

THE ATLANTIC-WIDE RESEARCH PROGRAMME FOR BLUEFIN
TUNA
(PHASE 9)

SHORT-TERM CONTRACT ICCAT GBYP 07/2019

2010-2019 Aerial Survey Data Re-Analysis

Final Report

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Background

The objectives of the comprehensive ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP) are to improve basic data collection and our understanding of key biological and ecological processes in order to develop a robust scientific management framework.

An important element of this program is to develop fisheries independent indices of population abundance. Therefore, in 2010 and 2011 aerial surveys were conducted in the Mediterranean on selected spawning grounds. Extended surveys were carried out in 2013 and 2015. In 2017 and 2018 new surveys were carried out again on selected spawning grounds, specifically on the “overlap areas” defined in 2015. The same areas as in 2017 and 2018 were surveyed in 2019, except for a modification in Area A.

Another difference in 2019 is that, after discussion about the issue of BFT sizes, which include some juveniles/non-reproductive animals, a separate analysis has been done removing the animals categorized as “small”, while still carrying out the analysis incorporating all animals, in order to compare the effect of those juveniles in the total estimate.

Objective

- Provide the re-analysis of aerial survey data collected by the GBYP for overlapping areas in previous years with the objective to correct possible errors and provide standardized series of abundance index. The data will be re-analyzed taking into account the new definition of area A and correcting potential errors. In that respect, a special effort will be made to clean the data, in order to ensure that all these refer to adult and not juvenile/non-reproductive bluefin tuna individuals.

Data re-processing and re-analysis

1. Data processing

All data from 2010 to 2019 has been reprocessed from the original data. This allowed to detect a few errors that went undetected before, but also allowed to do all years and areas in a homogeneous way. The main different processes taken were:

1.1. Fine-scale readjustment of the overlap areas and effort tracks

The different steps of the process were:

- A finer scale that previously layer of coastline was imported into GIS ("EuropeCoastline_ETRS").
- All blocks were redrawn on their coast border to adjust to this finer scale coast contour.
- Surface area was recalculated for all blocks using a European specific projection (ETRS_1989_LAEA, Lambert Azimuthal Equal Area), which was adjusted to each block by changing the Central Meridian of the projection to the approximate central meridian of the block:
 - Block A: central meridian 2°
 - Blocks C and E: central meridian 10°
 - Block G: central meridian 33°
- Three different blocks were adjusted for Area A to allow all possible comparisons with previous years and facilitate a final decision making about the area to be used in future surveys: a) the previous overlap area created in 2018 for the period 2010-2018; b) the new area created in 2019; and c) a new overlap between the previous overlap until 2018 and the new 2019 area, called from now on "overlap area 2018-2019". The other three blocks remained the same as the overlap 2010-2018 (Figures 1.1 and 1.2).
- All tracks were clipped to the readjusted blocks, labeling all the segments that fell inside each block as A, C, E and G respectively, and all the segments falling outside as A_out, C_out, E_out and G_out. In the case of Area A, three sets of clipped tracks were composed, for overlap 2010-2018, 2019, and 2018-2019 sets of block.
- All sightings were checked against effort tracks comparing the Date/Time stamp, and assigned to the correct segment of track, either inside or outside the readjusted blocks. In the same way, the effort status on/off was checked and readjusted in some cases according to the Date/Time stamp. As for effort, three sets of sightings assignments to blocks were created, according to the area configuration used for each analysis.

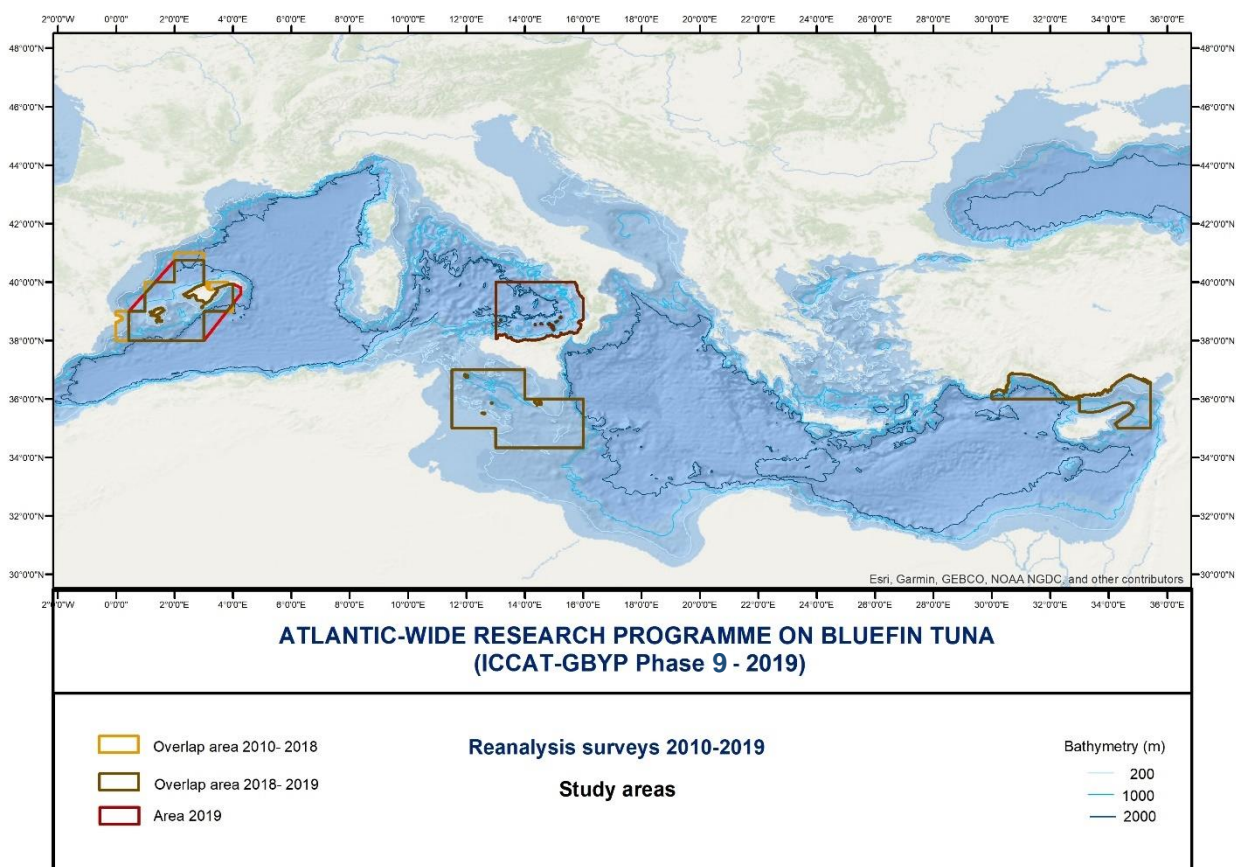


Figure 1.1 All study areas, showing the differences in area A for the three adjustments

