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Abundance of Marine Mammals in Waters of the U.S. Gulf of Mexico During the Summers of 2017 and 2018

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BACKGROUND AND STUDY OBJECTIVES

In this report, we describe the results of large vessel, visual line-transect surveys conducted by the NMFS, Southeast Fisheries Science Center in U.S. waters of the Gulf of Mexico during the summers of 2017 and 2018 as a part of the larger Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS). The primary objective of these surveys was to collect data and samples to support assessment of the abundance, habitats, and spatial distribution of cetaceans within U.S. waters. These data and resulting abundance estimates support 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 a Stock Assessment Report (SAR) for each stock to update abundance, stock structure, maximum net productivity, human-caused mortality, PBR, and status (*e.g.*, Hayes et al., 2019). This study describes the results of two vessel based surveys and resulting abundance estimates for U.S. Gulf of Mexico oceanic stocks of marine mammals.

METHODS

Survey Methods

The summer 2017 survey was conducted aboard the NOAA Ship *Gordon Gunter*, between 2 July – 25 August, and the summer 2018 survey was conducted aboard NOAA Ship *Pisces* during 11 August – 6 October. Both vessels are large oceanographic research vessels that include appropriate viewing platforms for visual observers. The surveys were conducted along “zig-zag” tracklines covering waters of the northern Gulf of Mexico from the 100m isobath to the U.S. EEZ. Tracklines were oriented to be perpendicular to the underlying bathymetry to the extent possible (Figure 1).

During both surveys, 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; Garrison, 2016). The survey employed the "independent observer" methodology to improve estimates of sighting probability. During the summer 2017 cruise, the observation stations for the two teams were 13.9 m and 11.2 m above the water. During the summer 2018, cruise, the observer stations were 15 m and 12.5 m above the water. 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 minute. intervals. A recorder position 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. The left and right side observers on each team 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. Observers were considered "on effort" whenever the ship was on a prescribed trackline or transit line, at survey speed, and the visual team was actively searching for cetaceans through the bigeyes. 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. This survey was primarily conducted in "passing mode" whereby the ship maintains a steady course and speed along the trackline while the visual teams identify the sighting to species if possible and estimate the number of individuals in the sighting.

For each cetacean sighting, time, position, bearing and reticle (a measure of radial distance) of the sighting, species, group-size, behavior, 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 30 seconds 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, glare, swell height, cloud cover, etc.). Cetaceans were identified to the lowest taxonomic level possible. Group size estimates were recorded independently by each observer. Observers were instructed to only enter values for sightings they observed entirely. Group size was counted as the minimum, maximum, and best number of animals for each sighting.

During the survey, the data recorder determined whether or not sightings were observed by one or both teams and identified probable re-sights (termed "linked" sightings). All possible re-sightings were reviewed after the cruise to verify whether or not they were seen by both teams. In general, all re-sights were recorded by the respective teams within 10 minutes of one another and had a spatial separation of less than 2 km based on the initial sighting position. Observer notes on the behavior and structure of the groups were also used to inform whether or not a pair of sightings by the two teams was classified as a re-sight.

Analytical Methods

Abundance estimates were derived using the independent observer approach assuming point independence (Laake and Borchers, 2004) implemented in package mrds (version 2.21, Laake et al., 2020) in the R statistical programming language. 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). Both model components 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 four groups of cetaceans: dolphins, small whales, large whales, and cryptic species to account for differences in body size, surface behavior, and associated differences in sighting probability (Barlow, 1995; Mullin and Fulling, 2003; Garrison, 2016). "Cryptic" species including beaked whales and pygmy/dwarf sperm whales (*Kogia spp.*) were grouped because these taxa are deep divers that 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, cloud cover, and survey conditions) 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). Model fit was assessed through chi-square goodness of fit tests.

The survey was designed and analyzed in three strata covering the eastern, central, and western Gulf of Mexico between the continental shelf break and the U.S. EEZ (Figure 1). Stratified abundance estimates for each individual taxon were calculated using stratum and species level encounter rates (groups per km of trackline). Unidentified taxa (e.g., unidentified dolphins, unidentified small whales, unidentified odontocetes) were apportioned among the identified taxa appropriate for each group based upon the proportional density of the identified taxa in each stratum.

For the "cryptic" species, there were an insufficient number of shared sightings between the two teams to estimate detection probability on the trackline. Therefore, detection probability on the trackline (p0) could not be estimated for these taxa.

The Gulf of Mexico Bryde's whale is primarily observed in the northeastern Gulf of Mexico in a relatively small area with the majority of sightings occurring in close proximity to the 200m isobath. The confirmed Bryde's whale sighting in the western Gulf during the 2017 survey is the first such sighting during SEFSC visual line transect surveys. The survey strata and effort used for the other species (i.e., waters deeper than ~200m) is therefore not representative of the Bryde's whale habitat. Further, the probability of detection of Bryde's whales and the likelihood of their detection on the trackline is not the same as that for sperm whales owing to differences in dive depths and times and surface behavior. There were insufficient numbers of sightings during the 2017 and 2018 cruises to derive a sighting detection function for Bryde's whales alone or to estimate p0. To address the representativeness of survey effort, the tracklines for the 2017 and 2018 surveys (and prior year surveys from 2003, 2004, and 2009, see below) were post-stratified to retain the survey effort occurring within the Bryde's whale core habitat area. Bryde's whale (and unidentified baleen whale) on effort sightings from SEFSC vessel surveys between 2003 and 2019 were used to develop a more representative detection function. This included 91 sightings from 12 research cruises. A single-team distance sampling model including covariates was developed and used to estimate abundance for the 2003, 2004, 2009, 2017, and 2018 surveys within the core habitat area. These estimates are not corrected for detection probability on the trackline and exclude the sighting from the western Gulf during 2017.

Trend Analysis

To evaluate possible trends in the abundance of identified species within the northern Gulf of Mexico, visual line-transect survey data collected during the summer of 2003 (Mullin, 2007), spring of 2004 (Mullin, 2007), and summer of 2009 (Garrison, 2016) were reanalyzed to align with the methods used for the current surveys. Prior year surveys were stratified to match the current strata definitions, unidentified taxa were apportioned among the identified species, and p0 corrections were applied based on the results from the 2017 survey. Each of these previous surveys was conducted aboard NOAA ship *Gordon Gunter* and conducted as single-team surveys from the flying bridge with a similar configuration to the flying bridge team of the 2017 survey. However, the prior year surveys were conducted in "closing mode", where the vessel turned to approach some encountered sightings (in particular small whales and dolphins) to confirm species identification and estimate group sizes, while the 2017 and 2018 surveys were conducted in "passing mode" in which the vessel does not generally turn to approach a sighting. Not all sightings were approached in prior surveys, particularly those far from the trackline, small groups of animals, or those that could not be tracked successfully by the observers. The primary expected differences between the two survey methods are in the proportion of sightings that are unidentified and the estimation of group sizes. The apportioning of unidentified sightings helps to address the first issue. Group size estimation is unlikely to be influenced for groups observed near the trackline and small groups occurring far from the trackline that were not approached during the prior year surveys. There is no evidence from the collected data in the surveys that detection distances were correlated with group size indicating that this source of bias is likely to be small. Given the differences in methodology, interpretation of trends should be treated with caution.

To assess the statistical significance of differences in abundance between the five surveys, accounting for the uncertainty in the estimates, a pairwise z-test was conducted on the log-transformed abundance estimates. Significance was interpreted at an alpha of $p = 0.10$, and p-values were adjusted for multiple comparisons using the "holm" method within the "p.adjust" function of the R programming language (R Core Team, 2020; Holm 1979).

RESULTS

Summer 2017 Vessel Survey

During the summer 2017 survey, 5,014 km of trackline were visually surveyed on effort by both survey teams within the defined strata (Figure 1). In addition, there were several tracklines that were surveyed with only the flying bridge team (team 1) active including 563 km of additional effort (Figure 1). Sighting conditions were fair to good throughout most of the survey, with sea states of 2-4 on most survey days and averaging 3.1 over the entire survey.

There were 251 unique marine mammal groups sighted while one or both teams were on effort from 15 confirmed species during the survey (Table 1). There were a total of 52 on-effort sperm whale (*Physeter macrocephalus*) sightings (Figure 2). Notable sightings included a single Bryde's whale (*Balaenoptera edeni*) sighted in the western GOM. Though there are a few sightings of either Bryde's or Sei whales reported in the western GOM during the 1990's, there has not been a verified sighting of Bryde's whales in the western GOM (Figure 2). Given the importance of the single verified Bryde's whale sighting in the western GOM, dedicated fine-scale tracklines were surveyed on 20 August in an attempt to increase effort in the area; however, no additional sightings were recorded. This additional effort was not used in the abundance estimation. A diverse suite of oceanic dolphin and small whale species were encountered including pantropical spotted dolphins (*Stenella attenuata*), Risso's dolphins (*Grampus griseus*), pygmy/dwarf sperm whales (*Kogia* sp.), beaked whales (Unid. Ziphiids and Mesoplodonts), and short-finned pilot whales (*Globicephala macrorhyncus*; Table 1, Figures 3-5). Another notable sighting was a group of killer whales (*Orcinus orca*, Figure 4), in which photographs of certain individuals were matched to photo-identification records from previous sightings in the GOM in 2001. Three species, Fraser's dolphins, Clymene dolphins, and Pygmy killer whale, were only seen in one sighting each on the tracklines where only team 1 was on effort.

Selected models for the detection functions for each taxonomic group are shown in Table 2. The selected models provided adequate fits to the data as indicated by non-significant (p-value > 0.05) GOF tests (Table 2). Notably, there was no apparent effect of distance (or other factors) in the mark-recapture component of the large whale and small whale mark-recapture model, and no evidence of a decline in re-sight rates with increasing distance from the trackline for these taxa. Detection functions for each group are shown in Figures 6-9. The small sample size in the Cryptic species results in an unreliable model fit and detection function (Figure 9).

Abundance estimates for each species are shown in Table 3. In each case, the abundance estimates include the apportioned unidentified taxa relevant for each species. For species seen only during the period when only team 1 was on effort, the abundance estimates were derived using a single observer model for team 1, and the estimated detection probability on the trackline was applied. The abundance estimates for the deep-diving "cryptic" species are 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 0.27 – 0.41 for the more common species. Rare species with a smaller number of sightings had higher CVs that exceeded 0.9 (Table 3). 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.

Summer 2018 Vessel Survey

During the summer 2018 survey, 5,205 km of trackline were visually surveyed on effort by both survey teams within the defined strata (Figure 10). Sighting conditions were fair to good throughout most of the survey, with sea states of 2-4 on most survey days and averaging 3.3 over the entire survey.

There were 215 unique marine mammal groups sighted while one or both teams were on effort from 10 confirmed species during the survey, not including unidentified taxa or taxa that could not be identified to species (Table 4). There were a total of 76 on-effort sperm whale (*Physeter macrocephalus*) sightings (Figure 11). Two sightings of baleen whales within the primary Bryde's whale habitat occurred, but animals could not be approached closely enough to confirm the species identification (Figure 11). These sightings were classified as Bryde's whales for abundance estimation. The most common identified oceanic dolphin was pantropical spotted dolphins (*Stenella attenuata*), but there were few identified sightings of other Stenellid species during the survey (Figure 12). There were also relatively few sightings of small whales throughout the survey with only a small number of identified Risso's dolphins (*Grampus griseus*) and short-finned pilot whales (*Globicephala macrorhyncus*, Figure 13). Two groups of killer whales were also observed including one in the northern portion of the survey area near the shelf break (Figure 13). A small number of cryptic species sightings including pygmy/dwarf sperm whales (*Kogia* sp.) and beaked whales (Unid. Ziphiids and Mesoplodonts) were observed in deep water during the survey (Figure 14).

Selected models for the detection functions for each taxonomic group are shown in Table 5. The selected models provided adequate fits to the data as indicated by non-significant (p-value > 0.05) GOF tests (Table 5). As with the 2017 survey, there was no apparent effect of distance (or other factors) in the mark-recapture component of the large whale and small whale mark-recapture model, and no evidence of a decline in resight rates with increasing distance from the trackline for these taxa. Detection functions for each group are shown in Figures 15-18. For both dolphins and small whales, there is a rapid decline in sighting rates with increasing distance from the trackline (Figures 16-17). This exponential increase near the trackline suggests difficulty in visualizing groups further away from the line during this survey. The shape of the function results in a low estimated probability of detection within the surveyed strip and high uncertainty (Table 5). The small sample size in the cryptic species results in an unreliable model fit and detection function (Figure 18).

Abundance Estimates

Abundance estimates for each species from the summer 2018 survey are shown in Table 6. In each case, the abundance estimates include the apportioned unidentified taxa relevant for each species. For small whale species, there were few identified sightings during the 2018 survey; therefore, the relative density in each stratum from the summer 2017 survey was used to partition unidentified odontocetes and unidentified small whales among the potential species. The abundance estimates for the deep-diving "cryptic" species are 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 0.32 – 0.46 for the more common species. Rare species with a smaller number of sightings had higher CVs that exceeded 0.9 (Table 6). This high uncertainty was associated with variation in encounter rates among different tracklines and uncertainty in the detection function estimation for the dolphin and small whale groups.

Bryde's whales

Ninety-one on effort sightings from twelve large vessel surveys conducted between 2003-2019 were used to estimate detection probability for Bryde's whales (Figure 19). While there was limited sampling effort in this habitat during the 2017 and 2018 cruises, the available tracklines traverse the entire area and represent both high and low density regions. The selected detection probability function did not include any detection covariates and used a half-normal key function (Figure 20). The detection probability within the strip width was 0.530 (CV = 0.083) and the model had a non-significant goodness of fit test ($p = 0.3916$).

Combined Abundance Estimates from the 2017-2018 Surveys

The inverse-variance weighted mean abundance from the summer 2017 and 2018 surveys for each identified taxon are shown in Table 7. These estimates, and their associated uncertainty, can be used to estimate abundance for oceanic cetaceans in NMFS Marine Mammal Stock Assessment Reports.

Trend Analysis

Abundance estimates and associated CVs are shown in Table 8, and information on the MCDS model output for each species group and survey are provided in Appendices 1-4. Results of pairwise comparison tests, where possible, are presented in Table 9. Comparisons were not possible for year pairs where there was an estimate of zero for the given taxa. All beaked whale species and taxa were combined ("All Ziphiids") for the purposes of the trend analysis. Due to the high level of uncertainty in individual species estimates, there is limited power to identify statistically significant trends. However, there are several significant differences between survey years for Pantropical spotted dolphins, Clymene dolphins, Risso's dolphins, Melon-headed whales, and False killer whales (Table 9). In general, the differences suggest declines in abundance between the 2017-2018 surveys and prior year surveys. It is also notable that spinner dolphins and striped dolphins had abundance estimates of zero and/or lower abundance estimates during the 2017-2018 surveys when they had been more commonly seen in prior year surveys. Taken together, the apparent trends in abundance suggest possible declines in the overall abundance of oceanic dolphins and at least some species of small whales in the most recent surveys.

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Tables

Table 1. Number of cetacean groups observed on effort during summer 2017 by each survey team.

Group	Species	Total	Team 1	Team 2	Recaptures
Large Whales	Sperm whale	52	29	11	12
Large Whales	unid. large whale	5	4	1	0
Large Whales	Bryde's whale	3	2	1	0
Dolphins	Bottlenose dolphin	13	5	3	5
Dolphins	unid. dolphin	46	25	18	3
Dolphins	Stenella sp.	26	15	5	6
Dolphins	Pantropical spotted dolphin	20	11	2	7
Dolphins	Bottlenose/Spotted dolphin	2	1	1	0
Dolphins	Atlantic spotted dolphin	4	2	1	1
Dolphins	Spinner dolphin	2	0	1	1
Dolphins	Fraser's dolphin	1	1	0	0
Dolphins	Clymene dolphin	1	1	0	0
Small Whales	Risso's dolphin	11	5	5	1
Small Whales	Pilot whales	7	4	1	2
Small Whales	unid. odontocete	20	10	9	1
Small Whales	unid. small whale	4	2	2	0
Small Whales	Melon-headed/Pygmy killer whale	2	1	0	1
Small Whales	False killer whale	1	0	0	1
Small Whales	Killer whale	1	0	0	1
Small Whales	Melon-headed whale	3	1	0	2
Small Whales	Pygmy killer whale	1	1	0	0
Cryptic	Cuvier's beaked whale	2	1	1	0
Cryptic	Unid. Ziphiid	7	3	4	0
Cryptic	Unid. Mesoplondont	4	3	1	0
Cryptic	Pygmy/Dwarf sperm whale	13	6	4	3
Total Sightings		**251**	**133**	**71**	**47**

Table 2. Detection probability model parameters and estimated detection probabilities for each taxa group for the summer 2017 abundance estimates. HN = Half-normal function, HR = Hazard rate model function. DS = distance function model component. MR = Mark-recapture model component. DS and MR Model columns indicates the covariates included in the selected model. p0 indicates estimated detection probability on the trackline while p indicates overall detection probability in the surveyed strip. p Chi-Sq GOF indicates the p-value for a chi-square goodness of fit test between the observed data and the outcomes of the MRDS model. CV = coefficient of variation.

