups of cetaceans: large dolphins, small dolphins, small whales, large whales, and cryptic species to account for differences in body size and surface behavior and associated differences in sighting probability (Table 1; Barlow, 1995; Mullin and Fulling, 2003; Garrison et al. 2011). “Cryptic” species including beaked whales (family Ziphiidae) and pygmy/dwarf sperm whales (*Kogia spp*.) were grouped because these taxa are deep divers that may have only a limited availability to visual surveys due to the long time spent underwater and difficulty in seeing them when at the surface. For each species group, sighting probability was estimated globally across strata. The perpendicular sighting distances were right-truncated to remove roughly 10% of the sightings with the farthest distances (Buckland *et al*., 2001). The form of the sighting function (hazard vs. half-normal) and the inclusion of covariates (including observer platform, group size, sea state, glare, swell height, wind speed) in the mark-recapture and detection probability components of the models were evaluated using model selection based upon the Akaike Information Criterion (AIC, Laake and Borchers, 2004). Stratified abundance estimates for each individual taxon were calculated using stratum and species level encounter rates (groups per km of trackline) and mean group size.

3. RESULTS AND DISCUSSION

A total of 4,400 km of survey effort were completed during the survey. There were 1,558 km of trackline on effort in the Blake Plateau stratum, 905 km in the Mid-Atlantic, 752 m in the Offshore-North, and 1,185 km in the Offshore-South. Weather conditions were good to fair throughout much of the survey, with sea states of Beaufort 3-4 on most survey days. Weather conditions precluded the completion of all planned tracklines in the Offshore-North stratum resulting in relatively large gaps in spatial coverage in this stratum (Figure 1).

Cetacean sightings by stratum are summarized in Table 1. As expected, the majority of sightings occurred along the continental shelf break with generally lower sighting rates over the continental slope (Figure 1). Large whale sightings included fin whales and sperm whales in (Figure 2). Pilot whale's and Risso's dolphins were the primary small whales sighted during the survey. A variety of delphinids were encountered during the survey with the majority of sightings along the shelf-break (Figure 3, Figure 4). A notably high concentration of beaked whale sightings occurred along a trackline offshore of North Carolina (Figure 5). This particular trackline also had a very high number of pygmy/dwarf sperm whale sightings.

The number of on effort sightings by taxonomic grouping is shown in Table 2. The number of resights (i.e., groups observed by both teams) was low for the "cryptic" species, which is to be expected due to the overall low detection probabilities for these taxa. The number of sightings of large whales was small, with only 24 on effort sightings during the survey. This small number of sightings makes resulting detection probability functions less reliable for this group. Overall, the number of sightings seen only by the upper teams was similar to that seen only by the lower team, suggesting that the ability of each team to detect cetaceans was roughly equal for most taxa.

Selected models for the mark-recapture (MR) and detection function (DS) components of the detection probability model and predicted detection probabilities are shown in Table 3. The most important environmental covariates for the detection functions were glare and sea state; however, the influence of covariates on detection probabilities overall was relatively small. Most selected MR models included only terms for the observer station and distance. There was evidence for a difference in detection probability between the upper and lower team for Small Whales and Small Dolphins as indicated by the selection of the observer x distance interaction term. In these groups, the estimate of detection probability on the trackline differed between the two teams (Table 3). The selected models provided adequate fits to the data as indicated by non-significant (p-value > 0.05) GOF tests for both the MR and DS components of the models (Table 3).

The detection probability functions generally showed a monotonic decrease in detection probabilities with increasing distance from the trackline (Figures 7-11). The exception was the function for large whales which showed a fairly uniform, non-decreasing trend with a high number of detections at large distances from the trackline (Figure 7). This function shape was most likely a result of the small sample size and the ability of observers to detect blows or large bodies at relatively large distances. The small number of detections makes the estimation of detection probabilities (and resulting abundance estimates) for large whales less reliable than those of the other taxa groups.

Abundance estimates for each species are shown in Table 4. The mid-Atlantic stratum had the highest diversity and abundance of cetaceans with 13 of the 16 species observed in this stratum. Bottlenose dolphins, Atlantic spotted dolphins, and short-finned pilot whales were the most abundant species observed during the survey. The abundance estimates for the deep-diving "cryptic" species are likely significantly negatively biased due to their long dive times and resulting low availability to visual observers. The uncertainty around all abundance estimates is relatively high, with the best CVs ranging between 0.39 – 0.55. Rare species with a small number of sightings had higher CVs that exceeded 0.9 (Table 4). The majority of this variability was associated with variation in encounter rates among different tracklines rather than variation in group sizes or uncertainty in the detection function. Therefore, spatially explicit estimation methods or alternative stratification may be able to reduce the uncertainty in resulting abundance estimates.

The data collected during this survey will be used to develop spatial models to explain animal spatial distribution and estimate abundance. In addition, the abundance estimates presented in Table 4 are combined with abundance estimates generated by the Northeast Fisheries Science Center to provide coastwide estimates of population size and the associated Potential Biological Removal benchmark for Annual Marine Mammal Protection Act stock assessment reports.

4. TABLES

Table 1: Number of cetacean groups sighted during GU11-02 by survey stratum.

Species	Taxa Group	Blake Plateau	Mid-Atlantic	Off-North	Off-South	Total
Atlantic spotted dolphin	Lg. Dolphin	6	13	2	0	21
Blainville's beaked whale	Cryptic	0	1	0	0	1
Bottlenose dolphin	Lg. Dolphin	39	16	0	0	55
Bottlenose/Spotted dolphin	Lg. Dolphin	1	0	0	0	1
Clymene dolphin	Sm. Dolphin	0	0	1	1	2
Common dolphin	Sm. Dolphin	0	2	0	0	2
Cuvier's beaked whale	Cryptic	0	1	0	1	2
Dwarf sperm whale	Cryptic	0	0	3	0	3
False killer whale	Sm. Whale	1	0	0	0	1
Fin whale	Lg. Whale	0	3	0	0	3
Pantropical spotted dolphin	Sm. Dolphin	0	0	2	0	2
Pilot whales	Sm. Whale	5	24	2	2	33
Pygmy/Dwarf sperm whale	Cryptic	0	2	14	0	16
Risso's dolphin	Lg. Dolphin	9	5	0	0	14
Rough-toothed dolphin	Lg. Dolphin	0	1	0	0	1
Sperm whale	Lg. Whale	0	15	4	4	23
Spinner dolphin	Sm. Dolphin	0	0	1	0	1
Stenella sp.	Sm. Dolphin	0	0	0	1	1
Striped dolphin	Sm. Dolphin	0	5	0	0	5
unid. dolphin	Sm. Dolphin	6	12	3	3	24
unid. large whale	Lg. Whale	0	4	0	0	4
Unid. Mesoplondant	Cryptic	0	4	7	3	14
unid. odontocete	Sm. Whale	2	4	11	1	18
unid. small whale	Sm. Whale	0	3	9	4	16
Unid. Ziphiid	Cryptic	0	0	11	0	11
Total		**69**	**115**	**70**	**20**	**274**

Table 2: Count of cetacean sightings by sighting history within taxa groups.