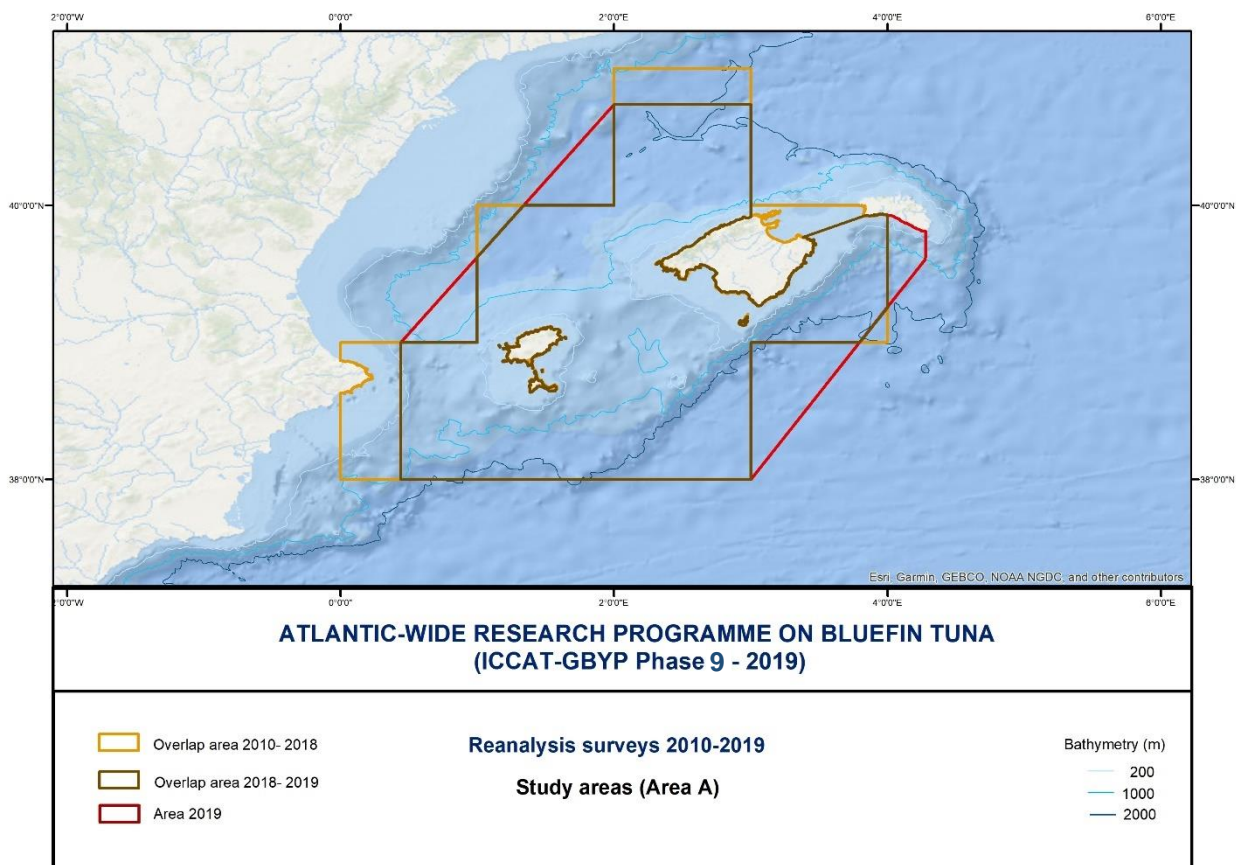


Figure 1.2 Detail of area A, showing the differences for the three adjustments

1.2. Assignment of adult/juvenile categories and recovery of missing data

The data on school size were recorded, in all years (except some areas in 2010) in two ways: estimated number of animals in the school and estimated total weight in kgs. of the school. Theoretically, a classification was made every year on four categories according to the weight of the animals: small, medium, large and giant. The protocol implemented in 2013 was to record what percentage of the school fell in each category, considering small as less than 25Kg, medium as 25-150Kg, large as 150-300Kgs and giant more than 300Kg.

However, several complications arose when re-examining the data:

- In 2010, Area A did not record any school size, only weight.
- Out of a total of 727 sightings of BFT (all years, areas and effort status comprised), 132 did not have recorded school size, 78 did not record total weight, and 131 did not record the proportion of size categories.
- According to the information provided on the “Comments”, or the calculated mean size of the animals in sightings with both school size and total weight, in 59 cases the proportion of animals in the different categories was wrong or missing.

Following some backwards calculations and assumptions, data on school size, weight or both, data could be recovered for many sightings. Several procedures were followed:

- a) All the sightings classified as Small (or with a proportion of Small) in which the weight of the animals was more than 25Kg, were removed from Small and assigned to Medium.
- b) All the sightings classified as Medium (or with a proportion of Medium) in which the weight of the animals was less than 25Kg, were assigned (or their proportional part) to Small.
- c) For those sightings with total weight and total school size but not proportion of weights, the mean weight was calculated by dividing the total weight by the total school size.
- d) For those sightings with total weight and proportion of and mean sizes but not total school size, the total number of animals were calculated for each size class and then summed up to obtain the total school size.
- e) For those sightings with total weight and proportion of sizes but not total school size nor mean weight per class, an assumption was made of the mean weight per class according to the observed mean in the sightings that did have that information, and then proceed as in the previous case (see explanation below and Tables 1.2.1 and 1.2.2).