Group	**DS Model**	**MR Model**	**p Chi-sq GOF**	**p0 (CV)**	**p (CV)**
Lg. Whale	HR: glare, cloud cover	null	0.362	0.770 (0.089)	0.480 (0.149)
Dolphins	HR: cloud cover	distance, sea state	0.372	0.747 (0.157)	0.261 (0.229)
Sm. Whale	HR: glare	null	0.079	0.677 (0.146)	0.253 (0.350)
Cryptic	HN: null	NA	0.546	NA	0.809 (0.163)

Table 3. Abundance estimates for cetacean species during summer 2017 (GU1703). CV = coefficient of variation.

Species	Density (n/km^2)	Abundance	CV
Sperm Whale	0.0029	1077.90	0.2935
Bryde's Whale*	0.00171	84.2	0.9239
Bottlenose dolphin	0.0237	8756.00	0.4117
Pantropical spotted dolphin	0.0742	27362.00	0.2737
Spinner dolphin	0.1622	5982.00	0.5404
Atlantic spotted dolphin	0.0089	3267.00	0.5211
Fraser's dolphin	0.0012	426.87	1.0278
Clymene dolphin	0.0028	1026.30	1.0331
Risso's dolphin	0.0081	2998.50	0.521
Pilot whales	0.0035	1274.40	0.5387
False killer whale	0.0029	1069.25	0.9739
Killer whale	0.0002	86.30	0.8738
Melon-headed whale	0.0073	2694.15	0.7595
Pygmy Killer Whale	0.0033	1226.27	1.149
Cuvier's Beaked Whale**	3.22E-05	11.87	1.006
Unid. Ziphiids**	4.47E-04	164.70	0.4743
Mesoplodon spp**	3.44E-04	126.86	0.6049
Pygmy/Dwarf sperm whale**	7.94E-04	292.78	0.5927

* The abundance estimate for Bryde’s whales is not corrected for p0, uses a detection function derived from all available Bryde’s whale or baleen whale sightings from 2003-2019, and survey effort in the core habitat area.

** Cryptic species estimates are not corrected for detection probability on the trackline.

Table 4. Number of cetacean groups on effort during summer 2018.

Group	Species	Sightings	Team 1 Only	Team 2 Only	Recaptures
Large Whales	Sperm whale	76	42	21	13
Large Whales	Sei/Bryde's/Fin whale	2	0	1	1
Large Whales	unid. large whale	2	2	0	0
Dolphins	Bottlenose dolphin	9	2	2	5
Dolphins	unid. dolphin	39	17	11	11
Dolphins	Stenella sp.	15	4	4	7
Dolphins	Pantropical spotted dolphin	16	3	4	9
Dolphins	Atlantic spotted dolphin	2	1	0	1
Dolphins	Striped dolphin	1	0	0	1
Dolphins	Bottlenose/Spotted dolphin	2	0	2	0
Small Whales	unid. odontocete	13	4	5	4
Small Whales	Melon-headed/Pygmy killer/False killer whale	2	1	0	1
Small Whales	Risso's dolphin	1	0	0	1
Small Whales	Pilot whales	3	1	1	1
Small Whales	Killer whale	2	0	2	0
Cryptic	Pygmy/Dwarf sperm whale	18	8	9	1
Cryptic	Unid. Mesoplodont	3	1	2	0
Cryptic	Gervais' beaked whale	1	0	1	0
Cryptic	Unid. Ziphiid	7	4	1	2
Cryptic	Cuvier's beaked whale	1	0	0	1
Total		215	90	66	59

Table 5. Detection probability model parameters and estimated detection probabilities for each taxa group for the summer 2018 abundance estimates. HN = Half-normal function, HR = Hazard rate model function. DS = distance function model component. MR = Mark-recapture model component. DS and MR Model columns indicates the covariates included in the selected model. p0 indicates estimated detection probability on the trackline while p indicates overall detection probability in the surveyed strip. p Chi-Sq GOF indicates the p-value for a chi-square goodness of fit test between the observed data and the outcomes of the MRDS model. CV = coefficient of variation.

Group	DS Model	MR Model	p Chi-sq GOF	p0 (CV)	p (CV)
Lg. Whale	HR: cloud cover	null	0.293	0.816 (0.061)	0.536 (0.143)
Dolphins	HR: null	distance	0.156	0.900 (0.049)	0.156 (0.330)
Sm. Whale	HR: sea state	null	0.278	0.834 (0.110)	0.181 (0.425)
Cryptic	HN: null	NA	0.740	NA	0.623 (0.147)

Table 6. Abundance estimates for cetacean species during summer 2018 (PC1805). CV = coefficient of variation.

Species	Density (n/km^2)	Abundance	CV
Sperm Whale	0.00035	1307.09	0.326
Bryde's Whale*	0.00081	39.80	0.547
Bottlenose dolphin	0.0158	5832.70	0.462
Pantropical spotted dolphin	0.1592	58725.50	0.405
Spinner dolphin	0	0.00	0
Striped dolphin	0.0099	3633.15	0.558
Atlantic spotted dolphin	0.0222	8178.50	0.553
Risso's dolphin	0.0017	632.16	0.596
Pilot whales	0.0038	1402.53	0.711
False killer whale	4.38E-04	161.73	0.741
Killer whale	1.22E-03	450.28	0.878
Melon-headed whale	1.23E-03	453.94	0.889
Cuvier's Beaked Whale**	6.39E-05	23.56	1.005
Gervias' beaked Whale**	1.10E-04	40.39	0.977
Unid. Ziphiids**	5.23E-04	192.84	0.402
Mesoplodon spp**	1.77E-04	65.244	0.650
Pygmy/Dwarf sperm whale**	9.72E-04	358.46	0.424

* The abundance estimate for Bryde’s whales is not corrected for p0, uses a detection function derived from all available Bryde’s whale or baleen whale sightings from 2003-2019, and survey effort in the core habitat area.

** Cryptic species estimates are not corrected for detection probability on the trackline

Table 7. Inverse variance weighted mean abundance estimates for cetacean species during 2017-2018. For the inverse-variance weighted means, the weighting is the inverse of the squared CVs for the two estimates.

Species	2017 Abundance (CV)	2018 Abundance (CV)	Weighted Mean (CV)
Sperm Whale	1078 (0.293)	1307 (0.326)	1180.4 (0.219)
Bryde's Whale*	84 (0.924)	40 (0.547)	51.3 (0.503)
Bottlenose dolphin	8756 (0.412)	5833 (0.462)	7462.1 (0.313)
Pantropical spotted dolphin	27362 (0.274)	58725 (0.405)	37195.1 (0.244)
Spinner dolphin	5982 (0.540)	0	2911.0 (0.540)
Striped dolphin	0	3633 (0.558)	1816.6 (0.558)
Atlantic spotted dolphin	3267 (0.521)	8178 (0.553)	5577.0 (0.414)
Fraser's dolphin	427 (1.028)	0	213.4 (1.028)
Clymene dolphin	1026.3 (1.033)	0	513.2 (1.033)
Risso's dolphin	2998 (0.521)	632 (0.596)	1973.5 (0.456)
Short-finned Pilot whales	1274 (0.539)	1402 (0.711)	1321.1 (0.430)
False killer whale	1069 (0.973)	162 (0.741)	494.5 (0.787)
Killer whale	86.3 (0.874)	450 (0.878)	267.4 (0.749)
Melon-headed whale	2694 (0.760)	454(0.889)	1748.9 (0.683)
Pygmy Killer Whale	1227 (1.149)	0	613.1 (1.150)
Cuvier's Beaked Whale**	12 (1.006)	24 (1.005)	17.7 (0.749)
Gervais' Beaked Whale**	0	40 (0.977)	20.2 (0.977)
Unid. Ziphiids**	165 (0.474)	193 (0.650)	181.1 (0.308)
Mesoplodon spp**	127 (0.605)	65 (0.650)	98.2 (0.464)
Pygmy/Dwarf sperm whale**	293 (0.593)	359 (0.424)	336.2 (0.346)

* The abundance estimate for Bryde's whales is not corrected for p0, uses a detection function derived from all available Bryde's whale or baleen whale sightings from 2003-2019, and survey effort in the core habitat area.

** Cryptic species estimates are not corrected for detection probability on the trackline

Table 8. Abundance estimates (CV) from prior year large vessel cruises used to assess trends in population size. For outputs from updated abundance estimates for 2003, 2004, and 2009 see Appendices 1-4.

Species	2003	2004	2009	2017	2018
Sperm Whale	2542 (0.336)	1686 (0.405)	2096 (0.546)	1078 (0.293)	1307 (0.326)
Bryde's Whale*	0	63.9 (0.880)	100.1 (1.03)	84.2 (0.924)	39.8 (0.547)
Bottlenose dolphin	21350 (0.472)	8864 (0.504)	9640 (0.659)	8756 (0.412)	5832.7 (0.462)
Pantropical spotted dolphin	72901 (0.198)	78878 (0.41)	84047 (0.363)	27362 (0.274)	58725 (0.405)
Spinner dolphin	5160 (0.551)	24535 (0.584)	19678 (0.531)	5982 (0.540)	0
Striped dolphin	5494 (0.427)	10764 (0.510)	3060 (0.727)	0	3633.2 (0.558)
Atlantic spotted dolphin	0	0	1161 (1.021)	3267 (0.521)	8178 (0.553)
Fraser's dolphin	0	0	0	426.8 (1.028)	0
Clymene dolphin	10899 (0.415)	13257 (0.808)	1319 (0.782)	1026.3 (1.033)	0
Rough-toothed dolphin	9253 (0.785)	0	3509 (0.668)	0	0
Risso's dolphin	4471 (0.471)	4641 (0.856)	7788 (0.672)	2998 (0.521)	632.2 (0.596)
Short-finned Pilot whales	2740 (0.519)	586.7 (0.884)	4788 (0.738)	1274 (0.539)	1402.3 (0.711)
False killer whale	1293 (0.635)	0	0	1069 (0.973)	161.7 (0.741)
Killer whale	0	197.6 (1.002)	51.5 (0.968)	86.3 (0.874)	450.3 (0.878)
Melon-headed whale	1502 (0.957)	7351 (0.871)	4188 (0.757)	2694 (0.760)	453.9 (0.889)
Pygmy Killer Whale	501 (0.739)	490.0 (0.871)	359 (0.955)	1226.7 (1.149)	0
All Ziphiids**	573 (0.435)	55.1 (0.719)	276 (0.588)	316.0 (0.278)	192.8 (0.650)
Pygmy/Dwarf sperm whale**	441 (0.424)	38.3 (0.711)	123.8 (0.604)	292.7 (0.593)	359.5 (0.424)

* The abundance estimate for Bryde's whales is not corrected for p0, uses a detection function derived from all available Bryde's whale or baleen whale sightings from 2003-2019, and survey effort in the core habitat area.

** Cryptic species estimates are not corrected for detection probability on the trackline

Table 9. Pairwise comparisons between abundance estimates for identified taxa. Comparisons where one of the surveys had an abundance estimate equal to 0 are not possible. Adjusted p-values reflect adjustment for multiple comparisons using the "holm" method. Statistically significant (p adjust < 0.10) comparisons are highlighted.

Species	Year 1	Year 2	z score	p-value	p.adjust
All Ziphiids	**2003**	**2004**	**3.046**	**0.0012**	**0.0116**
All Ziphiids	2003	2009	1.067	0.1430	0.8328
All Ziphiids	2003	2017	1.020	0.1538	0.8328
All Ziphiids	2003	2018	1.086	0.1388	0.8328
All Ziphiids	2004	2009	1.904	0.0285	0.1993
All Ziphiids	2004	2017	2.146	0.0159	0.1275
All Ziphiids	**2004**	**2018**	**2.436**	**0.0074**	**0.0669**
All Ziphiids	2009	2017	0.135	0.4463	1.0000
All Ziphiids	2009	2018	0.245	0.4031	1.0000
All Ziphiids	2017	2018	0.105	0.4583	1.0000
Atlantic spotted dolphin	2009	2017	1.059	0.1448	0.1975
Atlantic spotted dolphin	**2009**	**2018**	**1.971**	**0.0244**	**0.0731**
Atlantic spotted dolphin	2017	2018	1.289	0.0988	0.1975
Bottlenose dolphin	2003	2004	1.344	0.0895	0.7157
Bottlenose dolphin	2003	2009	1.060	0.1445	1.0000
Bottlenose dolphin	2003	2017	1.490	0.0681	0.6132
Bottlenose dolphin	2003	2018	2.065	0.0195	0.1946
Bottlenose dolphin	2004	2009	0.110	0.4564	1.0000
Bottlenose dolphin	2004	2017	0.020	0.4921	1.0000
Bottlenose dolphin	2004	2018	0.646	0.2592	1.0000
Bottlenose dolphin	2009	2017	0.134	0.4468	1.0000
Bottlenose dolphin	2009	2018	0.675	0.2499	1.0000
Bottlenose dolphin	2017	2018	0.687	0.2461	1.0000
Bryde's Whale	2004	2009	0.394	0.3468	1.0000
Bryde's Whale	2004	2017	0.254	0.3999	1.0000
Bryde's Whale	2004	2018	0.517	0.302	1.0000
Bryde's Whale	2009	2017	0.149	0.4408	1.0000
Bryde's Whale	2009	2018	0.928	0.177	1.0000
Bryde's Whale	2017	2018	0.799	0.212	1.0000
Clymene dolphin	2003	2004	0.241	0.4049	0.8097
Clymene dolphin	**2003**	**2009**	**2.648**	**0.0040**	**0.0243**
Clymene dolphin	**2003**	**2017**	**2.511**	**0.0060**	**0.0301**
Clymene dolphin	**2004**	**2009**	**2.332**	**0.0098**	**0.0394**
Clymene dolphin	**2004**	**2017**	**2.308**	**0.0105**	**0.0394**
Clymene dolphin	2009	2017	0.229	0.4096	0.8097
False killer whale	2003	2017	0.190	0.4247	0.4247
False killer whale	**2003**	**2018**	**2.360**	**0.0091**	**0.0274**