Group	Upper Team Only	Lower Team Only	Both Teams
Cryptic	18	23	5
Large Dolphins	49	25	32
Large Whales	9	5	9
Small Dolphins	16	18	6
Small Whales	17	31	15
Total	**109**	**102**	**67**

Table 3: Detection probability model parameters and estimated detection probabilities for each taxa group.

HN = Half-normal function, HR = Hazard rate model function. MR model = mark-recapture model component, DS = distance function model component. MR Model and DS Model columns indicate covariates included in the respective model.

Group	**MR Model**	**MR Model Chi-Square GOF (p-value)**	**DS Model**	**DS Model Chi-Square GOF (p-value)**	**p(0) (CV)**	**Avg. Detection Probability (CV)**
Large Whales	distance	1.50 (6 df, p = 0.958)	HN – no covar	0.40 (2 df, p = 0.398)	Upper: 0.551 (0.326) Lower:0.551 (0.326)	0.799 (0.202)
Large Dolphins	distance + glare + seastate + condition	17.78 (11 df, p = 0.086)	HR – glare + seastate	4.38 (3 df, p = 0.224)	Upper: 0.417 (0.241) Lower:0.417 (0.241)	0.232 (0.328)
Small Whales	observer + distance + observer x distance	18.80 (12 df, p = 0.095)	HN - seastate	4.33 (5 df, p = 0.503)	Upper: 0.283 (0.329) Lower:0.431 (0.296)	0.345 (0.219)
Small Dolphins	observer + distance + observer x distance	2.43 (6 df, p = 0.877)	HN – no covar	0.68 (3 df, p = 0.878)	Upper: 0.419 (0.481) Lower:0.949 (0.081)	0.525 (0.192)
Cryptic	distance + cluster size	4.46 (7 df, p = 0.725)	HN – glare	4.11 (2 df, p = 0.128)	Upper: 0.342 (0.262) Lower:0.342 (0.262)	0.280 (0.275)

Table 4: Abundance estimates for cetacean species during GU11-02. LW = large whale, LD = large dolphin, SW = small whale, SD = small dolphin, CR = cryptic.

Group	Species	Blake Plateau (CV)	Mid-Atlantic (CV)	Northern Offshore (CV)	Southern Offshore (CV)	Total N (CV)
LW	Sperm whale	0	135 (0.54)	300 (0.57)	260 (0.63)	695 (0.39)
LW	Fin Whale	0	23 (0.76)	0	0	23 (0.75)
LW	Unid. Large Whale	0	17 (0.74)	0	0	17 (0.74)
LD	Bottlenose dolphins	42,671 (0.63)	8,154 (0.44)	0	0	50,765 (0.55)
LD	Risso's dolphins	2,615 (0.49)	438 (0.82)	0	0	3,052 (0.44)
LD	Rough-toothed dolphins	0	271 (1.00)	0	0	271 (1.00)
LD	Atlantic spotted dolphins	6,512 (0.63)	11,404 (0.52)	0	0	17,917 (0.42)
SW	Short-finned pilot whale	4,762 (0.62)	6,711 (0.52)	1,634 (1.17)	3,837 (1.10)	16,946 (0.43)
SW	False Killer Whale	422 (1.06)	0	0	0	422 (1.06)
SW	Unid. Small Whale	0	106 (0.58)	651 (0.89)	78 (0.58)	968 (0.69)
SD	Common dolphins	0	2,993 (0.87)	0	0	2,993 (0.87)
SD	Striped dolphins	0	7,924 (0.66)	0	0	7,924 (0.66)
SD	Pantropical spotted dolphins	0	0	3,332 (0.91)	0	3,332 (0.91)
CR	Cuvier's beaked whale	0	0	1,537 (0.66)	33 (1.07)	1,570 (0.65)
CR	Mesoplodon spp.	0	247 (0.56)	1,248 (0.84)	99 (0.60)	1,594 (0.67)
CR	Kogia spp.	0	79 (0.94)	1,923 (0.71)	0	2,002 (0.69)

5. FIGURES

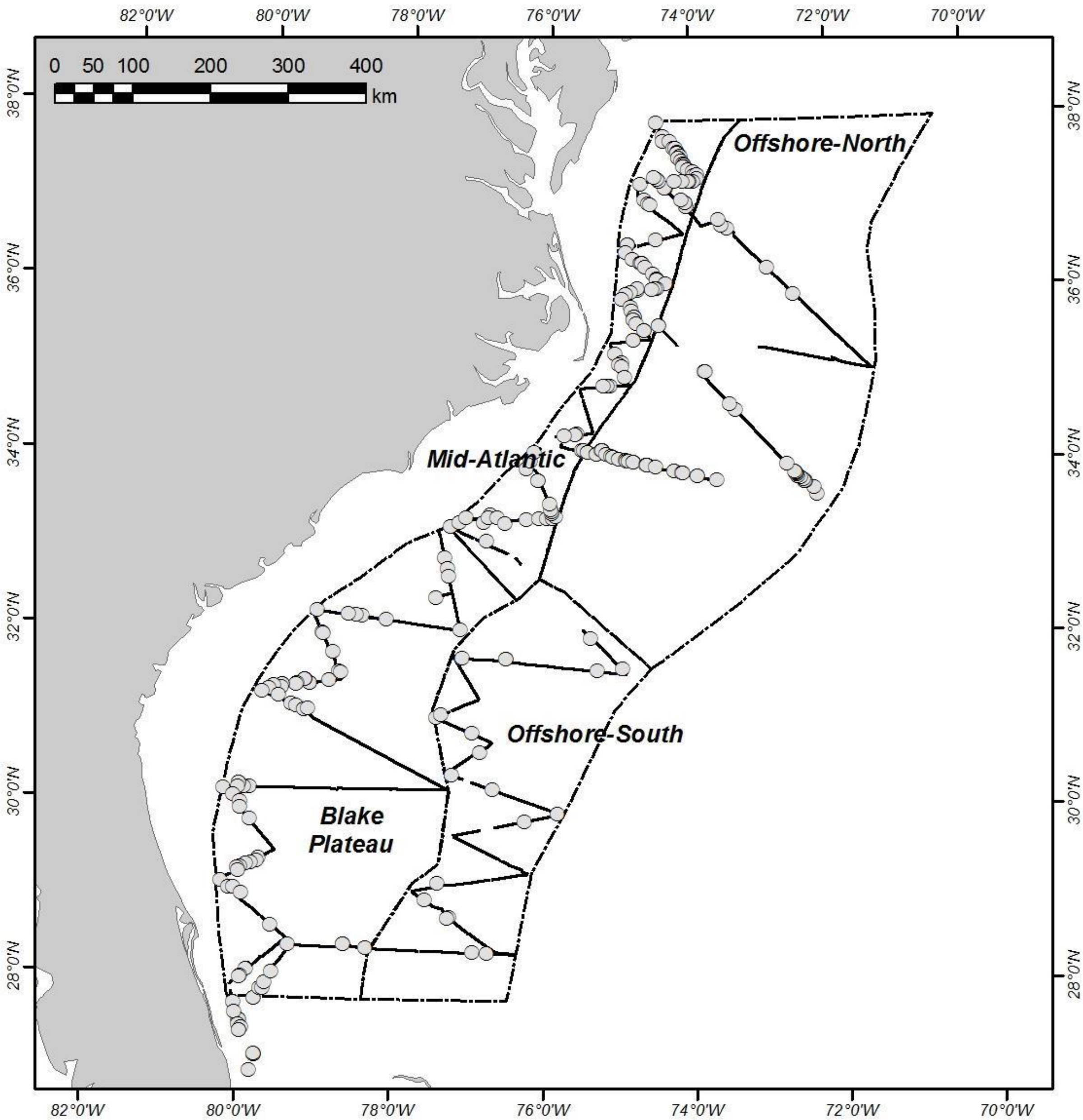


Figure 1: Survey tracklines and cetacean sightings during GU11-02 and survey strata.