To make the assumptions of the (missing) mean weight per class for those sightings which did not record that information, the mean weight per class for the sightings which did have that information was calculated and stratified initially by year and by block, after proceeding with steps a) and b) above. A main stratification was done also into West (A and C blocks) and East (E and G blocks) regions. Table 1.2.1 shows the recorded mean sizes per year, and Table 1.2.2 the recorded mean sizes per block. The tables show in red the chosen mean values per size class to be applied to the sightings missing this information. The rationale behind these choices was the following:

- Giant: Chosen overall mean (305Kg). There were only 7 sightings in total with information, and not much variation.
- Large: Chosen mean for the East blocks (195Kg) and for the West blocks (183Kg). There were 207 sightings with animals classified as large. Of those, 27 in the East, with mean 195 varying between 150 and 215 depending on the year, but with too few sightings per year, not enough to properly discriminate. In the West there were 180 sightings with animals classified as large, varying between 174 and 195 depending on the year, and of which the majority (150) were recorded in block A.

Having the West many more large animals than the East, the mean from the west weights too much in the overall mean (184Kg) misleading the weight of the east part. Therefore, it was decided to keep for regions separated for the mean, but it was considered that there were not enough records per year or block within each to further stratify.

- Medium: Chosen mean per block: 70Kg for A, 83Kg for C, 56Kg for E and 34Kg for G. There are enough records per block in this category, and with large variability among the blocks means.
- Small: Chosen mean for the East blocks (14Kg) and for the West blocks (9Kg). Here the same reasoning as for large was applied, although inverse (many more records in the East, 144, than in the West, 26).

Table 1.2.1. Mean recorded weight per size class by region (East/West) and year. Red numbers indicate the chosen value to be applied to the sightings missing this information.

	Mean				Standard Deviation				Count			
	Small	Medium	Large	Giant	Small	Medium	Large	Giant	Small	Medium	Large	Giant
East	14	49	195	311	4.9	28.6	39.9	19.2	144	142	27	3
2010	7	54	150		5.3	32.2			14	21	1	
2011	15	43	215		7.1	26.5	26.6		2	51	7	
2013	11	71	191		3.9	23.2	40.9		37	19	4	
2015	16	69	210	311	3.2	33.1	45.5	19.2	8	9	9	3
2017	14	29	156		3.8	6.3	13.4		52	14	5	
2018	19	45			2.1	28.4			24	21		
2019	17	46	180		2.4	20.8			7	7	1	
West	9	73	183	300	5.8	37.8	25.2		26	79	180	4
2010	8	42	195	300	0.0	19.2	31.6		4	24	20	1
2011	7	70	189		5.5	33.3	25.7		11	15	16	
2013	8	81	192	300	4.5	33.7	27.8		5	10	16	2
2015		110	182			40.1	23.7			7	29	
2017	14	99	181		7.3	42.2	24.2		6	10	39	
2018		88	178	300		26.7	21.7			8	29	1
2019		93	174			24.2	21.7			5	31	
Total	13	58	184	305	5.4	34.1	27.8	12.6	170	221	207	7

Table 1.2.2. Mean recorded weight per size class by region (East/West) and block. Red numbers indicate the chosen value to be applied to the sightings missing this information.

	Mean				Standard Deviation				Count			
	Small	Medium	Large	Giant	Small	Medium	Large	Giant	Small	Medium	Large	Giant
East	14	49	195	311	4.9	28.6	39.9	19.2	144	142	27	3
D	13								1			
E	11	56	195	311	7.0	30.2	38.9	19.2	29	97	25	3
E-out	20		250						1		1	
F	9				6.3				4			
G	15	34	150		3.7	16.4			98	45	1	
G-out	11				2.0				11			
West	9	73	183	300	5.8	37.8	25.2	0.0	26	79	180	4
A	9	70	181	300	5.4	37.6	25.1	0.0	14	57	150	4
A-out			185				25.8				7	
B			217				28.9				3	
C	8	83	192		6.4	37.5	21.2		12	22	20	
C-out												
Total	13	58	184	305	5.4	34.1	27.8	12.6	170	221	207	7

In total, for 89 sightings a total school size could be assigned, and for 38 a total weight could be assigned. Table 1.2.3 shows the data recovered per year, area, and effort status.

Table 1.2.3. Original and recovered data on school size and weight

	Original data						Recovered data					
	Off		On		Total		Off		On		Total	
	Size	Weight	Size	Weight	Size	Weight	Size	Weight	Size	Weight	Size	Weight
2010	6	23	36	83	42	106	17	0	46	3	63	3
A	1	13	0	12	1	25	12	0	12	0	24	0
C	1	1	6	6	7	7	0	0	0	0	0	0
E	4	9	24	35	28	44	5	0	11	0	16	0
G			6	30	6	30	0	0	23	3	23	3
2011	22	22	66	66	88	88	0	0	0	0	0	0
A	8	8	11	11	19	19	0	0	0	0	0	0
C	1	1	10	10	11	11	0	0	0	0	0	0
E	13	13	45	45	58	58	0	0	0	0	0	0
2013	35	36	78	77	113	113	17	15	9	10	26	25
A	10	12	14	13	24	25	2	0	1	2	3	2
A-out	3	3	3	3	6	6	0	0	0	0	0	0
C	6	5	12	12	18	17	0	0	0	0	0	0
D	0	0	1	1	1	1	0	0	0	0	0	0
E	8	8	22	22	30	30	0	0	0	0	0	0
E-out	5	5	1	1	6	6	0	0	0	0	0	0
F			2	2	2	2	0	0	0	0	0	0
G	2	2	15	15	17	17	9	9	7	7	16	16
G-out	1	1	8	8	9	9	6	6	1	1	7	7
2015	39	36	37	35	76	71	0	3	0	2	0	5
A	22	20	8	7	30	27	0	2	0	1	0	3
A-out	3	3	3	3	6	6	0	0	0	0	0	0
B			3	2	3	2	0	0	0	1	0	1
C			3	3	3	3	0	0	0	0	0	0
C-out	2	2	2	2	4	4	0	0	0	0	0	0
D	1	0			1	0	0	1	0	0	0	1
E	11	11	12	12	23	23	0	0	0	0	0	0
E-out			1	1	1	1	0	0	0	0	0	0
F			1	1	1	1	0	0	0	0	0	0
G			2	2	2	2	0	0	0	0	0	0
G-out			2	2	2	2	0	0	0	0	0	0
2017	37	37	91	91	128	128	0	0	0	0	0	0
A	19	19	22	22	41	41	0	0	0	0	0	0
C	1	1	15	15	16	16	0	0	0	0	0	0
E	1	1	9	9	10	10	0	0	0	0	0	0
G	16	16	45	45	61	61	0	0	0	0	0	0
2018	13	13	74	69	87	82	0	0	0	5	0	5
A	1	1	29	27	30	28	0	0	0	2	0	2
C			8	5	8	5	0	0	0	3	0	3
E			11	11	11	11	0	0	0	0	0	0
G	12	12	26	26	38	38	0	0	0	0	0	0
2019	10	10	51	51	61	61	0	0	0	0	0	0
A	5	5	25	25	30	30	0	0	0	0	0	0
C			4	4	4	4	0	0	0	0	0	0
E	5	5	11	11	16	16	0	0	0	0	0	0
G			11	11	11	11	0	0	0	0	0	0
Total	162	177	433	472	595	649	34	18	55	20	89	38