False killer whale	**2017**	**2018**	**1.797**	**0.0362**	**0.0723**
Killer whale	2004	2009	1.155	0.1241	0.4965
Killer whale	2004	2017	0.737	0.2305	0.6914
Killer whale	2004	2018	0.732	0.2321	0.6914
Killer whale	2009	2017	0.466	0.3207	0.6914
Killer whale	2009	2018	1.953	0.0254	0.1524
Killer whale	2017	2018	1.548	0.0608	0.3040
Melon-headed whale	2003	2004	1.442	0.0747	0.5230
Melon-headed whale	2003	2009	0.977	0.1644	0.8434
Melon-headed whale	2003	2017	0.556	0.2891	0.8653
Melon-headed whale	2003	2018	1.078	0.1406	0.8434
Melon-headed whale	2004	2009	0.558	0.2884	0.8653
Melon-headed whale	2004	2017	0.994	0.1601	0.8434
Melon-headed whale	**2004**	**2018**	**2.601**	**0.0047**	**0.0465**
Melon-headed whale	2009	2017	0.463	0.3217	0.8653
Melon-headed whale	2009	2018	2.184	0.0145	0.1304
Melon-headed whale	2017	2018	1.748	0.0402	0.3218
Pantropical spotted dolphin	2003	2004	0.178	0.4292	1.0000
Pantropical spotted dolphin	2003	2009	0.353	0.3619	1.0000
Pantropical spotted dolphin	**2003**	**2017**	**2.944**	**0.0016**	**0.0162**
Pantropical spotted dolphin	2003	2018	0.496	0.3101	1.0000
Pantropical spotted dolphin	2004	2009	0.120	0.4523	1.0000
Pantropical spotted dolphin	2004	2017	2.214	0.0134	0.1073
Pantropical spotted dolphin	2004	2018	0.531	0.2976	1.0000
Pantropical spotted dolphin	**2009**	**2017**	**2.536**	**0.0056**	**0.0505**
Pantropical spotted dolphin	2009	2018	0.683	0.2473	1.0000
Pantropical spotted dolphin	2017	2018	1.613	0.0533	0.3734
Pilot whales	2003	2004	1.706	0.0440	0.3958
Pilot whales	2003	2009	0.681	0.2481	0.9507
Pilot whales	2003	2017	1.090	0.1378	0.8270
Pilot whales	2003	2018	0.832	0.2026	0.9507
Pilot whales	2004	2009	2.087	0.0185	0.1846
Pilot whales	2004	2017	0.850	0.1976	0.9507
Pilot whales	2004	2018	0.877	0.1901	0.9507
Pilot whales	2009	2017	1.594	0.0555	0.4437
Pilot whales	2009	2018	1.337	0.0907	0.6347
Pilot whales	2017	2018	0.118	0.4532	0.9507
Pygmy killer whale	2003	2004	0.022	0.4912	1.0000
Pygmy killer whale	2003	2009	0.320	0.3746	1.0000
Pygmy killer whale	2004	2009	0.282	0.3888	1.0000
Pygmy killer whale	2004	2009	0.282	0.3888	1.0000
Pygmy killer whale	2004	2017	0.774	0.2194	1.0000
Pygmy killer whale	2009	2017	1.007	0.1570	0.9420
Pygmy/Dwarf sperm whale	**2003**	**2004**	**3.227**	**0.001**	**0.006**

Pygmy/Dwarf sperm whale	2003	2009	1.843	0.033	0.229
Pygmy/Dwarf sperm whale	2003	2017	0.602	0.274	0.821
Pygmy/Dwarf sperm whale	2003	2018	0.362	0.359	0.821
Pygmy/Dwarf sperm whale	2004	2009	1.383	0.083	0.417
Pygmy/Dwarf sperm whale	**2004**	**2017**	**2.415**	**0.008**	**0.063**
Pygmy/Dwarf sperm whale	**2004**	**2018**	**2.952**	**0.002**	**0.014**
Pygmy/Dwarf sperm whale	2009	2017	1.100	0.136	0.542
Pygmy/Dwarf sperm whale	2009	2018	1.540	0.062	0.370
Pygmy/Dwarf sperm whale	2017	2018	0.296	0.383	0.821
Risso's dolphin	2003	2004	0.043	0.4828	1.0000
Risso's dolphin	2003	2009	0.734	0.2316	1.0000
Risso's dolphin	2003	2017	0.602	0.2736	1.0000
Risso's dolphin	**2003**	**2018**	**2.755**	**0.0029**	**0.0264**
Risso's dolphin	2004	2009	0.539	0.2950	1.0000
Risso's dolphin	2004	2017	0.491	0.3115	1.0000
Risso's dolphin	2004	2018	2.157	0.0155	0.1239
Risso's dolphin	2009	2017	1.219	0.1113	0.6680
Risso's dolphin	**2009**	**2018**	**3.053**	**0.0011**	**0.0113**
Risso's dolphin	2017	2018	2.110	0.0174	0.1239
Rough-toothed dolphin	2003	2009	1.0521	0.1464	0.1464
Sperm Whale	2003	2004	0.807	0.2099	1.0000
Sperm Whale	2003	2009	0.318	0.3751	1.0000
Sperm Whale	2003	2017	1.971	0.0244	0.2436
Sperm Whale	2003	2018	1.458	0.0724	0.6515
Sperm Whale	2004	2009	0.338	0.3676	1.0000
Sperm Whale	2004	2017	0.924	0.1778	1.0000
Sperm Whale	2004	2018	0.506	0.3064	1.0000
Sperm Whale	2009	2017	1.134	0.1284	1.0000
Sperm Whale	2009	2018	0.784	0.2165	1.0000
Sperm Whale	2017	2018	0.450	0.3265	1.0000
Spinner dolphin	2003	2004	2.087	0.0185	0.1107
Spinner dolphin	2003	2009	1.868	0.0308	0.1423
Spinner dolphin	2003	2017	0.205	0.4189	0.7643
Spinner dolphin	2004	2009	0.300	0.3822	0.7643
Spinner dolphin	2004	2017	1.904	0.0285	0.1423
Spinner dolphin	2009	2017	1.676	0.0468	0.1423
Striped dolphin	2003	2004	1.065	0.1433	0.5734
Striped dolphin	2003	2009	0.761	0.2233	0.6700
Striped dolphin	2003	2018	0.625	0.2661	0.6700
Striped dolphin	2004	2009	1.554	0.0601	0.3607
Striped dolphin	2004	2018	1.532	0.0627	0.3607
Striped dolphin	2009	2018	0.206	0.4185	0.6700

Figures

Figure 1. Survey tracklines and cetacean sightings during summer 2017 (GU1703). The 200m, 2000m, and 3000m isobaths are shown. The survey area is indicated with the inner boundary defined by the 200m isobath and the outer boundary defined by the US EEZ, and boundaries of three strata are shown.

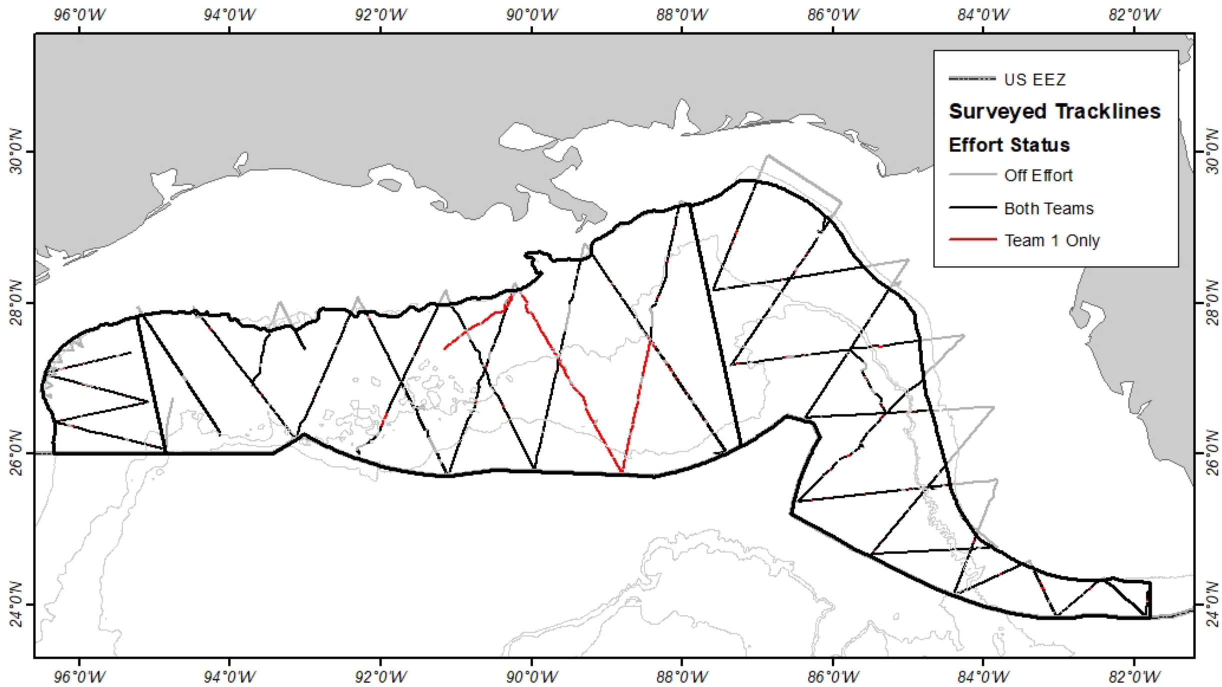


Figure 2. Large whale sightings during summer 2017 (GU1703)

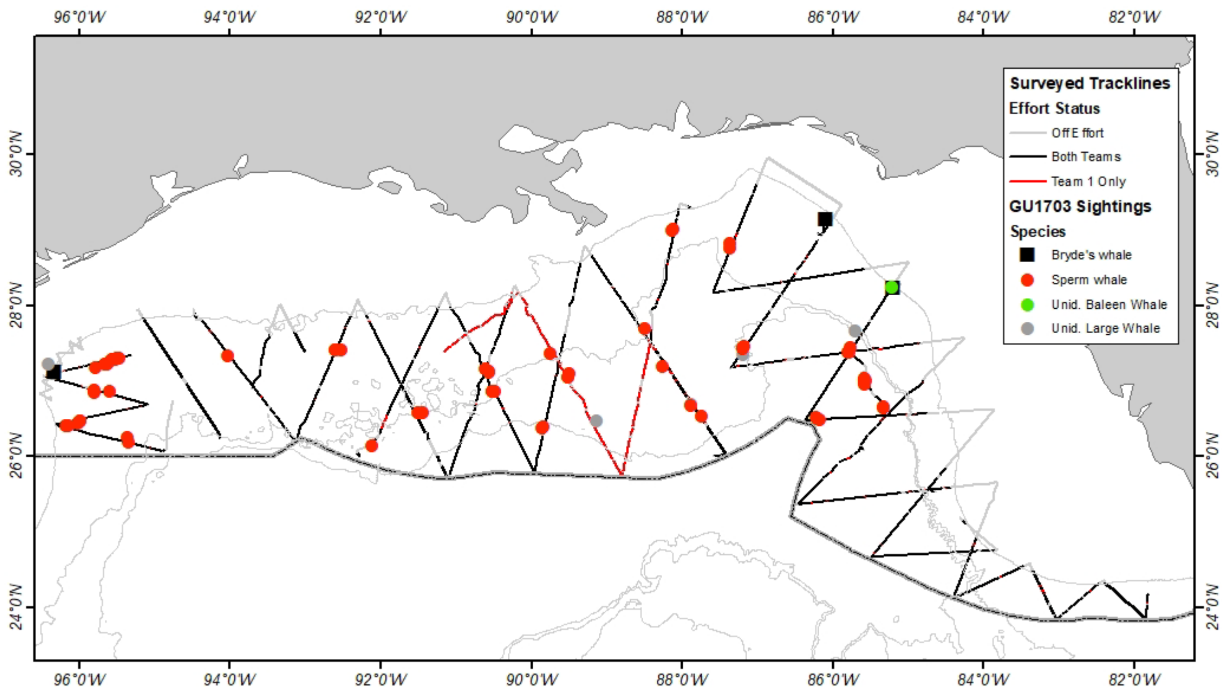


Figure 3. Dolphin sightings during summer 2017 (GU1703)

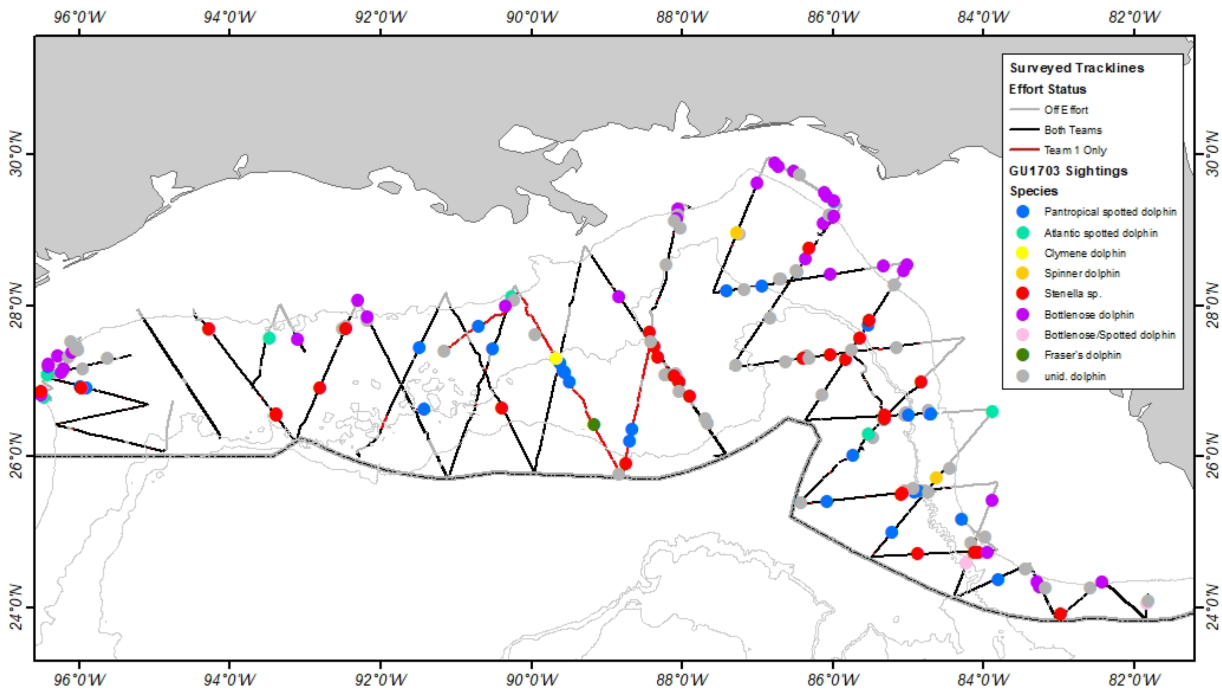


Figure 4. Small whale sightings during summer 2017 (GU1703)

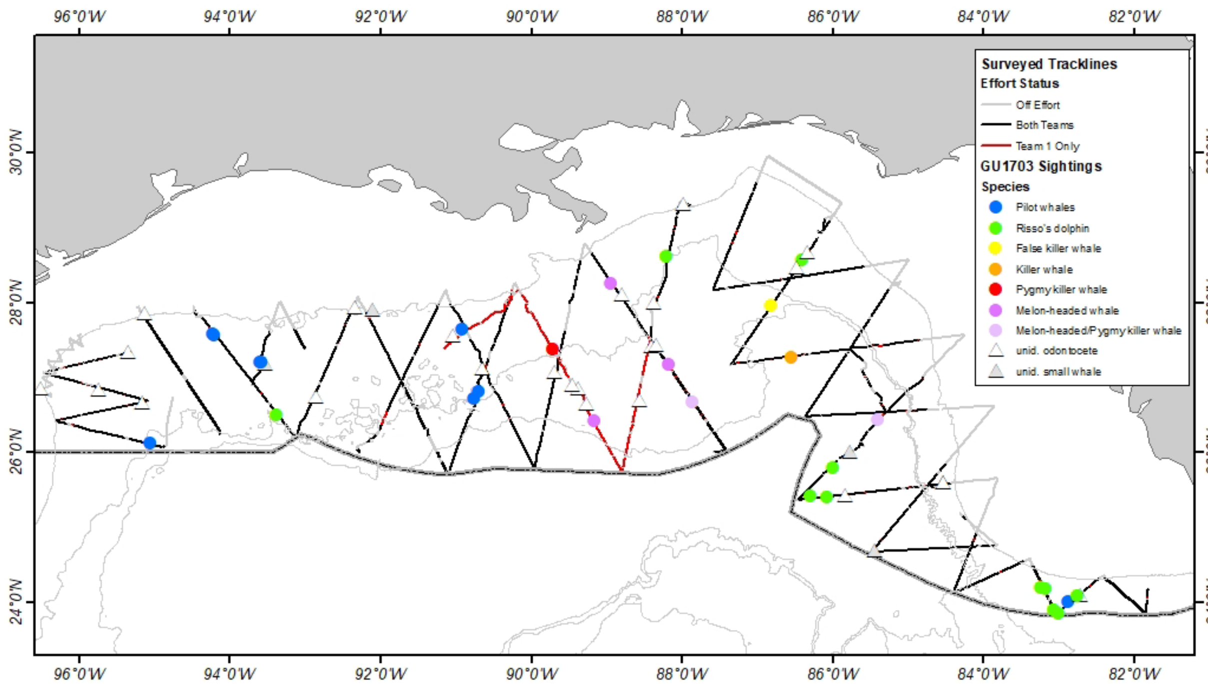


Figure 5. Cryptic species sightings during summer 2017 (GU1703)