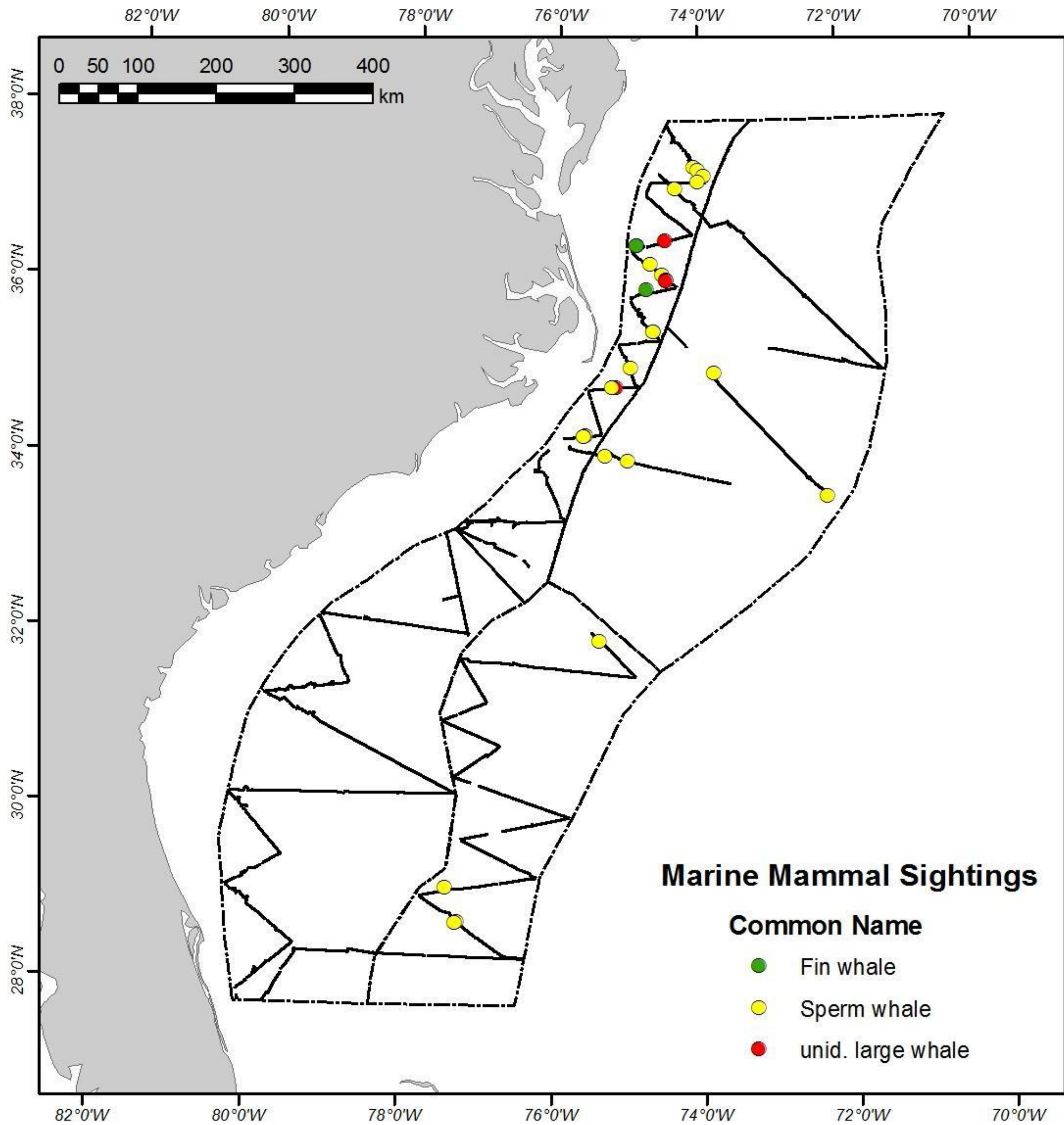


Figure 2: Large whale sightings during GU11-02.