1.3. Re-checking the use of bubble windows

Bubble windows were not always used in the airplanes, and when used, only the back seats had bubble windows while the co-pilot (and pilot) seats had flat windows. The main issue of the bubble windows is that they allow to search below the airplane, i.e., over the track line, which is one of the fundamental assumptions of the line transect methodology. When there are no bubble windows in an airplane, then a “left truncation” of the data needs to be applied in the settings of the detection function to eliminate that strip of area under the plane that is not available to be searched by the observers, so it is not taken into account when estimating density, avoiding in this way a bias in the results.

When there is a mix situation, like in the last years of the BFT surveys, the observers in the back seats (the SS – scientific spotters in these surveys) focus more on searching close to the track line, and the observers in the front seat (theoretically the PS – professional spotters in these surveys) focus a bit further away. So, overall, it is considered a survey with bubble windows because some observers have the ability to search under the plane. However, ideally, the same type of observer should be linked to the same type of window, especially since PS tend, by habit, to search far away even when having bubble windows and despite having been told repeatedly to search closer by.

Several issues were found when revising this point:

- 2010: none of the airplanes had bubble windows
- 2011: in area A bubble windows were only installed on 7 July, so before then, their part of the survey was done without bubble windows. In the rest of the blocks (and A after 7 July), it is only recorded that the survey was done with bubble windows, but not if the observer making the detection used bubble window or not. Furthermore, it is not very clear which observer was seated where in the plane (front or back) in some areas, and some assumptions were made to try to retrieve this information. In area E it only indicated observers codes for left and right (one code per side) without indicating whether they were in the front or the back. Same issue for area A but giving two observers codes for each side, without knowing who were in front and who in the back. In block C there is one observer code for the left (who must be in the back because it is not the pilot code), and two for the right indicating who is in front and who in the back. In E, many times the observer making the detection is not any of the observers recorded in the effort file as being on effort; therefore I have assumed that the observer making the detection was sitting in the front and the codes given for observers are those in the back seats. In A, after 7 July, one of the two observers recorded for the left side is the pilot, so it means that the other one is in the back seat. Assuming that the pairs of observers were recorded in the same order on both sides (back-front, following the order on the left side), I assigned back or front seat to all the pairs on the right side. In this way, all areas considered, I changed 49 BFT sightings to “without bubble” because they were made presumably from the front seat. Even so, there are still 13 sightings realized by the PS from the back seat, with bubble window, happening on the three areas (one even has angle 90, i.e. 0°, under the plane).
- 2013: In many occasions the PS was seating on the back seats and a SS in the front seat, so they are all mixed. But there were also errors. For Perigod, there is a column with the position of the observer and in many cases the pilot is recorded “back”, which is obviously not possible, so I transfer him to front and without bubble window. In addition, revising one by one, I found 33 that were incorrectly assigned, recorded as back with bubble but they were actually in the front without bubble, now corrected. After all the corrections, 56 sightings were detected by PS from the back seats with bubble windows, occurring in the 4 areas.
- 2015: All the PS were recorded as without bubble and minimum distance 86m (74 °). Everything seems correct.
- 2017, 2018 and 2019: All PS are recorded as with bubble, but the minimum distance (maximum angle) recorded for their sightings are within the range of a flat window. Therefore, they were all assigned as with bubble because the survey itself was with bubble windows. Now all the PS are assigned as “without bubble”.

Looking at the differences between the periods 2010-2013 (some surveys without bubbles, and total mix and confusion between PS and SS siting randomly at the back or at the front) and 2015-2019 (all survey with bubble windows, and PS always sitting at the front and SS at the back), it was decided to separate the two periods for analysis purposes, using left truncation in the first one (even if that means losing sightings made with bubble windows close to the track line), and no left truncation in the second one (see below).

1.4. Creation of parallel datasets

Due to all the issues mentioned above and the new questions about adults and juveniles, the full dataset was divided into 12 different parallel datasets to be analyzed independently for cluster size, and then repeated for weight (so they become 24). The criteria to separate datasets were:

- Two **periods** 2010-2013 and 2015-2019 because of the differences in the use of bubble windows and the positioning behavior of PS and SS
- Three **areas configuration** (applied in each case to all years): previous overlap 2010-2018; new area 2019; and new overlap 2018-2019 (overlap between the previous 2010-2018 and the new 2019 areas)
- Two **size classes**: All sizes pooled together (juveniles + adults) and only adults (removing juvenile individuals)
- All repeated twice: using school size as size **variable** (obtaining an estimate of number of animals) and using weight as size variable (obtaining an estimate of weight).

Figures 1.4.1 to 1.4.6 show the 4 areas with all the sightings pooled together, with different color codes according to their status: inside or outside the readjusted areas, on or off effort, unusable due to missing data, and unusable because they are beyond truncation distance. Three maps are presented for area A, showing the three configurations of overlap area.