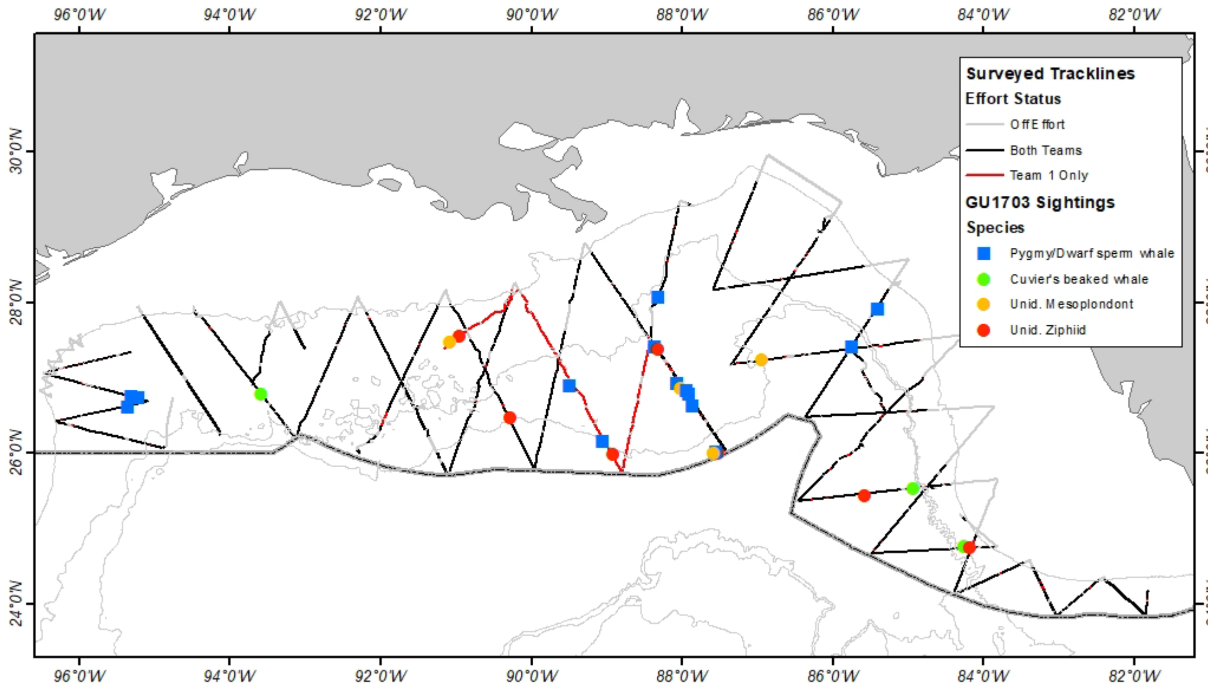


Figure 6. Detection probability functions for large whales from summer 2017 (GU1703).

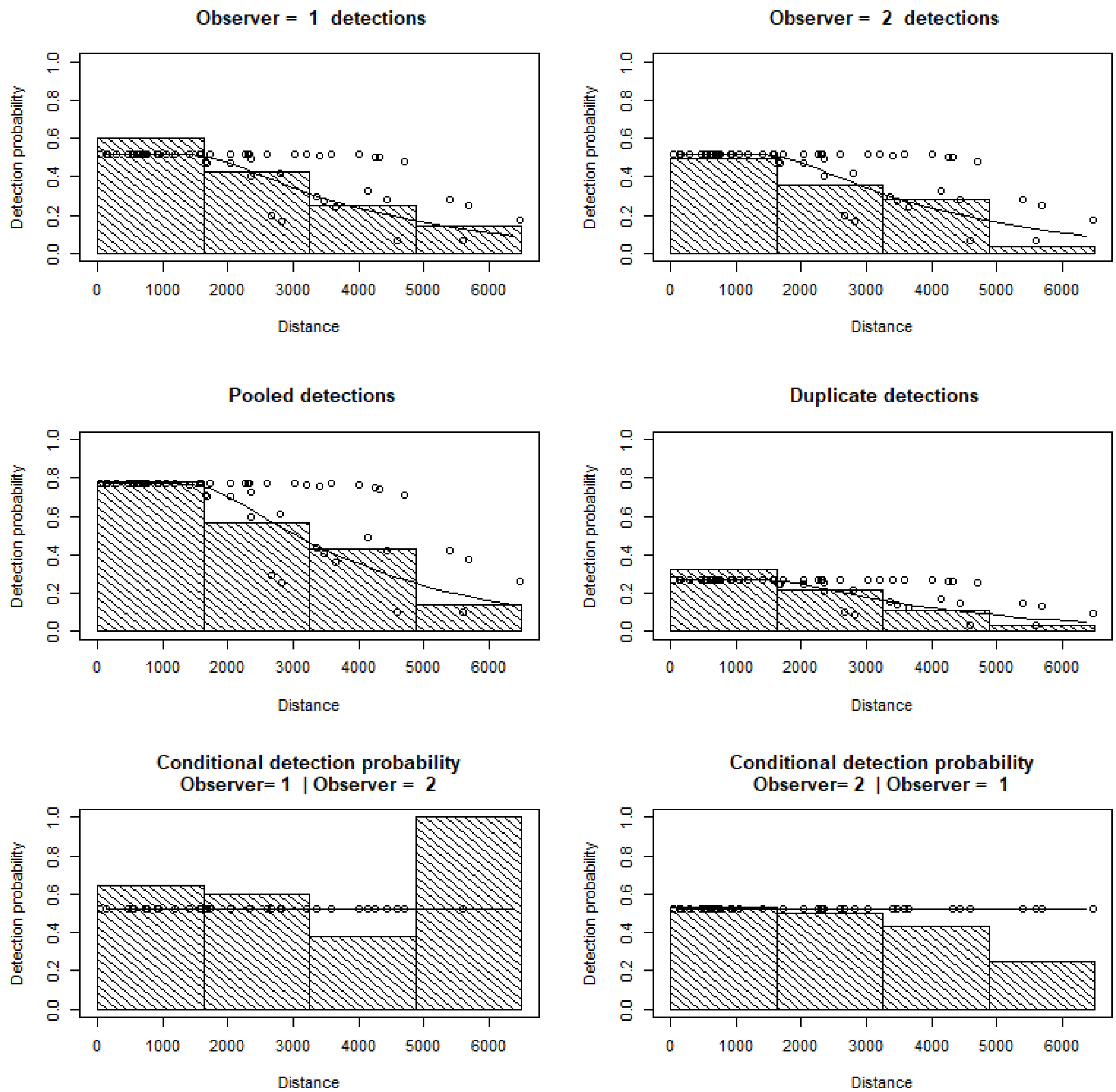


Figure 7. Detection probability functions for dolphins from summer 2017 (GU1703).

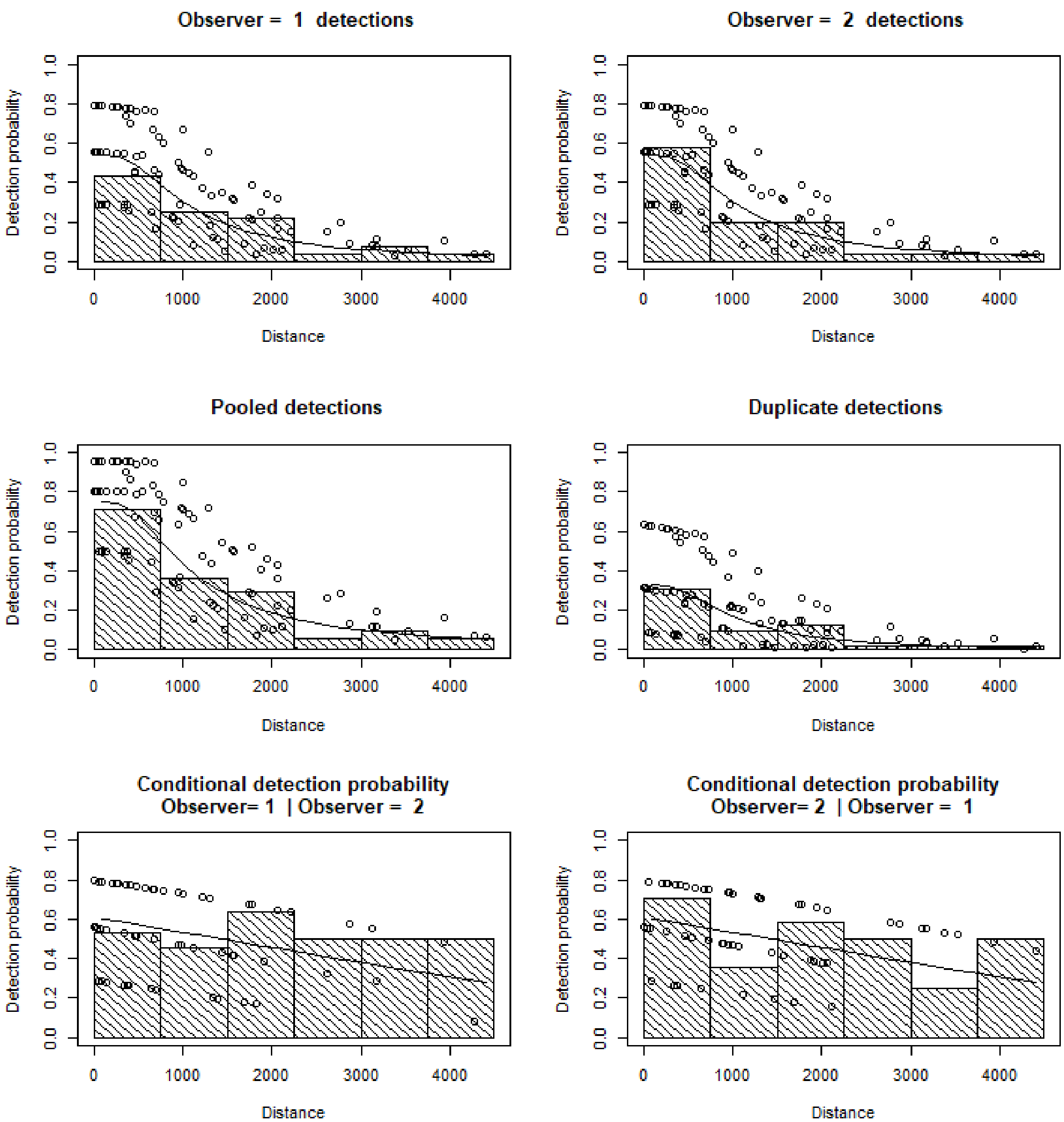


Figure 8. Detection probability functions for small whales from summer 2017 (GU1703).

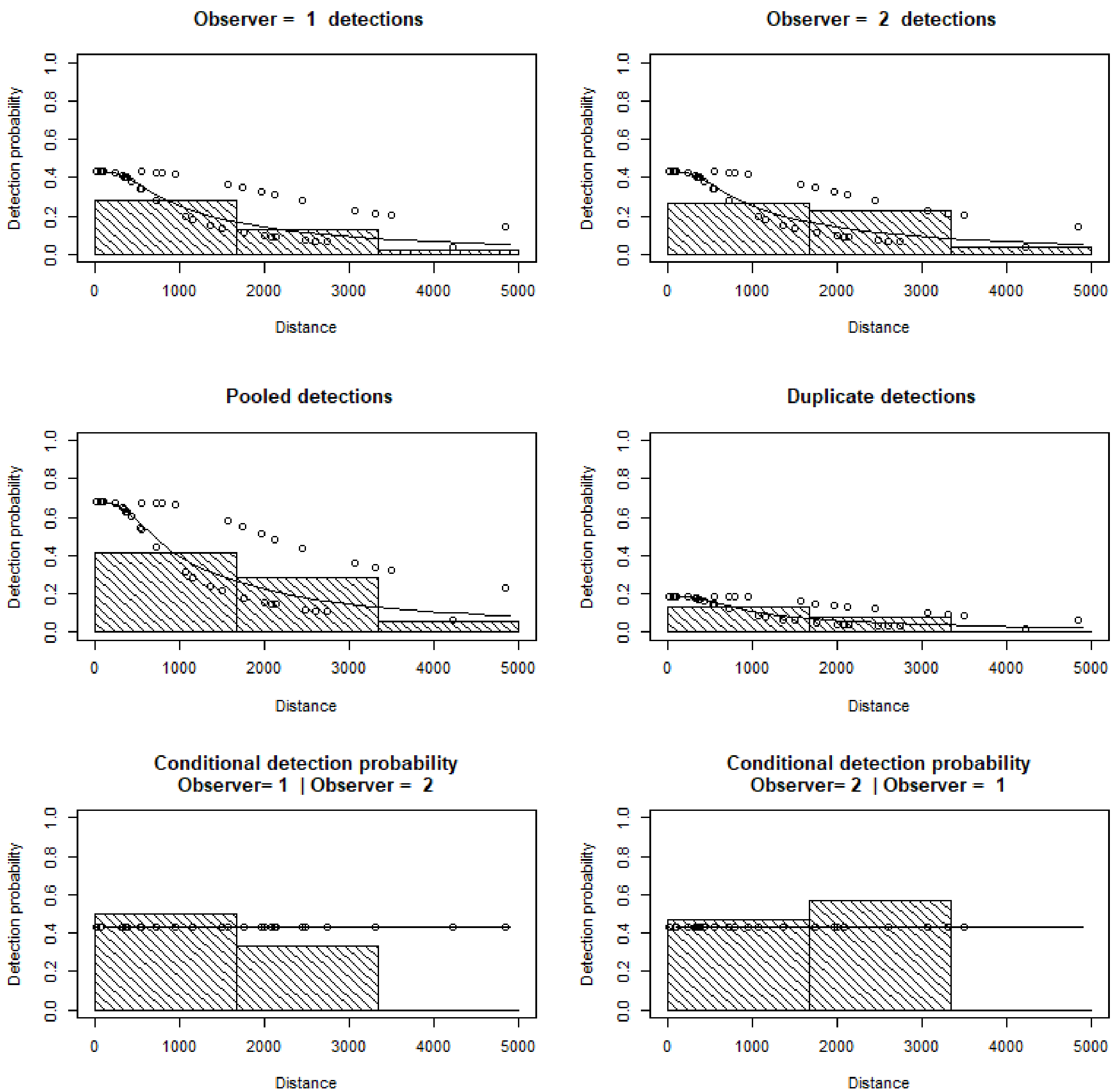


Figure 9. Detection probability functions for cryptic species from summer 2017 (GU1703). The mark-recapture distance sampling model could not be fit for these species due to the small number of resights and small sample size.

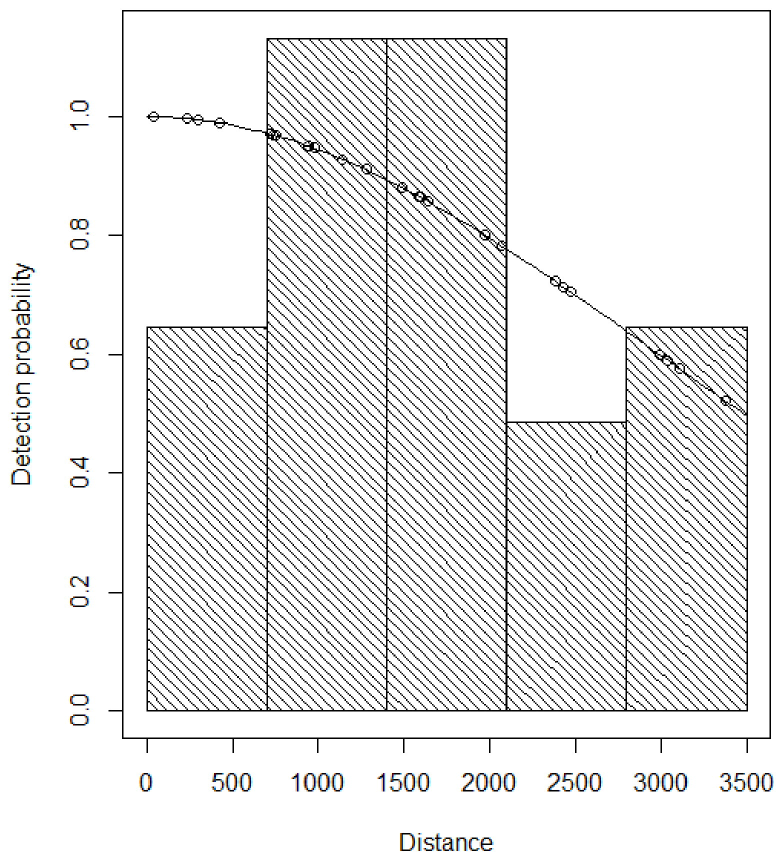


Figure 10. Survey tracklines and cetacean sightings during summer 2018 (PC1805). The 200m, 2000m, and 3000m isobaths are shown. The survey area is indicated with the inner boundary defined by the 200m isobath and the outer boundary defined by the US EEZ, and boundaries of three strata are shown.