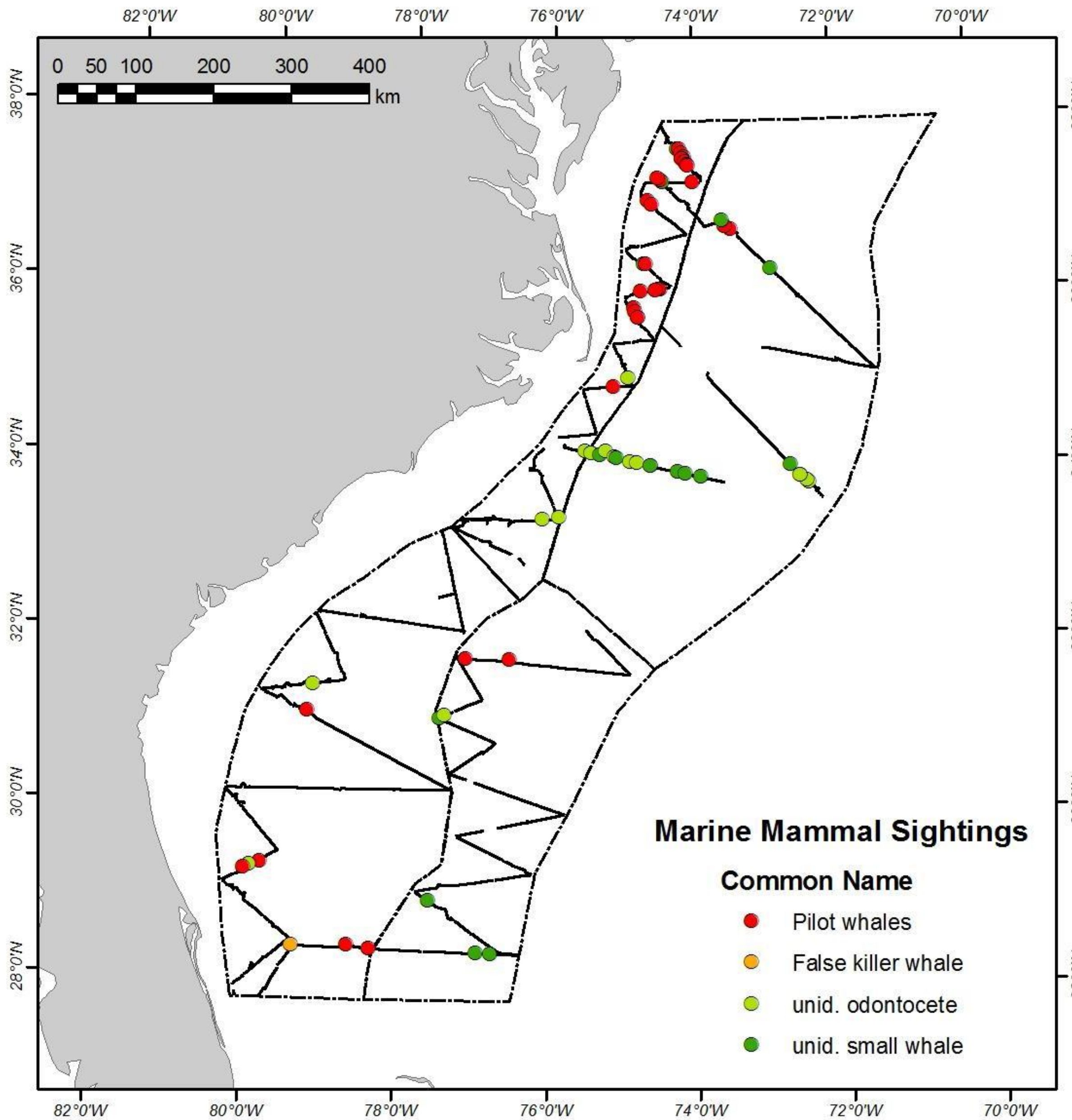


Figure 3: Small whale sightings during GU11-02.

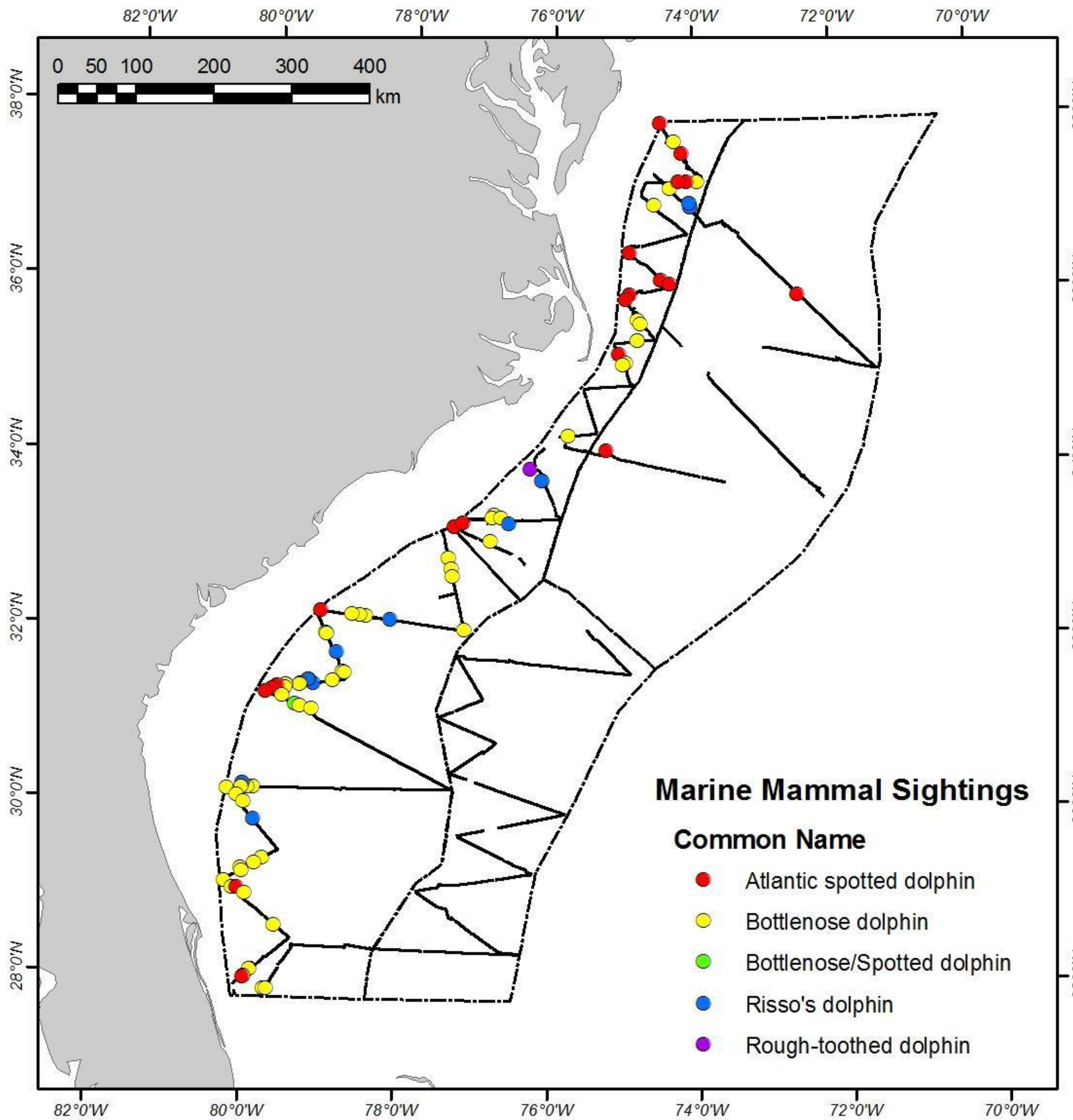


Figure 4: Large dolphin sightings during GU11-02.