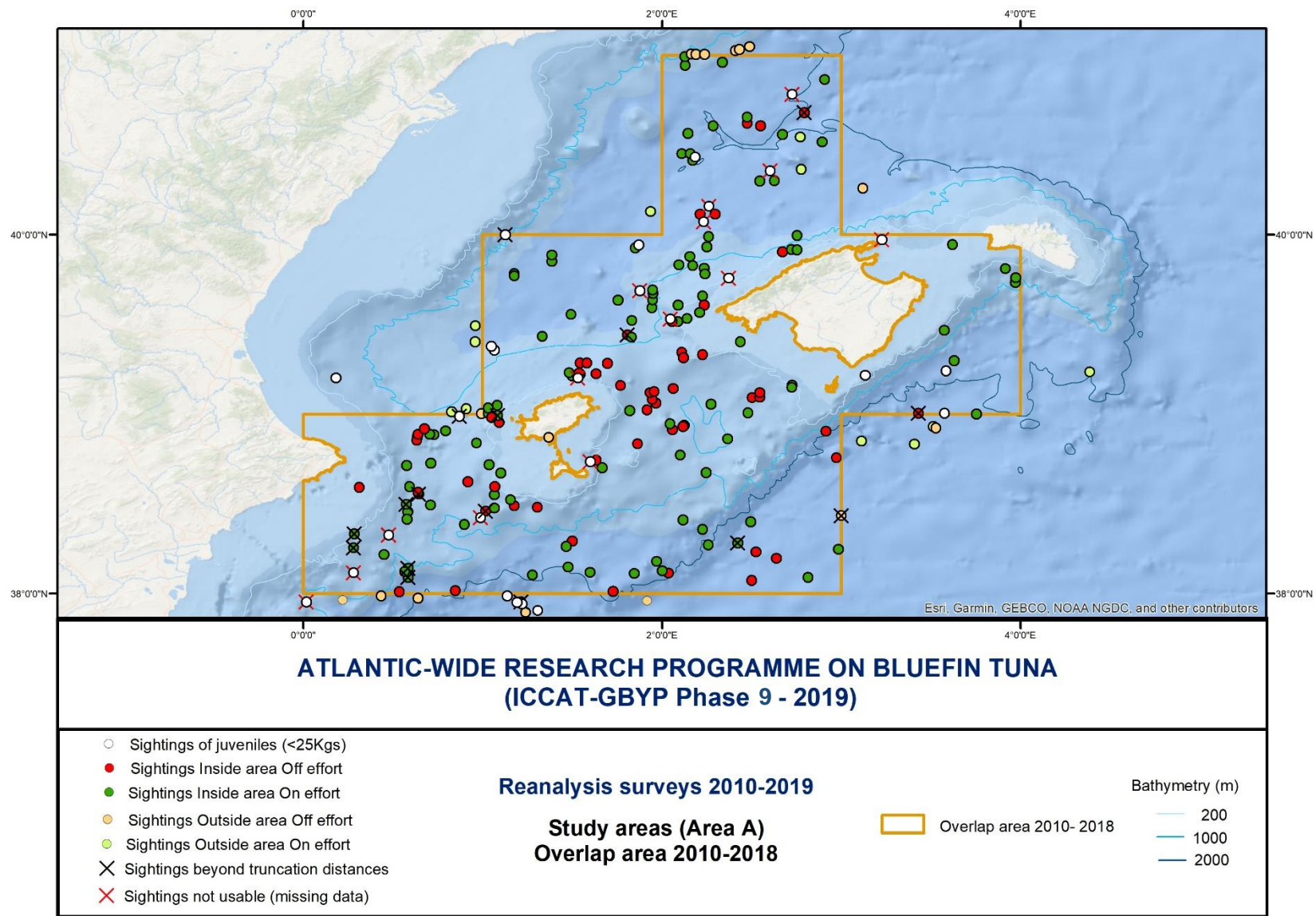


Figure 1.4.1. Sightings status in Area A for area configuration 2010-2018

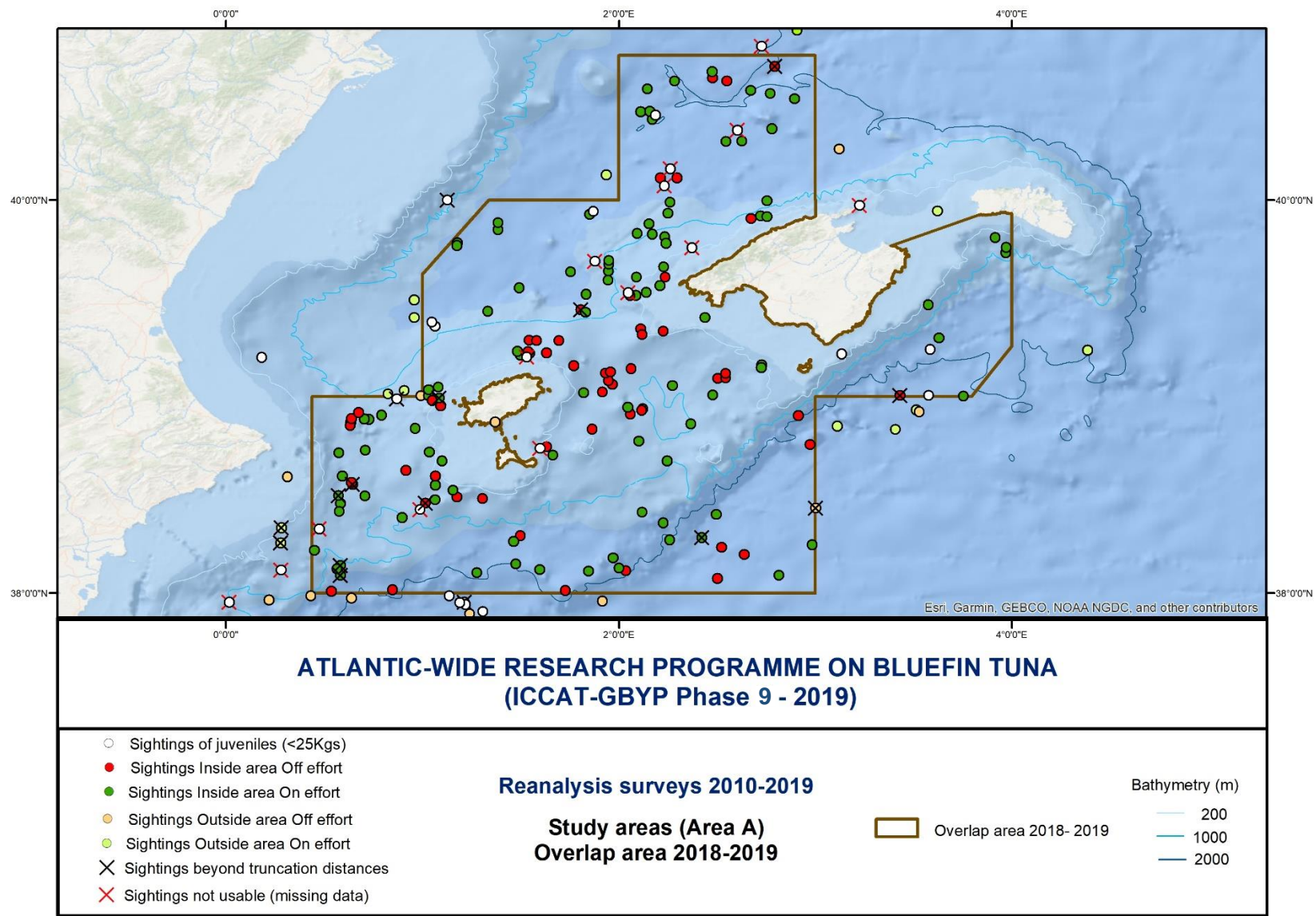


Figure 1.4.2. Sightings status in Area A for area configuration 2018-2019

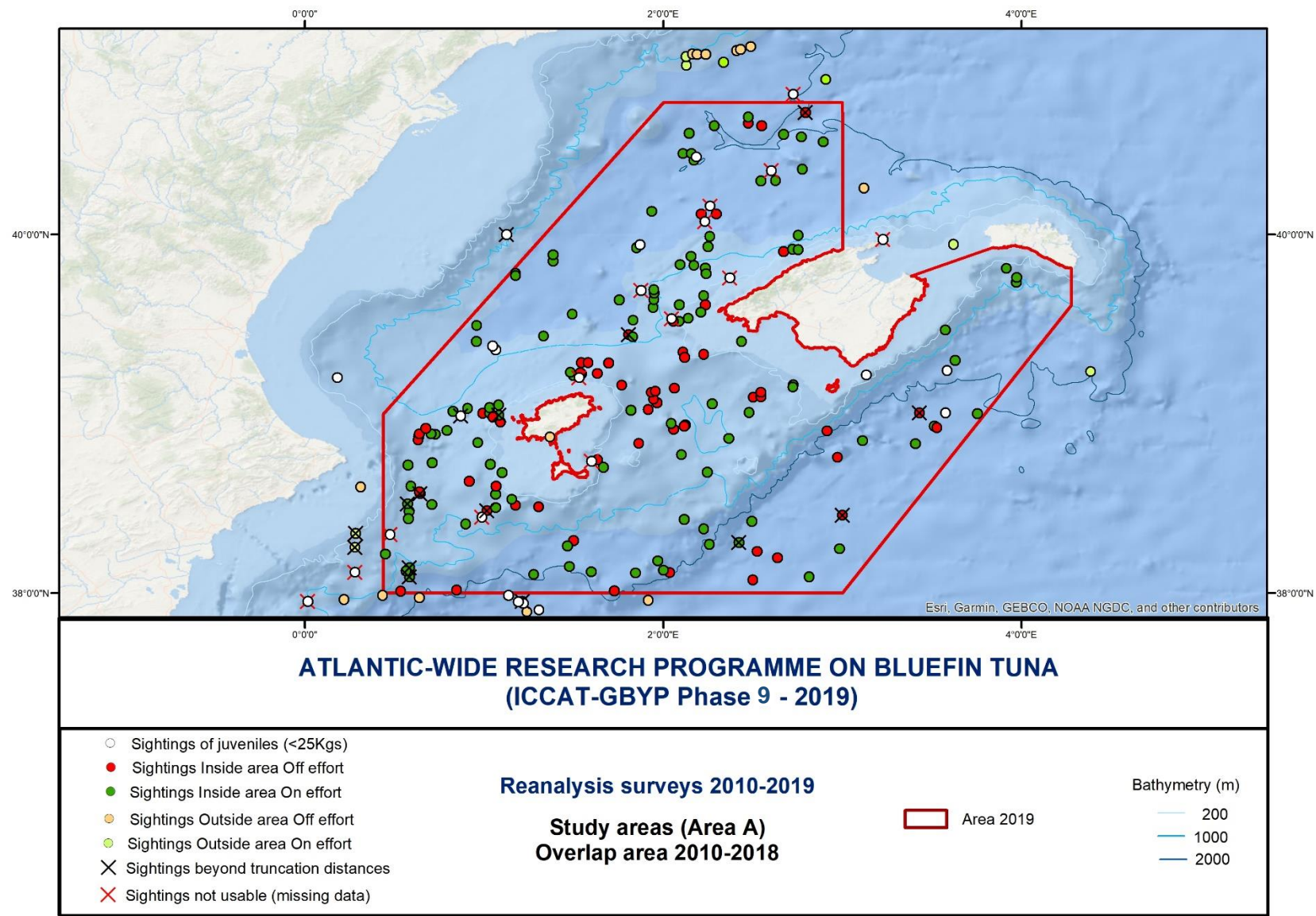


Figure 1.4.3. Sightings status in Area A for area configuration 2019

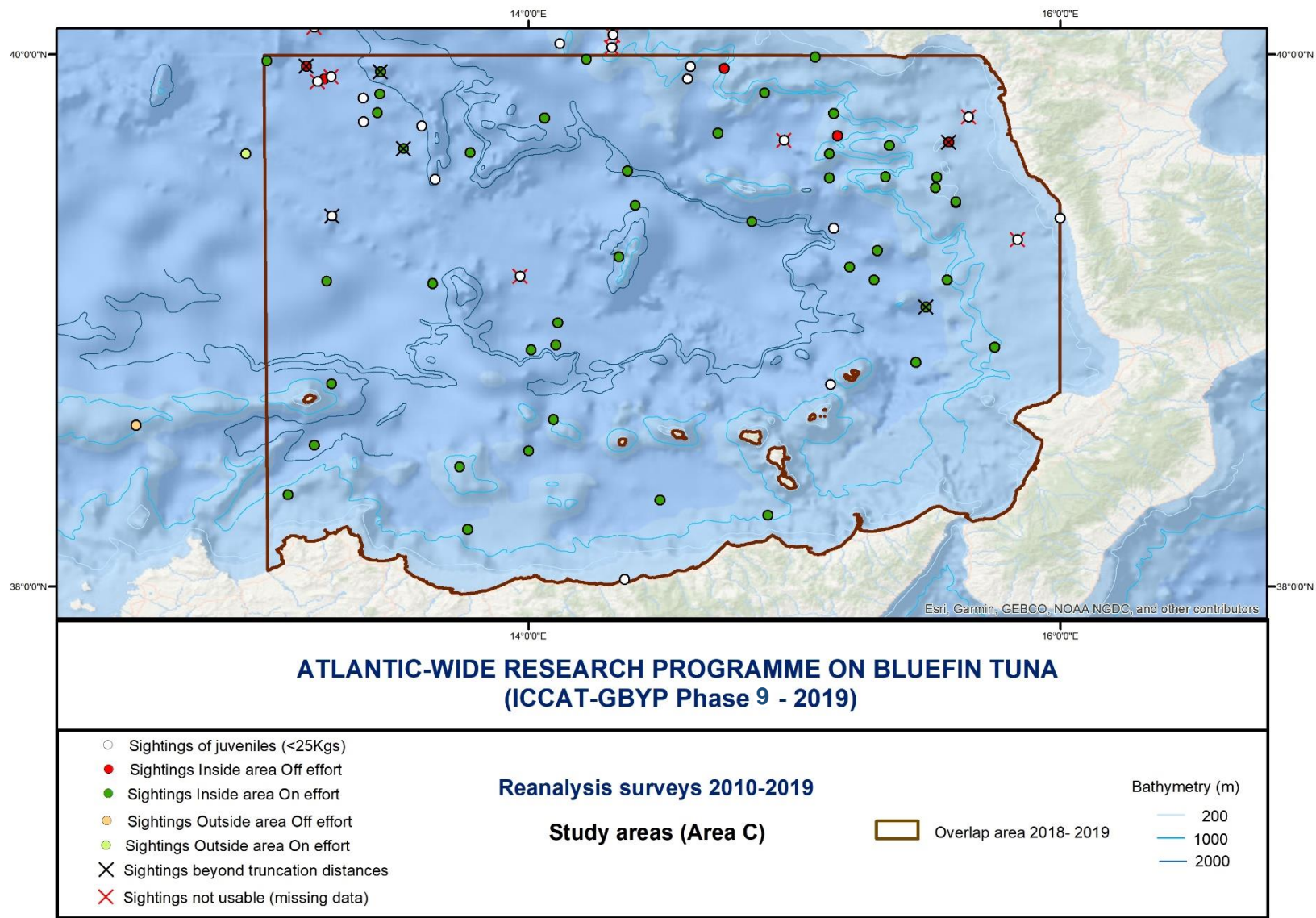


Figure 1.4.4. Sightings status in Area C

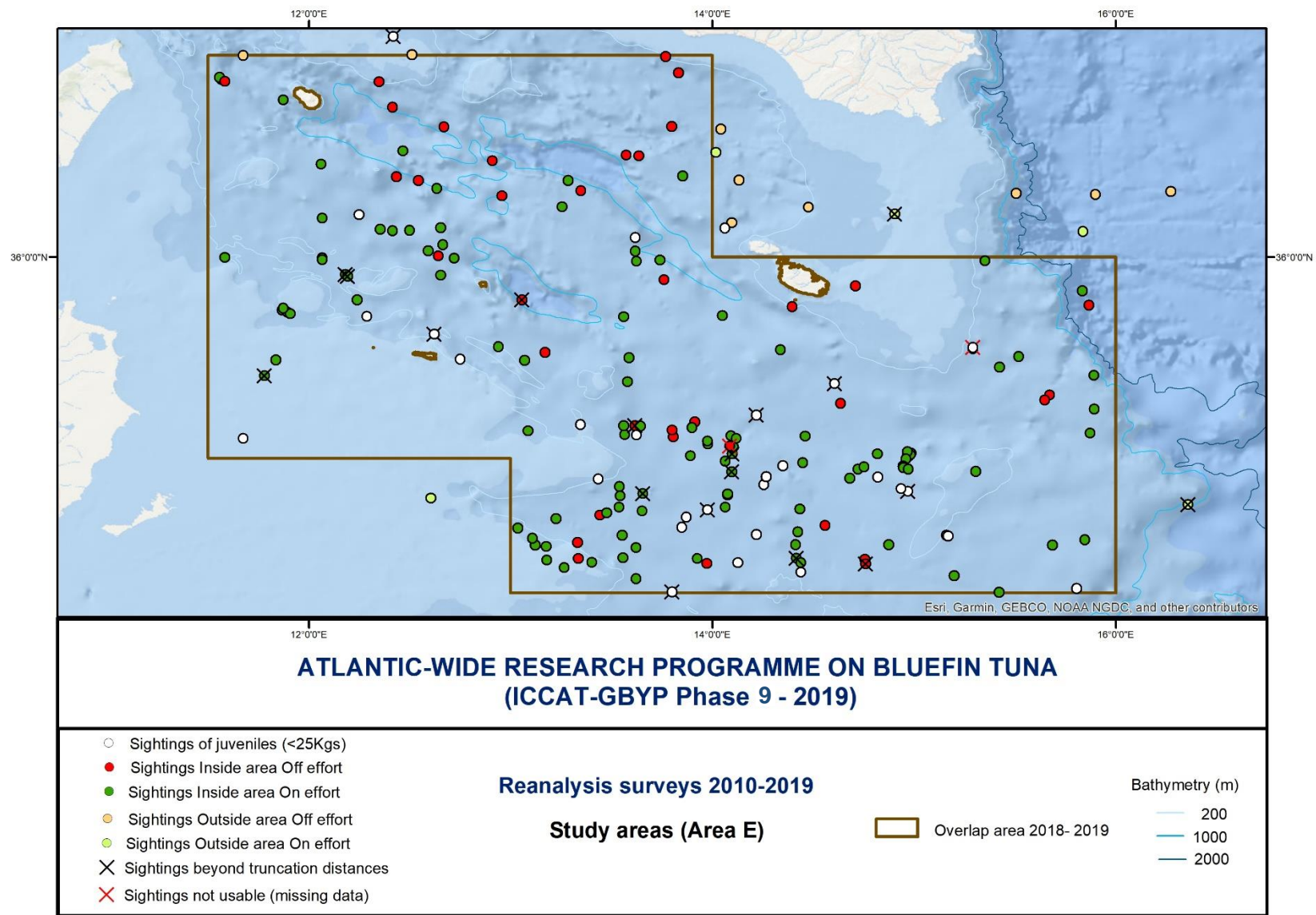


Figure 1.4.5. Sightings status in Area E

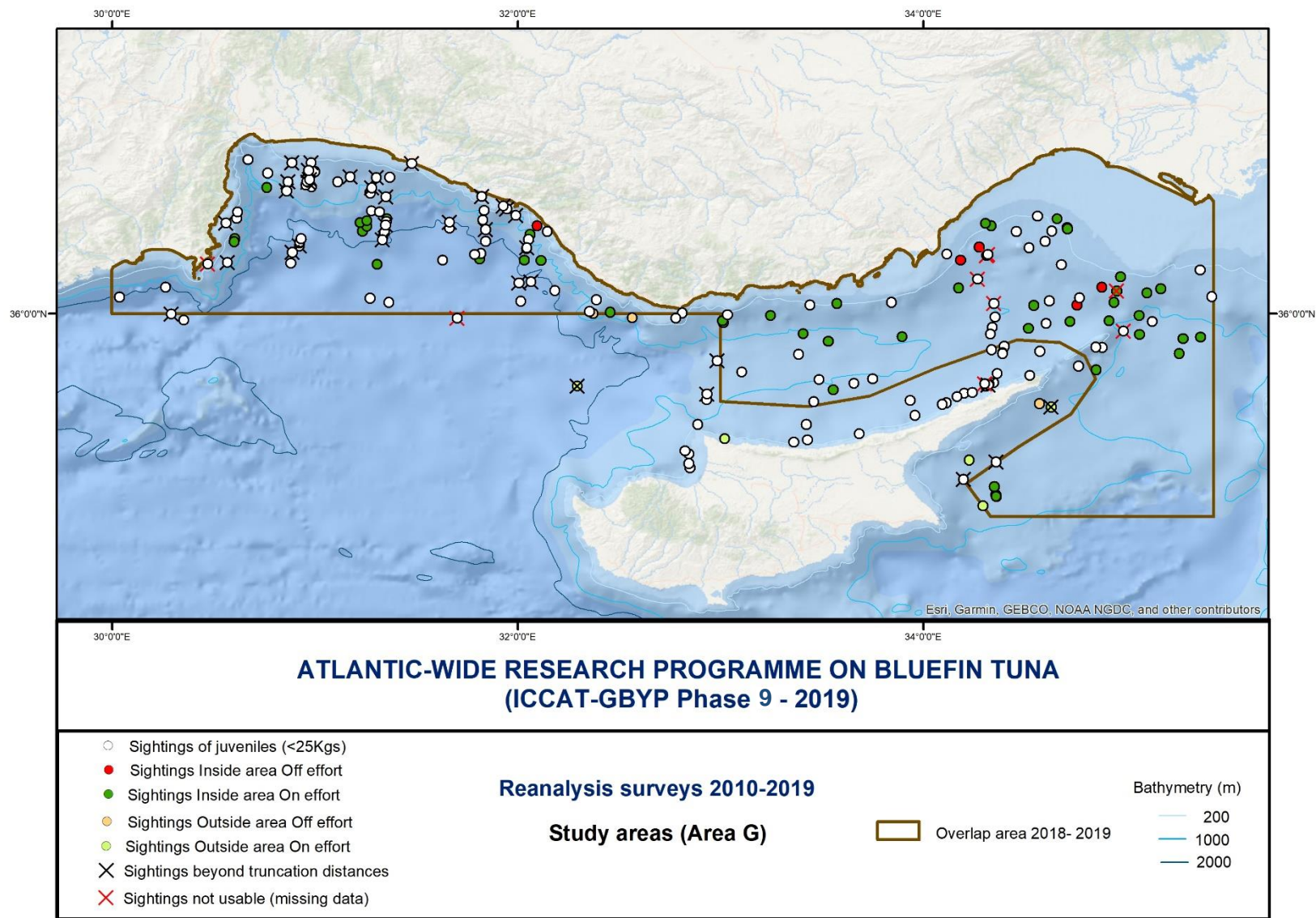


Figure 1.4.&. Sightings status in Area G

2. Methodology for Re-analysis

2.1. General aspects