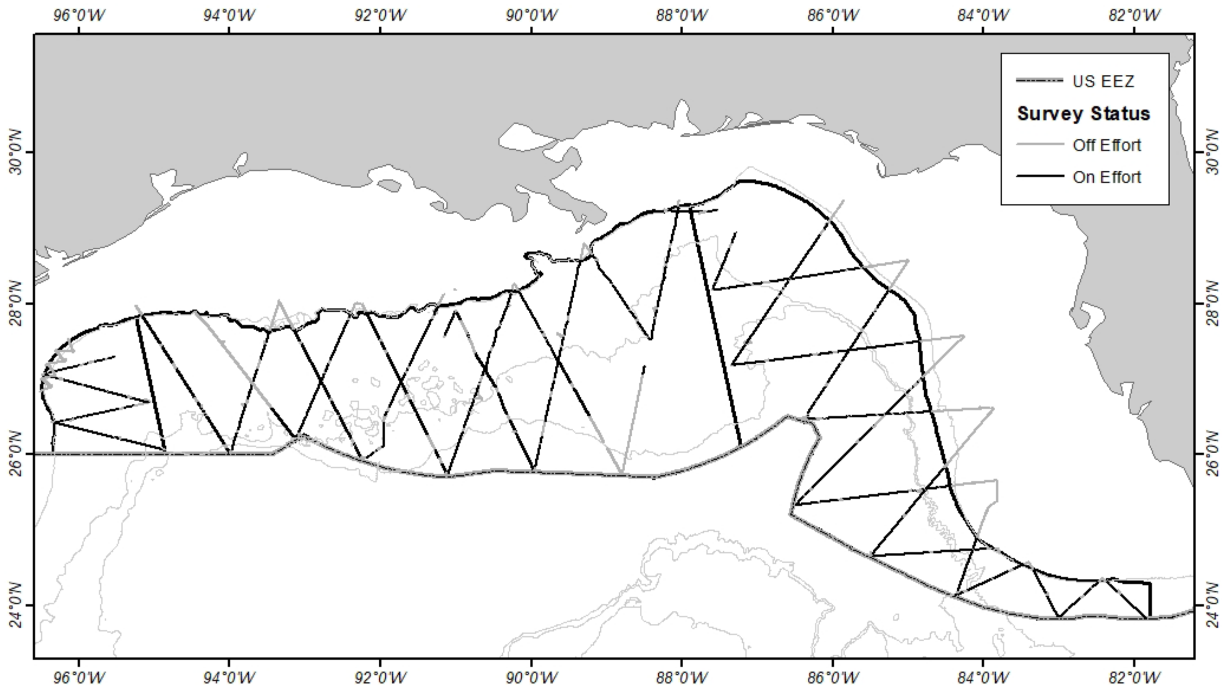


Figure 11. Large whale sightings during summer 2018 (PC1805)

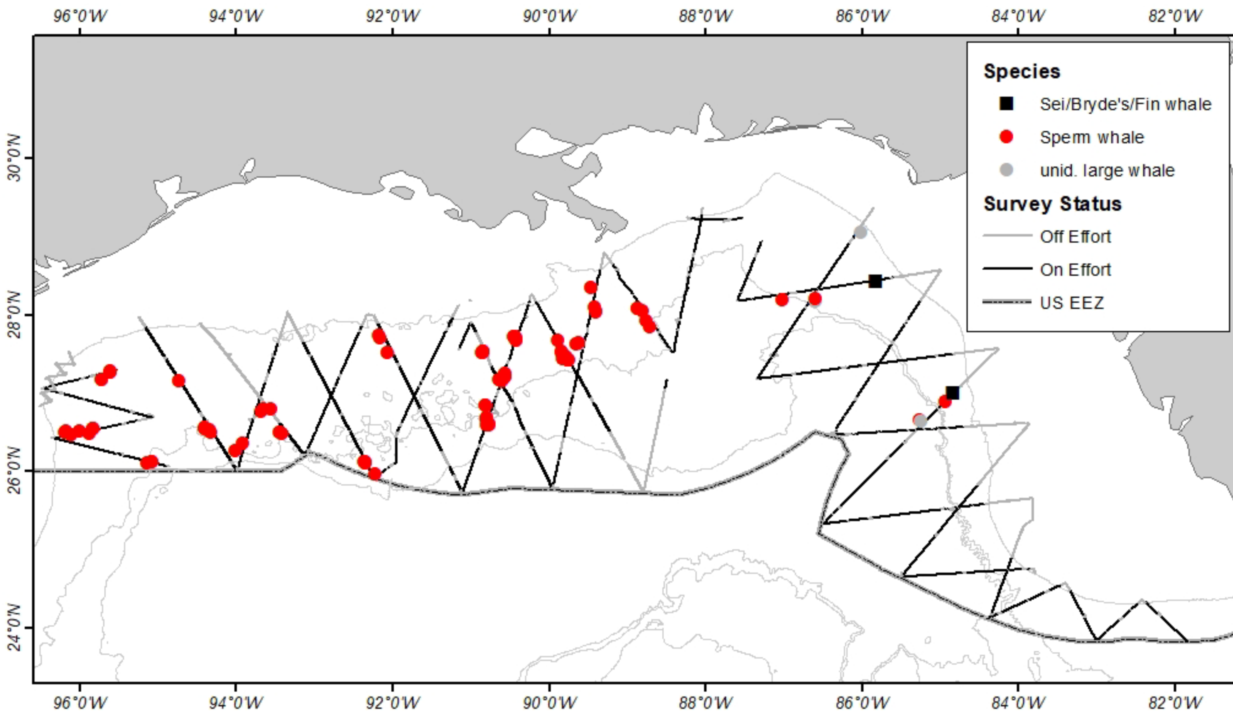


Figure 12. Dolphins sightings during summer 2018 (PC1805)

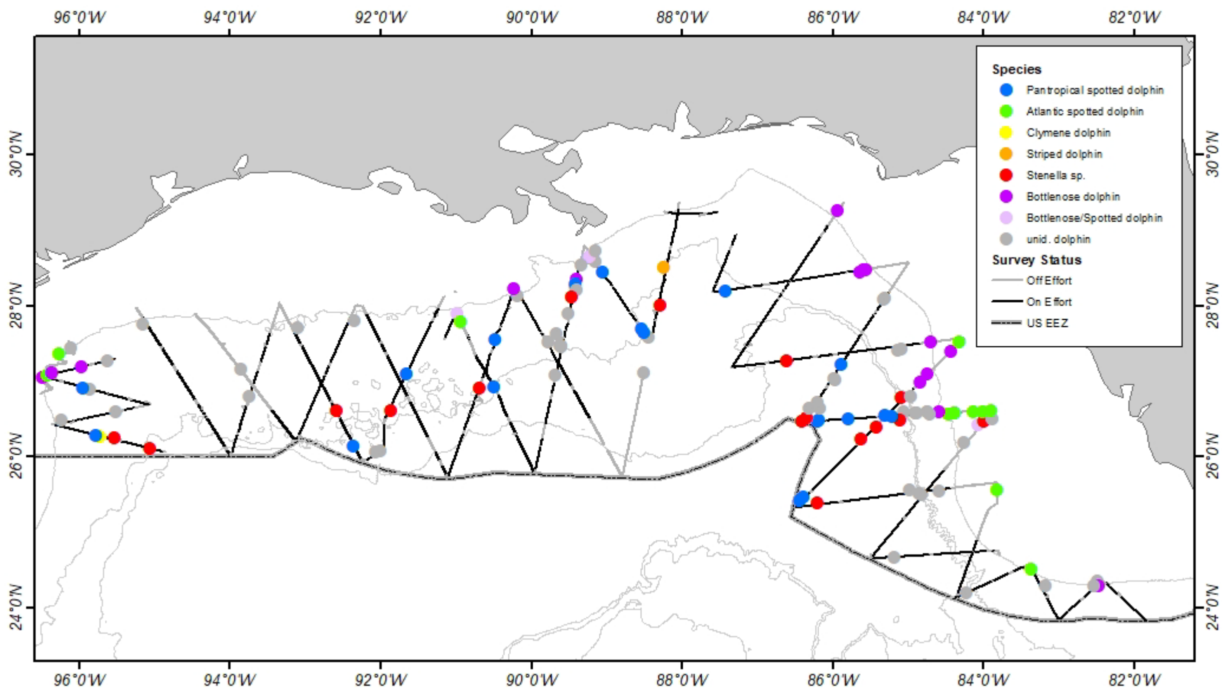


Figure 13. Small whale sightings during summer 2018 (PC1805)

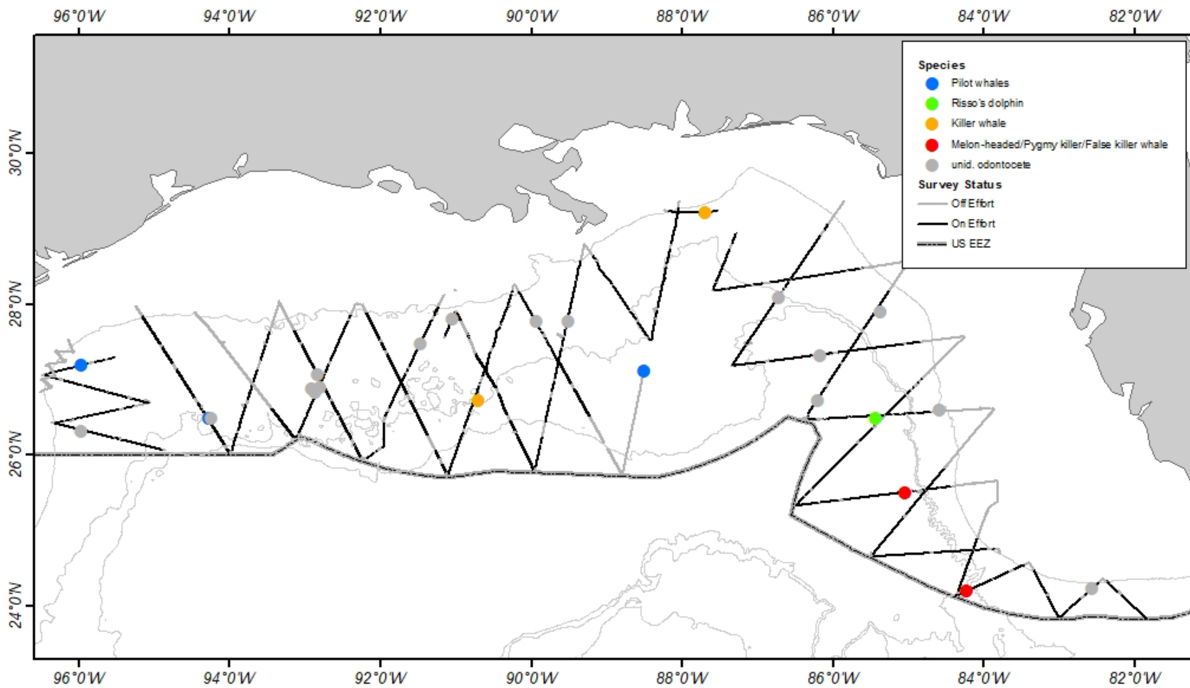


Figure 14. Cryptic species sightings during summer 2018 (PC1805)

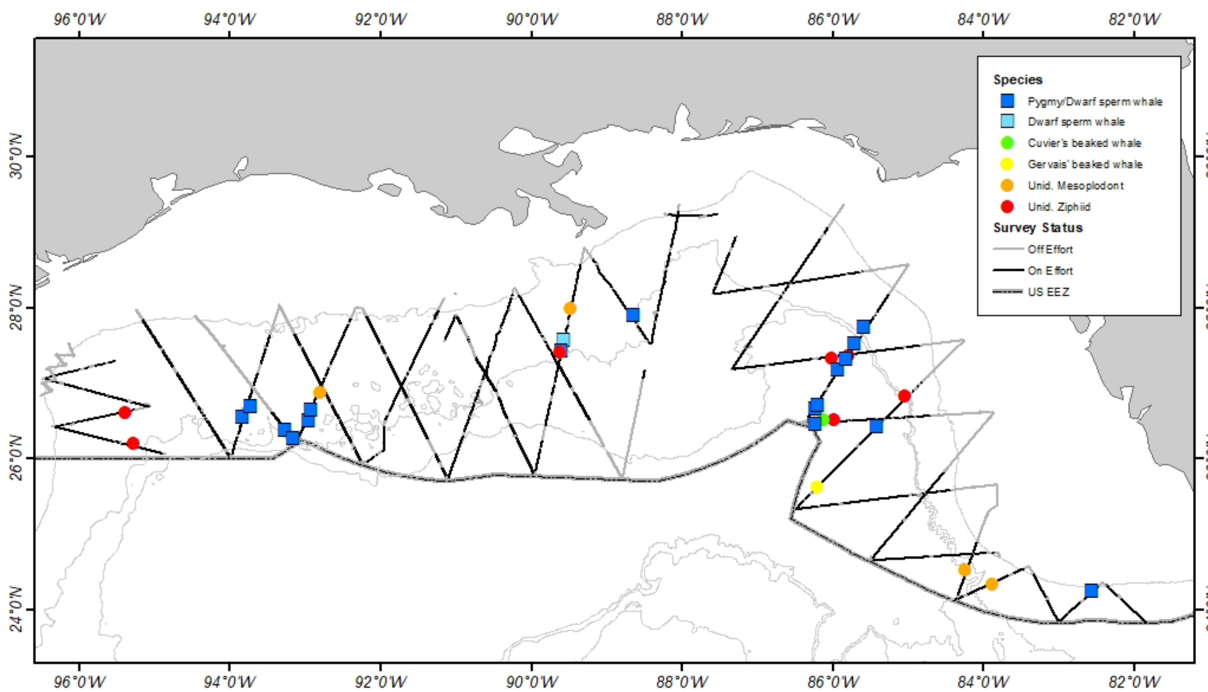


Figure 15. Detection probability functions for large whales from summer 2018 (PC1805).

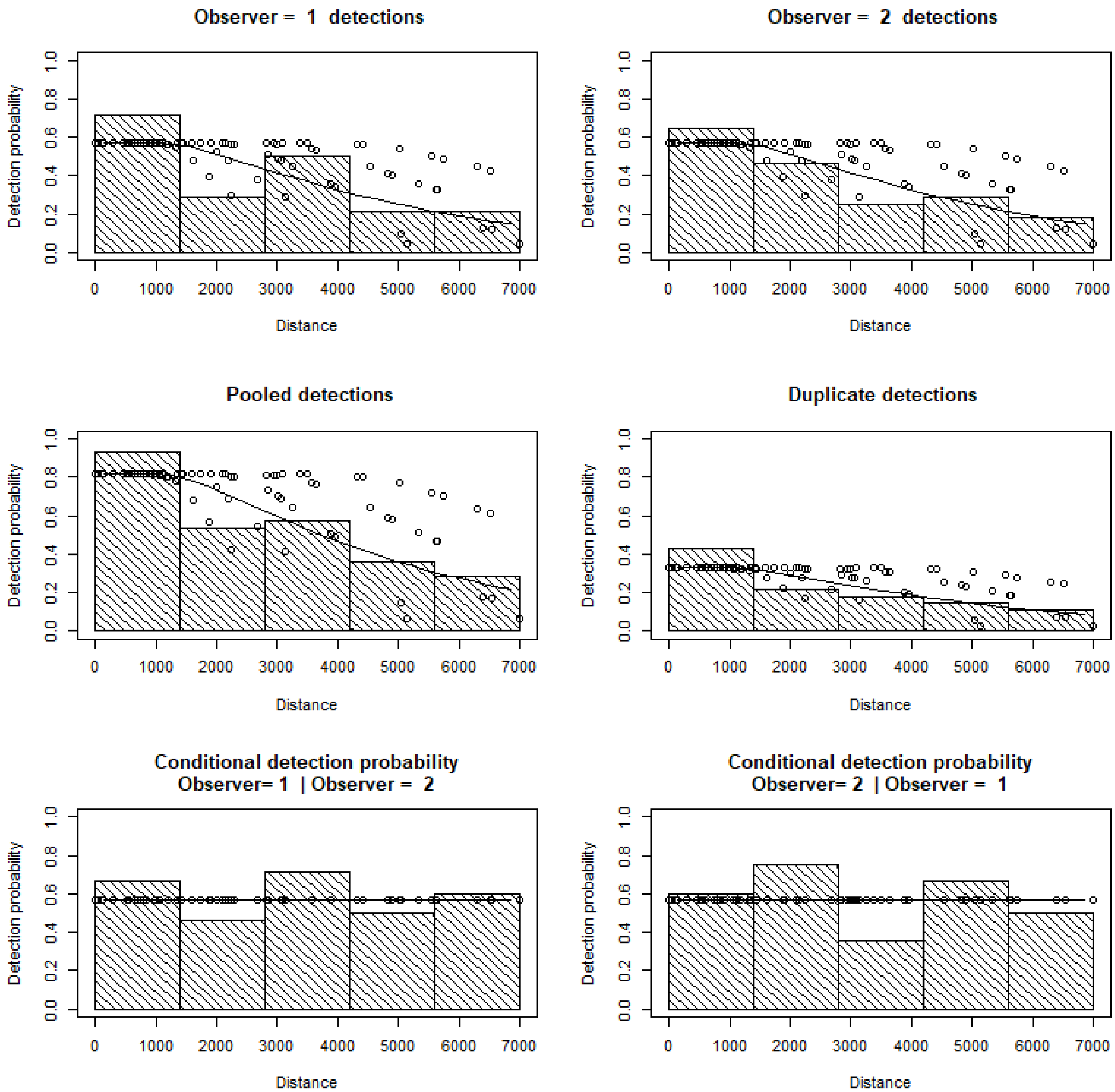


Figure 16. Detection probability functions for dolphins from summer 2018 (PC1805).