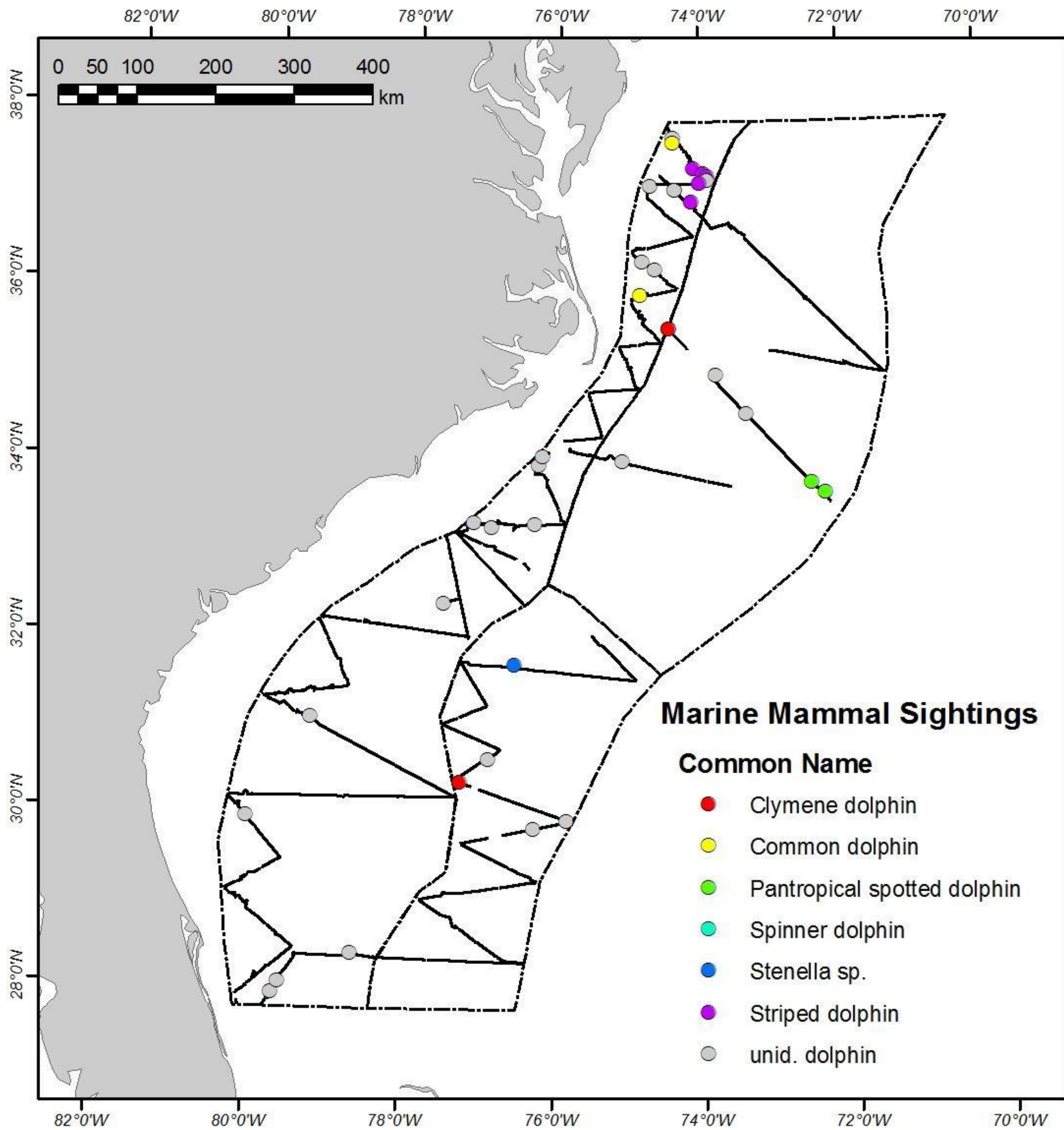


Figure 5: Small dolphin sightings during GU11-02.

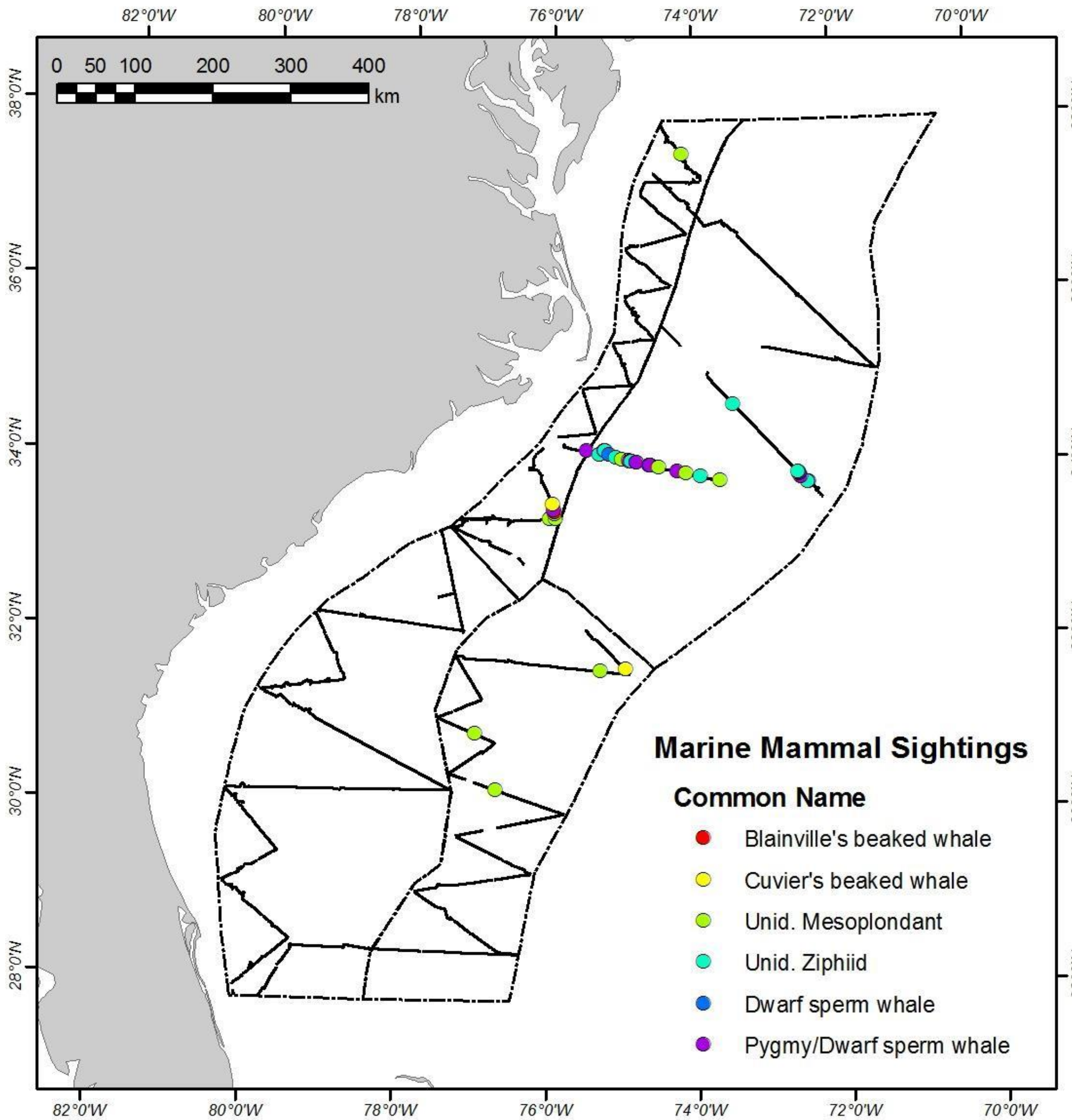


Figure 6: Cryptic species sightings during GU11-02.