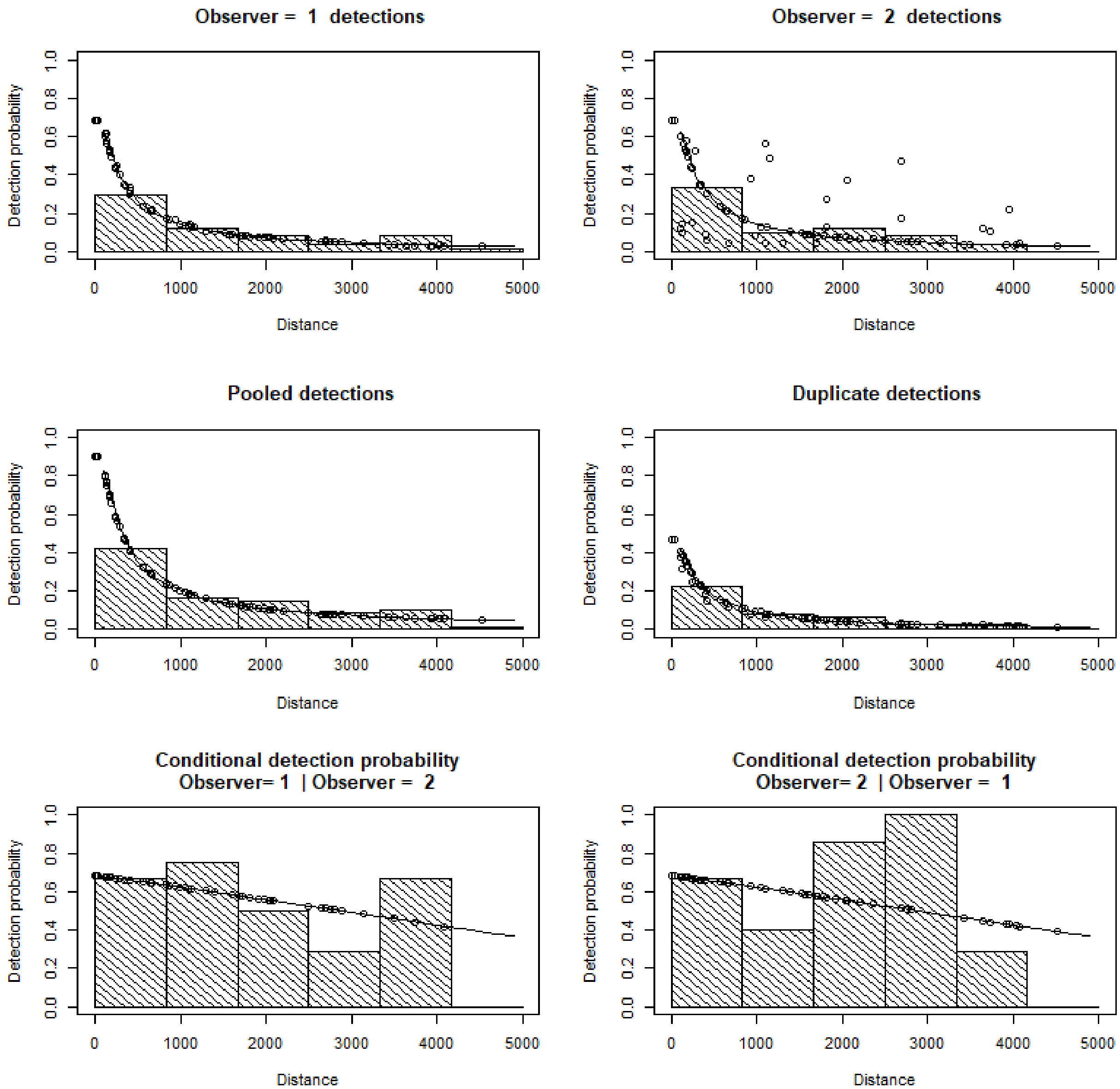


Figure 17. Detection probability functions for small whales from summer 2018 (PC1805).

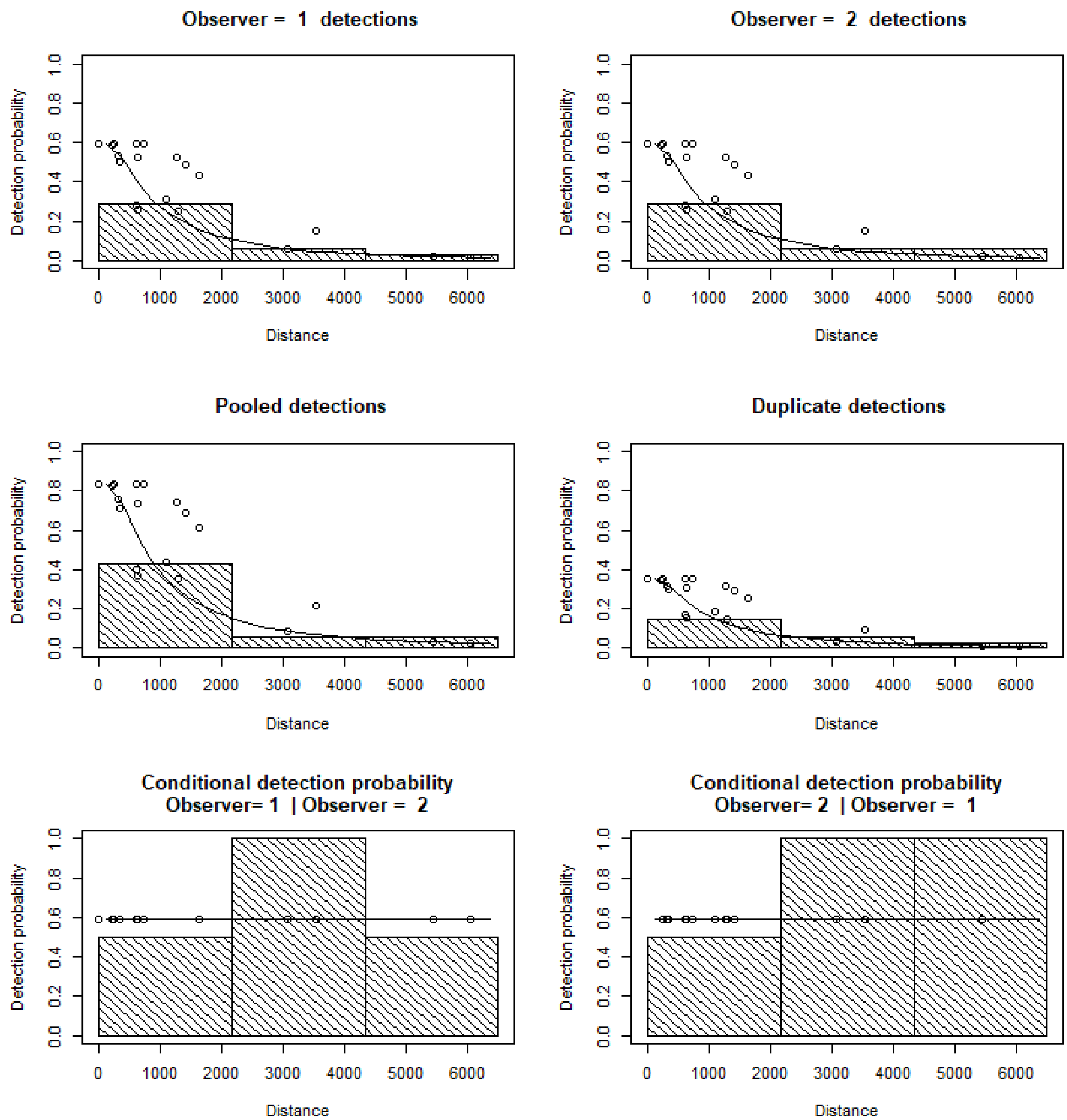


Figure 18. Detection probability functions for cryptic species from summer 2018 (PC1805). The mark-recapture distance sampling model could not be fit for these species due to the small number of resights and small sample size.

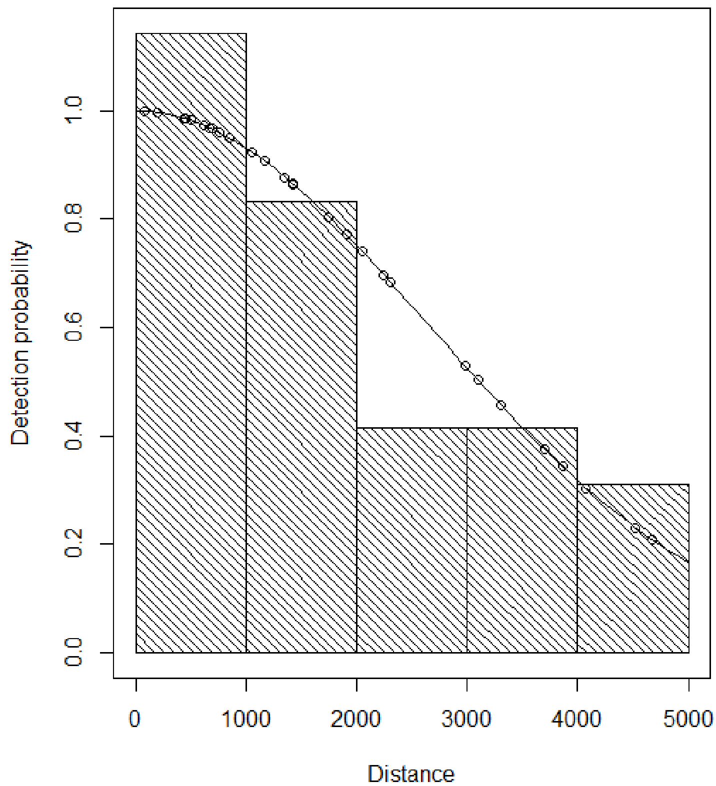


Figure 19. Bryde's whale and unidentified baleen whale sightings from 2003-2019 used to estimate detection probability on the trackline. Survey effort for the 2017 and 2018 cruises (black lines) and prior year cruises (2003, 2004, and 2009; gray lines) within the core habitat area are shown. A sighting in the western Gulf from summer 2017 is not included in this area and is excluded from the abundance estimate.

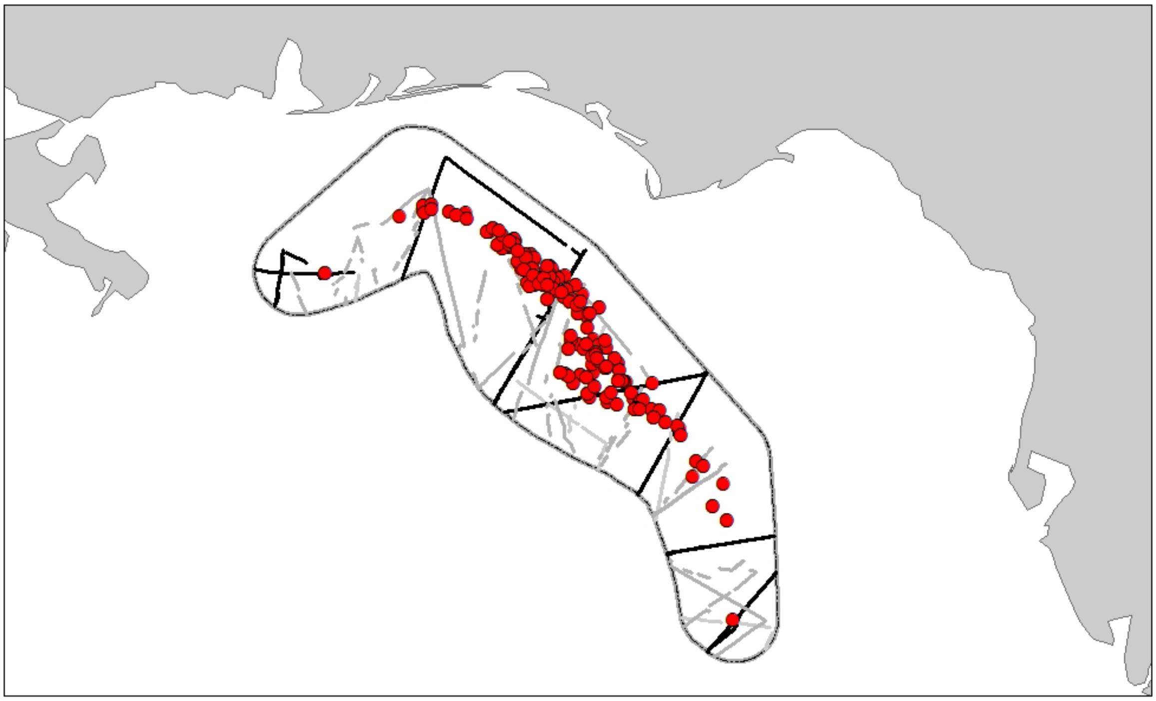
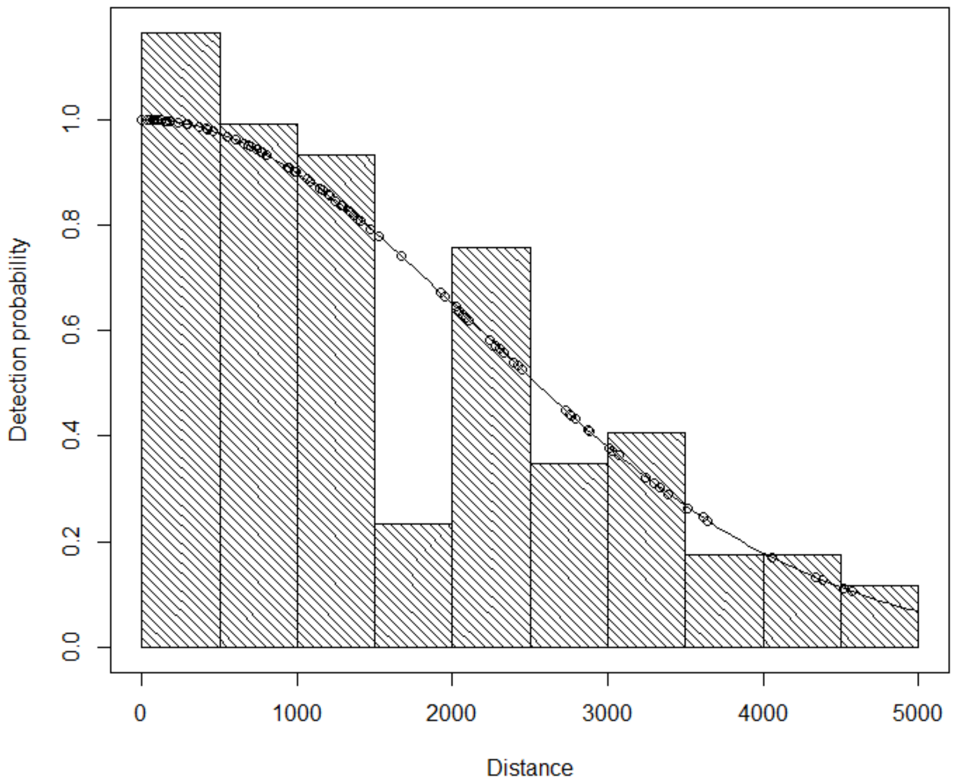


Figure 20. Detection probability function for 91 on effort Bryde's whale and baleen sightings from 2003-2019.