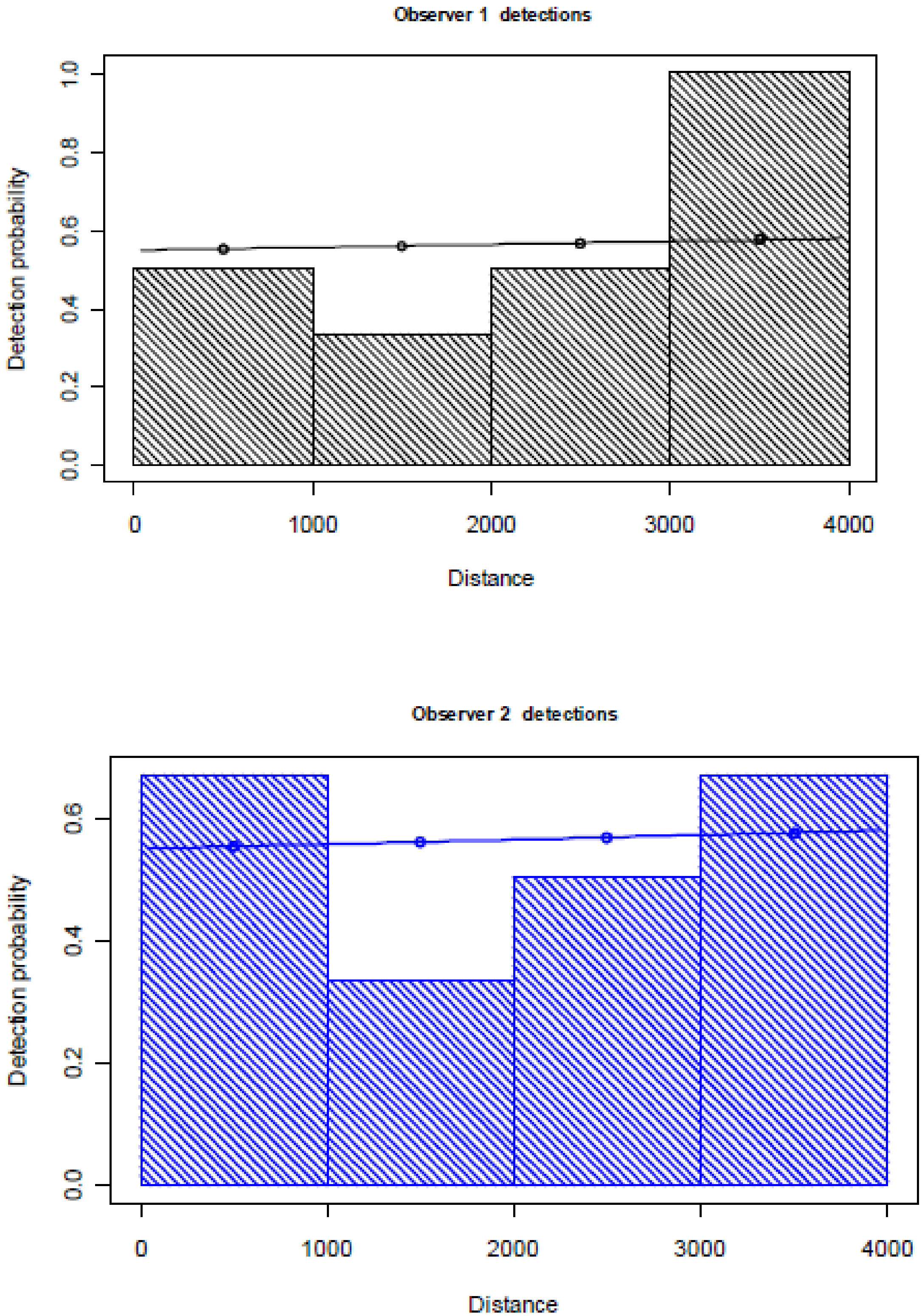


Figure 7: Detection functions for the upper (observer 1) and lower (observer 2) survey teams for large whales. The line indicates the modeled detection probability averaged over covariate values.

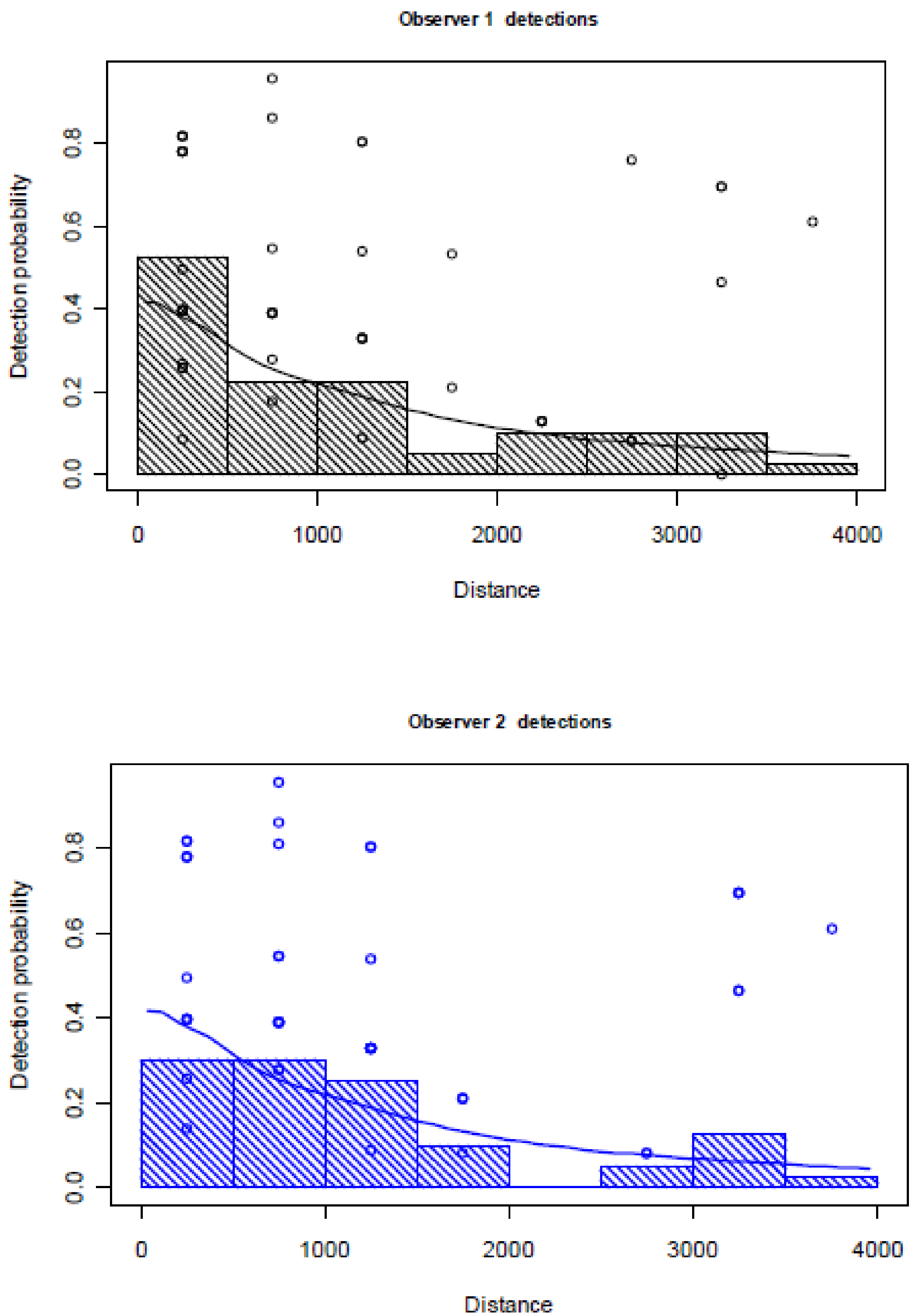


Figure 8: Detection functions for the upper (observer 1) and lower (observer 2) survey teams for small whales. The line indicates the modeled detection probability averaged over covariate values.