Appendices

Appendix 1: Prior year surveys and updated abundance estimates: Large Whales

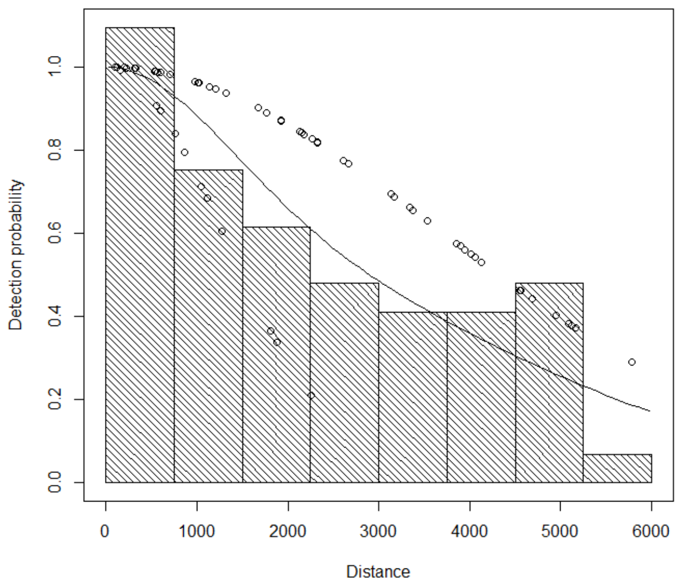
GU0302

Sightings by Species

```
  CommonName          n.sight mu.GS tot.n
1 Sperm whale              63  2.41   152
2 unid. large whale         3  2        6
```

Detection function

```
 [1] "~ vis2"
                        Estimate          SE        CV
Average p              0.5390119  0.08009115 0.1485888
N in covered region 116.8805389 20.44405855 0.1749141
```



Abundance Estimates: Nc includes p0 correction derived from GU1703

```
      spe           D        N        CV      p0  p0.se       Nc     CV.c
 Sperm whale 0.003587752 1323.263 0.2094996 0.52055 0.1366 2542.047 0.335785
```

GU0402

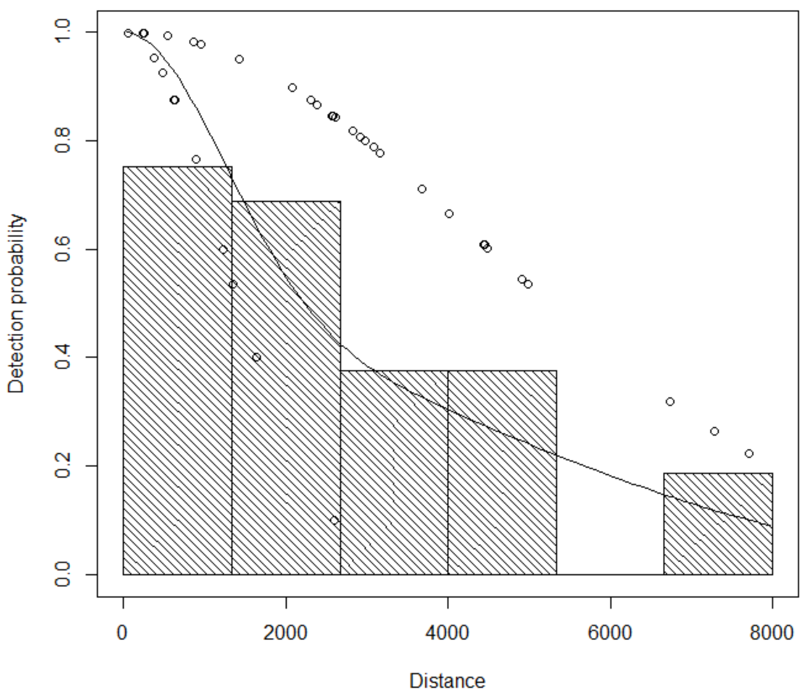
Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Bryde's whale	2	2	4
2	Sperm whale	35	2.94	103
3	unid. large whale	2	1.5	3

Detection function

[1] "~ vis2"

	Estimate	SE	CV
Average p	0.3966998	0.06974268	0.1758072
N in covered region	95.7903107	21.46591870	0.2240928



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	CV	p0	p0.se	Nc	CV.c
1	Sperm whale	2.379772e-03	877.72625	0.3086883	0.52055	0.1366	1686.1517	0.4051543
2	Bryde's whale	5.093256e-05	18.78535	1.0597094	0.52055	0.1366	36.0875	1.0917168

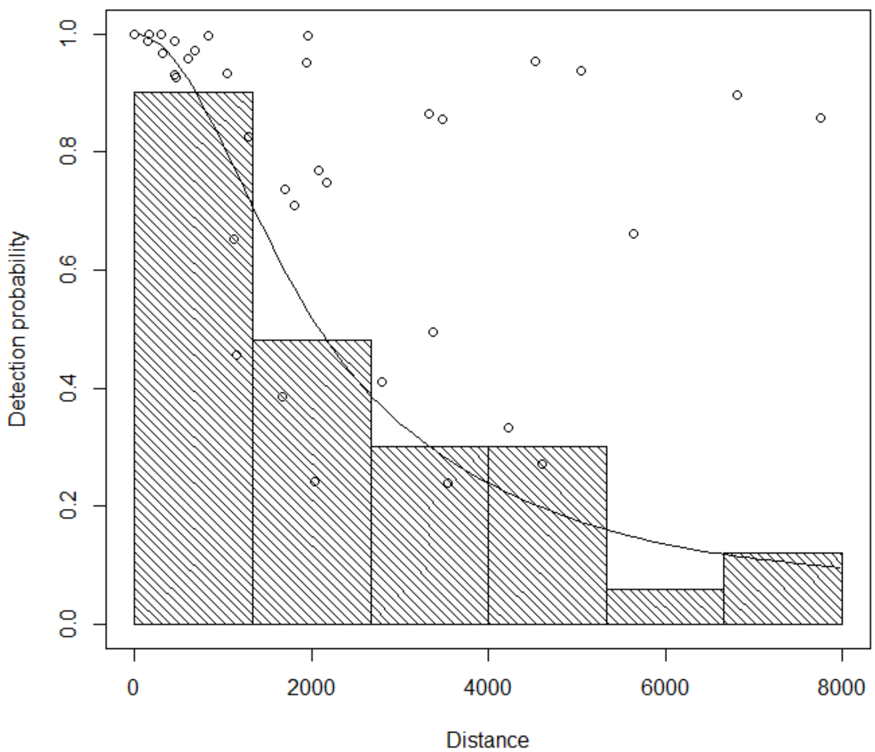
GU0903

Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Bryde's whale	2	1.5	3
2	Sperm whale	34	2.05	69.7
3	unid. large whale	2	1	2

Detection function

```
[1] "~ vis2+g2+cc2"
                      Estimate          SE        CV
Average p            0.3608681  0.07584715 0.2101797
N in covered region 99.7594531 25.65751885 0.2571939
```



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	CV	p0	p0.se	Nc	CV.c
1	Sperm whale	2.957563e-03	1090.83150	0.4792144	0.52055	0.1366	2095.53645	0.5463588
2	Bryde's whale	8.075083e-05	29.78315	1.0295754	0.52055	0.1366	57.21478	1.0624909

Appendix 2: Prior year surveys and updated abundance estimates: Dolphins

GU0302

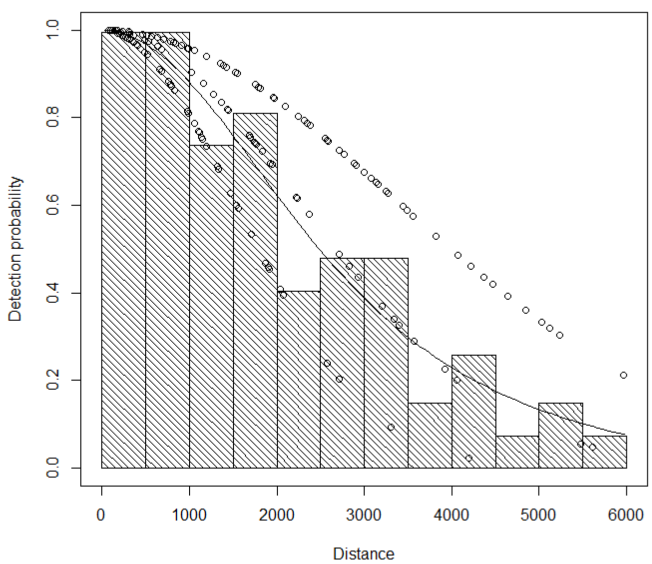
Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Bottlenose dolphin	17	67.8	1152
2	Clymene dolphin	11	53.3	586
3	Pantropical spotted dolphin	82	47.5	3896
4	Rough-toothed dolphin	9	42.3	381
5	Spinner dolphin	4	89.8	359
6	Stenella sp.	9	25.3	228
7	Striped dolphin	8	50.2	402
8	unid. dolphin	19	6.74	128

Detection function

[1] "~ ss2"

	Estimate	SE	CV
Average p	0.4662474	0.03024863	0.06487678
N in covered region	326.0072067	29.17797468	0.08950101



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	cv	p0	p0.se	Nc	CV.c
1	Pantropical spotted dolphin	0.116568298	42993.637	0.1566818	0.589751	0.07158775	72901.336	0.1982015
2	Striped dolphin	0.008784534	3239.981	0.4090340	0.589751	0.07158775	5493.811	0.4266655
3	Bottlenose dolphin	0.034138439	12591.208	0.4512055	0.589751	0.07158775	21350.040	0.4672484
4	Spinner dolphin	0.008250323	3042.949	0.5372933	0.589751	0.07158775	5159.718	0.5508346
5	Rough-toothed dolphin	0.014796028	5457.188	0.7754338	0.589751	0.07158775	9253.375	0.7848772
6	Clymene dolphin	0.017428206	6428.008	0.3972653	0.589751	0.07158775	10899.529	0.4153967

GU0402

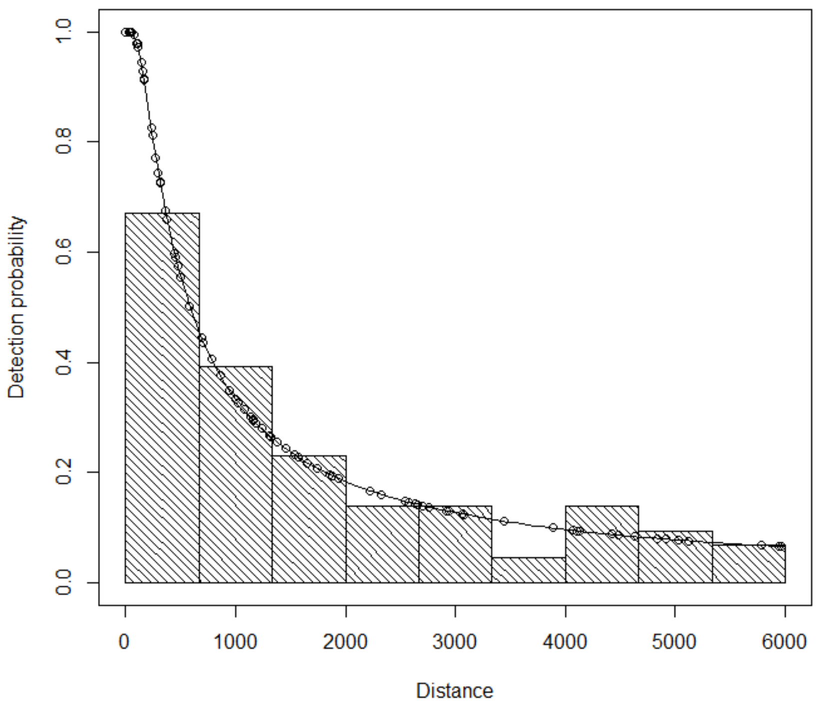
Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Atlantic spotted dolphin	2	17	34
2	Bottlenose dolphin	11	25.9	285
3	Clymene dolphin	4	104.	418
4	Pantropical spotted dolphin	40	50.6	2026
5	Spinner dolphin	6	110.	658
6	Stenella sp.	1	30	30
7	Striped dolphin	8	37.2	298
8	unid. dolphin	16	6.25	100

Detection function

[1] "~1"

	Estimate	SE	CV
Average p	0.2096184	0.06305927	0.3008288
N in covered region	391.1869634	123.78875495	0.3164440



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	cv	p0	p0.se	Nc	CV.c
1	Bottlenose dolphin	0.015146662	5586.5112	0.4921239	0.6302441	0.0686089	8864.044	0.5040204
2	Pantropical spotted dolphin	0.134786341	49712.9583	0.3968794	0.6302441	0.0686089	78878.901	0.4115385
3	Striped dolphin	0.018393757	6784.1300	0.4983560	0.6302441	0.0686089	10764.290	0.5101072
4	Clymene dolphin	0.022653695	8355.3142	0.8005655	0.6302441	0.0686089	13257.268	0.8079331
5	Atlantic spotted dolphin	0.001717618	633.5056	0.8802219	0.6302441	0.0686089	1005.175	0.8869280
6	Spinner dolphin	0.041926223	15463.5595	0.5736748	0.6302441	0.0686089	24535.828	0.5839122

GU0903

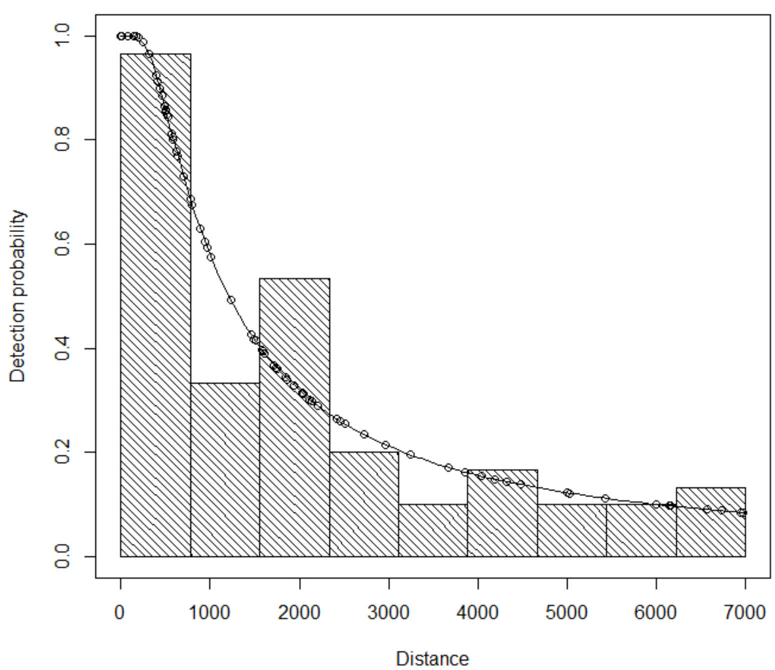
Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Atlantic spotted dolphin	1	37.3	37.3
2	Bottlenose dolphin	10	28.6	286.
3	Clymene dolphin	2	18.1	36.2
4	Pantropical spotted dolphin	37	64.0	2367.
5	Rough-toothed dolphin	4	28.2	113.
6	Spinner dolphin	4	133.	531.
7	Stenella sp.	3	69.7	209
8	Striped dolphin	2	43	86
9	unid. dolphin	17	10.5	178.