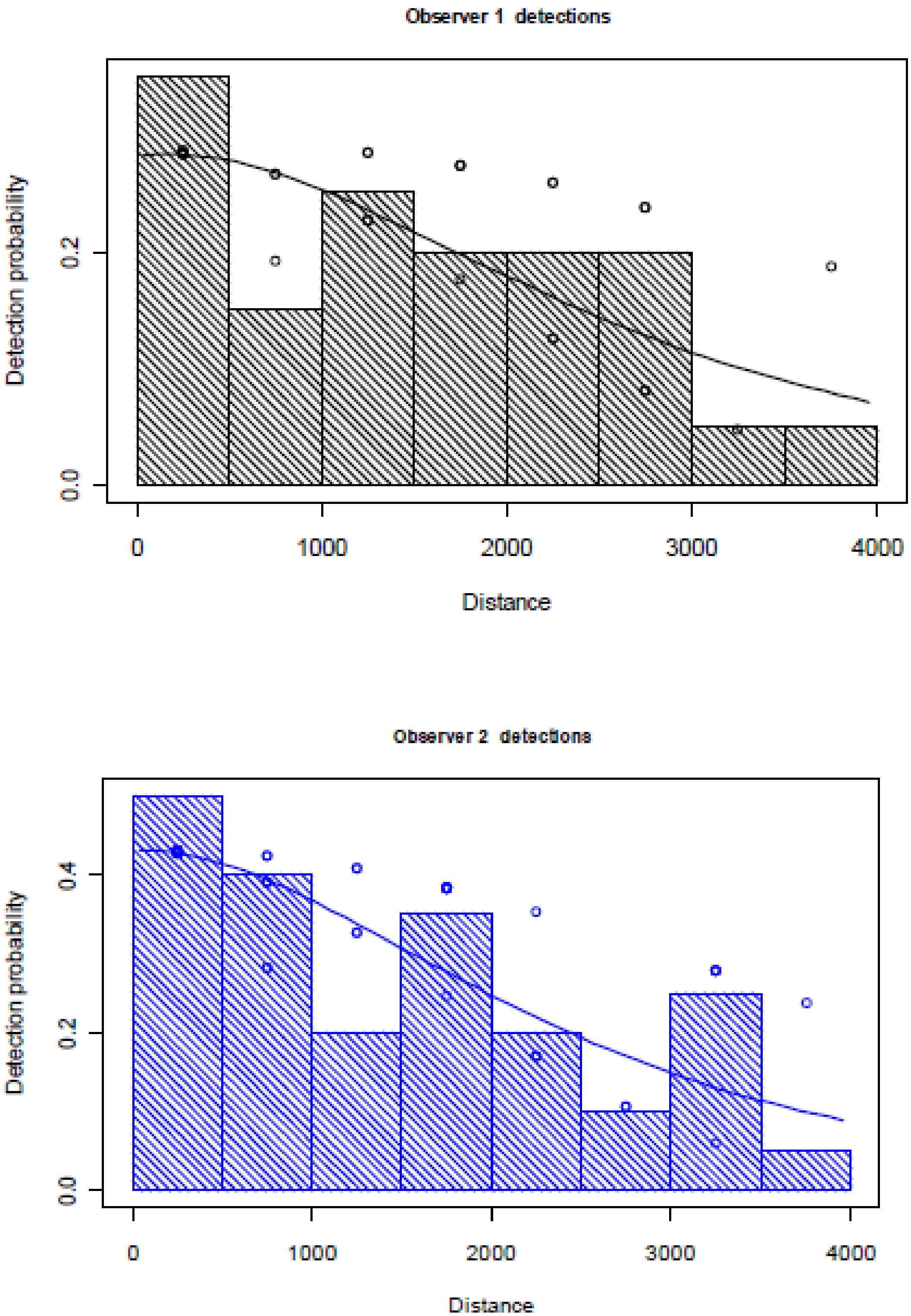
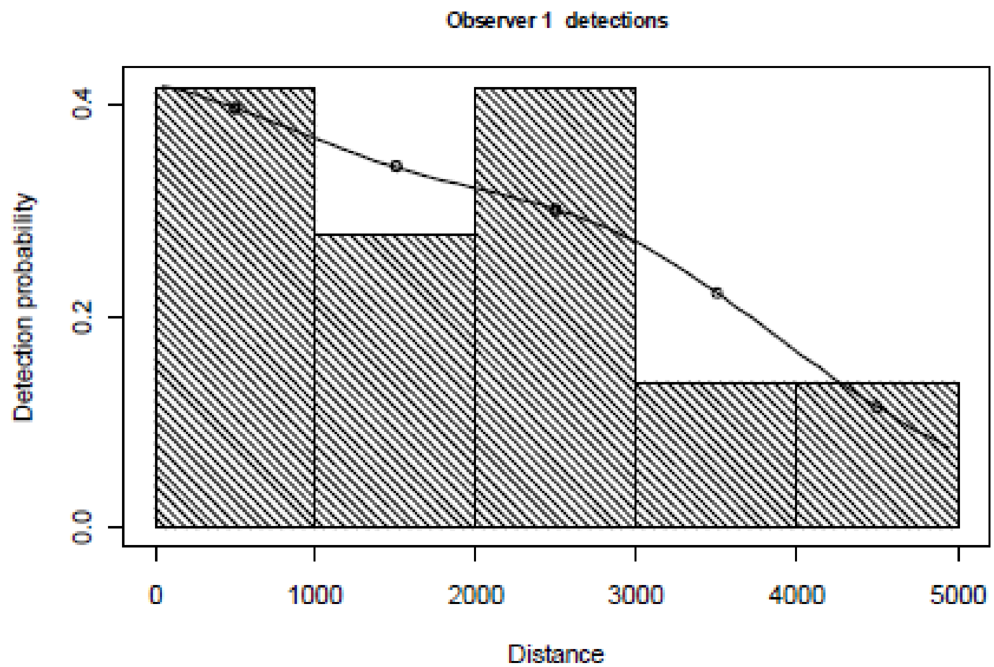


Figure 9: Detection functions for the upper (observer 1) and lower (observer 2) survey teams for large dolphins. The line indicates the modeled detection probability averaged over covariate values.



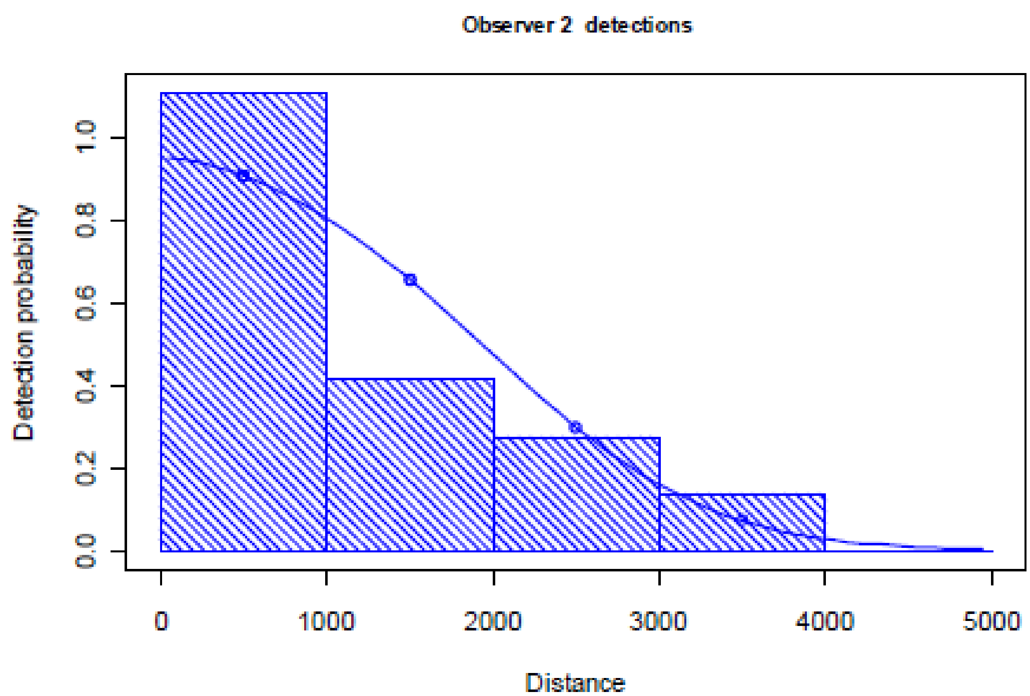


Figure 10: Detection functions for the upper (observer 1) and lower (observer 2) survey teams for small dolphins. The line indicates the modeled detection probability averaged over covariate values.

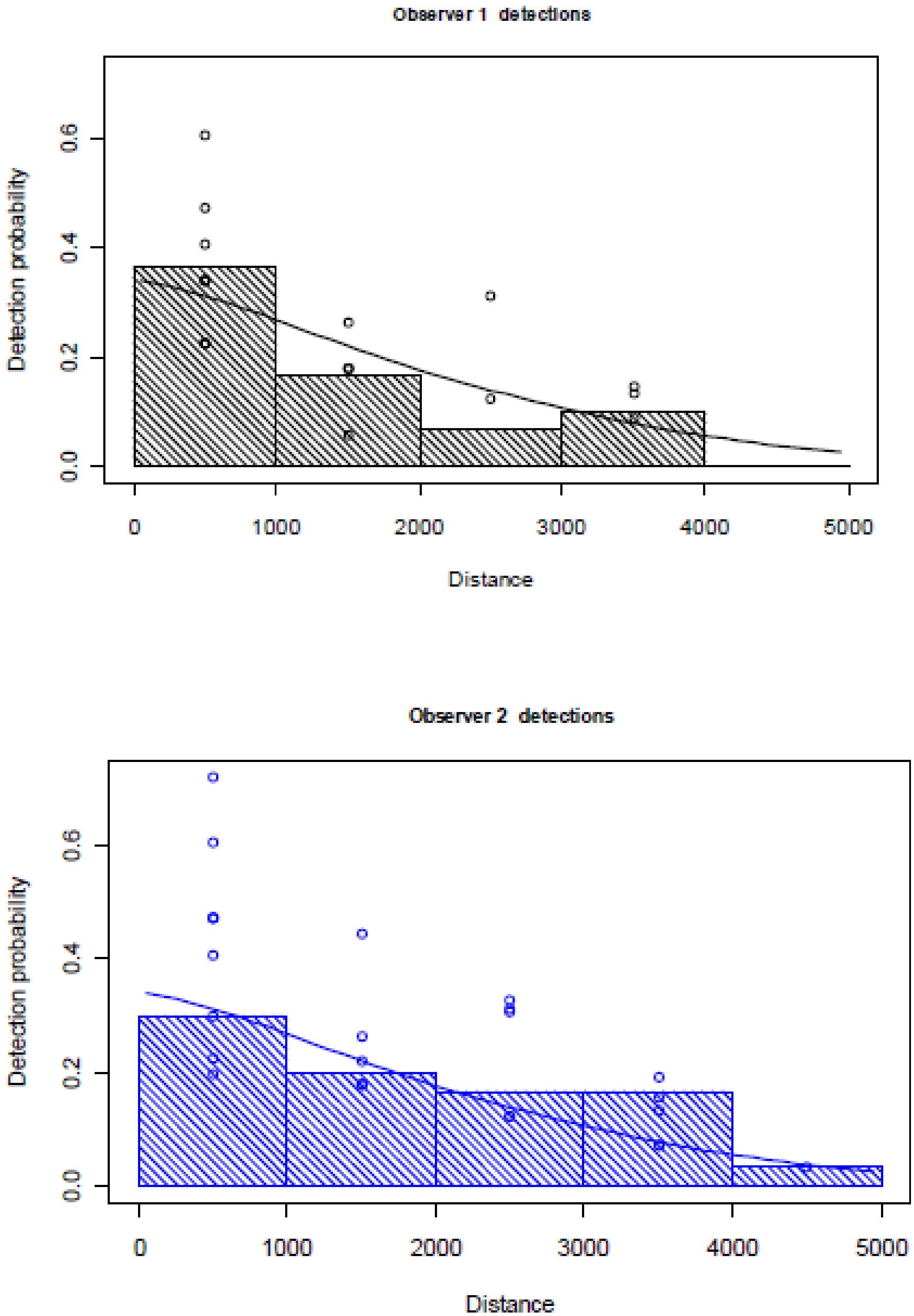


Figure 11: Detection functions for the upper (observer 1) and lower (observer 2) survey teams for cryptic species. The line indicates the modeled detection probability averaged over covariate values.

REFERENCES

Barlow, J. 1995. "The abundance of cetaceans in California waters. Part I: Ship surveys in summer and fall of 1991." *Fishery Bulletin* 93: 1-14.

Barlow, J., S.L. Swartz, T.C. Eagle, and P.R. Wade. 1995. "U.S. marine mammal stock assessments: Guidelines for preparation, background, and a summary of the 1995 assessments." NOAA Tech. Mem. NMFS-OPR-6., 73.

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.* New York: Oxford University Press.

Garrison, L.P., Martinez, A.M., Foley, K.M. 2011. "Habitat and abundance of marine mammals in continental slope waters of the southeastern U.S. Atlantic." *Journal of Cetacean Research and Management.* 11: 267-277.

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

Mullin, K.D. and G.L. Fulling. 2003. "Abundance of cetaceans in the southern U.S. North Atlantic Ocean during summer 1998." *Fishery Bulletin* 101: 603-613.

Thomas, L., Laake, J.L., Rexstad, E., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Burt, M.L., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. and Marques, T.A. 2009. "Distance 6.0. Release 2." *Research Unit for Wildlife Population Assessment.* University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/.

Wade, P.R. and R.P. Angliss. 1997. "Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop April 3-5, 1996." NOAA Tech. Memo. NMFS-OPR 12, Seattle, Washington, 93.

Waring, G.T., E. Josephson, K. Maze-Foley, and P.E. Rosel eds. 2016. "U.S. Atlantic and Gulf of Mexico marine mammal stock assessments 2015." NOAA Tech. Mem. NMFSNE-238.