Detection function

[1] "~ 1"

	Estimate	SE	CV
Average p	0.2923465	0.07444675	0.2546524
N in covered region	270.2272380	73.41307851	0.2716716



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	cv	p0	p0.se	Nc	CV.c
1	Bottlenose dolphin	0.017640024	6506.1325	0.6515340	0.6748876	0.06806108	9640.320	0.6592927
2	Pantropical spotted dolphin	0.153790940	56722.3840	0.3485095	0.6748876	0.06806108	84047.160	0.3628074
3	Spinner dolphin	0.036007128	13280.4322	0.5212420	0.6748876	0.06806108	19677.992	0.5309083
4	Striped dolphin	0.005599627	2065.2986	0.7196294	0.6748876	0.06806108	3060.211	0.7266614
5	Clymene dolphin	0.002413259	890.0771	0.7749859	0.6748876	0.06806108	1318.852	0.7815200
6	Rough-toothed dolphin	0.006420820	2368.1772	0.6607227	0.6748876	0.06806108	3508.995	0.6683748
7	Atlantic spotted dolphin	0.002124466	783.5623	1.0164078	0.6748876	0.06806108	1161.026	1.0213986

Appendix 3: Prior year surveys and updated abundance estimates: Small Whales

GU0302

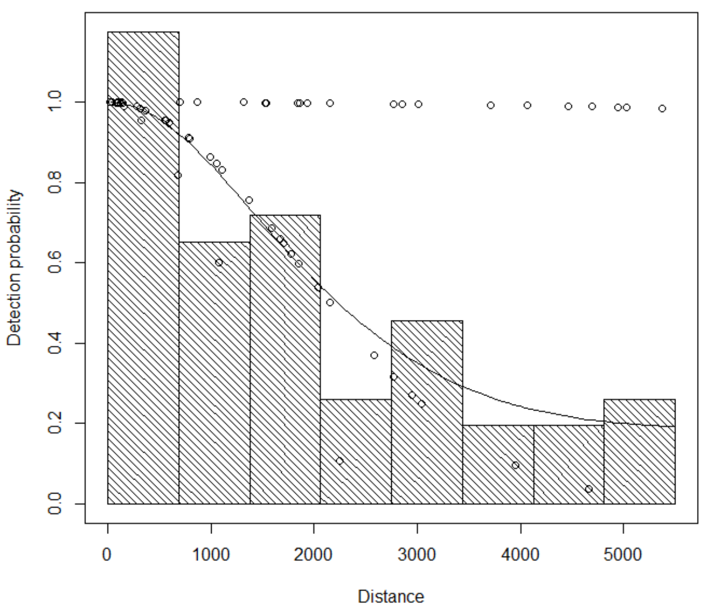
Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	False killer whale	5	21.6	108
2	Melon-headed whale	2	71.5	143
3	Pilot whales	10	14.2	142
4	Pygmy killer whale	3	8.67	26
5	Risso's dolphin	22	10	220
6	unid. odontocete	13	1.69	22
7	unid. small whale	7	3.14	22

Detection function

[1] "~ vis2 + sw2"

	Estimate	SE	CV
Average p	0.4896704	0.0613984	0.1253872
N in covered region	122.5314064	19.9096287	0.162485



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	cv	p0	p0.se	Nc	CV.c
1	Risso's dolphin	0.0071831707	2649.3535	0.3456244	0.5926	0.1893	4470.7282	0.4706357
2	Pilot whales	0.0044019683	1623.5686	0.4084766	0.5926	0.1893	2739.7377	0.5185507
3	False killer whale	0.0020780798	766.4537	0.5485297	0.5926	0.1893	1293.3745	0.6347650
4	Pygmy killer whale	0.0008043784	296.6772	0.6664993	0.5926	0.1893	500.6364	0.7390961
5	Melon-headed whale	0.0024128692	889.9334	0.9016967	0.5926	0.1893	1501.7438	0.9566080

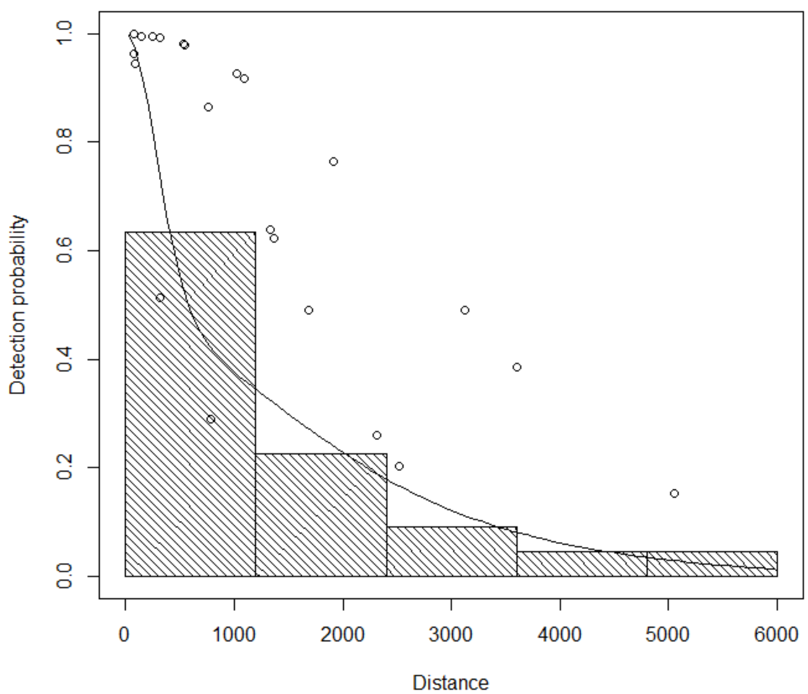
GU0402

Sightings by Species

```
  CommonName          n.sight mu.GS tot.n
1 Killer whale              1  6        6
2 Melon-headed whale        2 64      128
3 Pilot whales              1 45       45
4 Pygmy killer whale        3 12       36
5 Risso's dolphin           7 13       91
6 unid. odontocete          8  2.38    19
7 unid. small whale         3  1.33     4
```

Detection function

```
[1] "~ ss2 + vis2"
                          Estimate          SE        CV
Average p                0.1945637  0.08601666 0.4421004
N in covered region 123.3529481 60.19982030 0.4880290
```



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	cv	p0	p0.se	Nc	CV.c
1	Risso's dolphin	0.0074572004	2750.4233	0.7944769	0.5926	0.1893	4641.2813	0.8562916
2	Melon-headed whale	0.0118114178	4356.3800	0.8098489	0.5926	0.1893	7351.2994	0.8705728
3	Pygmy killer whale	0.0007868320	290.2056	0.5121940	0.5926	0.1893	489.7158	0.6036426
4	Killer whale	0.0003174277	117.0762	0.9501984	0.5926	0.1893	197.5636	1.0024564
5	Pilot whales	0.0009426444	347.6735	0.8243647	0.5926	0.1893	586.6918	0.8840922

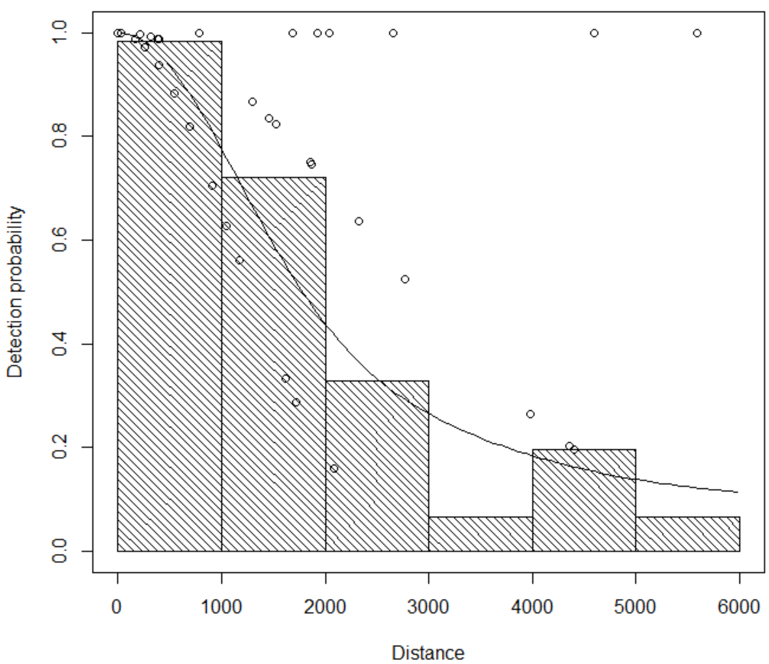
GU0903

Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Killer whale	1	2	2
2	Melon-headed whale	2	81.1	162.
3	Melon-headed/Pygmy killer whale	1	15	15
4	Pilot whales	6	32.1	193.
5	Pygmy killer whale	1	11.2	11.2
6	Risso's dolphin	11	15.8	174.
7	unid. odontocete	15	2.25	33.8

Detection function

```
[1] "~ ss2 + cc2"
                       Estimate         SE        CV
Average p             0.3937474  0.1030184 0.2616358
N in covered region 91.4291644 27.3115998 0.2987187
```



Abundance Estimates: Nc includes p0 correction derived from GU1703

	spe	D	N	cv	p0	p0.se	Nc	CV.c
1	Risso's dolphin	1.251336e-02	4615.27691	0.5909566	0.5926	0.1893	7788.18243	0.6717674
2	Melon-headed whale	6.728639e-03	2481.70967	0.6861589	0.5926	0.1893	4187.83272	0.7568723
3	Killer whale	8.276292e-05	30.52527	0.9132143	0.5926	0.1893	51.51075	0.9674720
4	Pilot whales	7.693010e-03	2837.39647	0.6651629	0.5926	0.1893	4788.04670	0.7378912
5	Pygmy killer whale	5.766083e-04	212.66922	0.8995687	0.5926	0.1893	358.87482	0.9546023

Appendix 4: Prior year surveys and updated abundance estimates: Cryptic Species

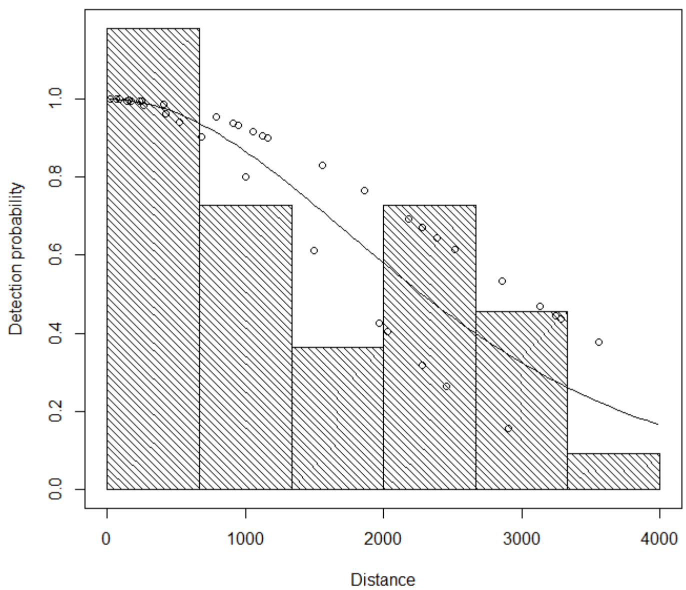
GU0302

Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Cuvier's beaked whale	1	3	3
2	Pygmy/Dwarf sperm whale	23	1.52	35
3	Unid. Mesoplondont	2	3	6
4	Unid. Ziphiid	15	2.87	43

Detection function

```
[1] "~ sw2"
                      Estimate          SE        CV
Average p            0.5907341  0.08520333 0.1442330
N in covered region 66.0195560 11.79233162 0.1786188
```



Abundance Estimates: No g0 correction applied

	spe	D	N	cv
1	Unid. Ziphiid	1.287818e-03	474.98325	0.5042523
2	Cuvier's beaked whale	9.245821e-05	34.10116	1.0072080
3	Unid. Mesoplondont	1.724784e-04	63.61486	0.7883130
4	Pygmy/Dwarf sperm whale	1.197005e-03	441.48889	0.4237104

GU0402

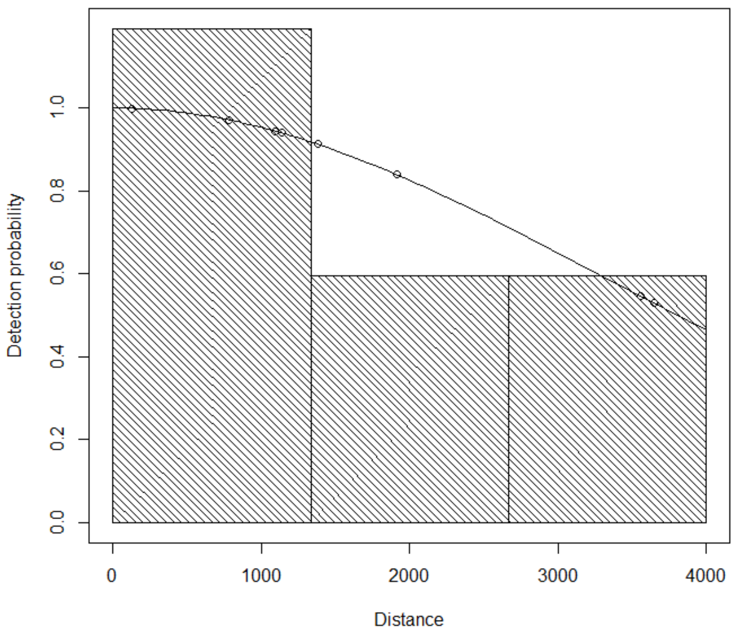
Sightings by Species

	CommonName	n.sight	mu.GS	tot.n
1	Cuvier's beaked whale	1	3	3
2	Pygmy/Dwarf sperm whale	4	1.25	5
3	Unid. Ziphiid	3	1.33	4

Detection function

```
[1] "~ 1"
```

	Estimate	SE	CV
Average p	0.7944043	0.2388328	0.3006439
N in covered region	10.0704394	3.4311422	0.3407143



Abundance Estimates: No g0 correction applied

	spe	D	N	cv
1	Cuvier's beaked whale	4.360082e-05	16.08120	1.1004085
2	Pygmy/Dwarf sperm whale	1.037781e-04	38.27625	0.7108183
3	Unid. Ziphiid	1.059008e-04	39.05917	0.8669628

GU0903

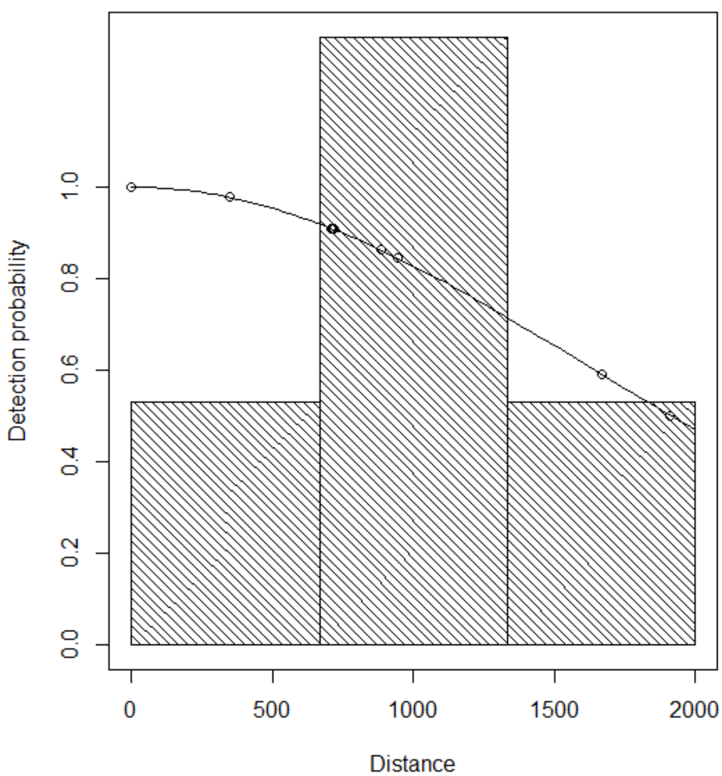
Sightings by Species

	spename	n.sight	mu.GS	tot.n
1	Cuvier's beaked whale	1	2	2
2	Pygmy/Dwarf sperm whale	5	1	5
3	Unid. Mesoplondont	1	3	3
4	Unid. Ziphiid	2	2.25	4.5

Detection function

[1] "~ 1”

	Estimate	SE	CV
Average p	0.796612	0.2420058	0.3037938
N in covered region	11.297846	3.8294424	0.3389533



Abundance Estimates: No g0 correction applied

	spe	D	N	cv
1	Cuvier's beaked whale	0.0001572603	58.00197	1.0751067
2	Unid. Ziphiid	0.0003538356	130.50444	0.7828722
3	Pygmy/Dwarf sperm whale	0.0003355639	123.76532	0.6041607
4	Unid. Mesoplondont	0.0002358904	87.00296	1.0566815