Analysis of the data followed standard line transect methodology (Buckland *et al.* 2001). Density of schools was estimated from the number of schools sighted, the length of transect searched and the estimated *esw* (reciprocal of the probability of detecting a school within a strip defined by the data). The equation that relates density to the collected data is:

$$\hat{D} = \frac{n \bar{s}}{2 esw L}$$

where \hat{D} is density (the hat indicates an estimated quantity), n is the number of separate sightings of schools, \bar{s} is mean school size (see below), L is the total length of transect searched, and *esw* is the estimated effective strip half-width. The quantity $2 esw L$ is thus the area of the strip that has been searched. The effective strip half-width is estimated from the perpendicular distance data for all the detected animals. It is effectively the width at which the number of animals detected outside the strip equals the number of animals missed inside the strip, assuming that everything is seen at a perpendicular distance of zero. To calculate the effective strip half-width, we fitted a detection function (see below and Buckland *et al.* 2001 for further details).

Abundance was estimated as:

$$\hat{N} = A \hat{D}$$

where A is the size of the survey area.

Because school size was measured in tons in one of the analysis, the final estimate of abundance is the total estimated weight of tunas in the surveyed areas in that case.

All analysis was initially undertaken in software DISTANCE <http://www.ruwpa.st-and.ac.uk/distance/>, which estimates all quantities and their uncertainties. However, after consultation with the Distance developers at CREEM (University of St Andrews), we decided to shift to “Distance in R” in software R, which is where most advancements are being done lately. For this purpose, an R script was developed completely customized according to the needs of the ICCAT BFT analysis. After many trials, finally a working script was finalized and used for the analysis.

Given the small sample size of sightings “on effort”, a two steps process was followed: (a) a detection function was fitted to all sightings, on and off effort; and (b) an estimate of abundance was obtained using the fitted detection function but applied only to data on effort.

The detection functions either using weight or number of animals as school size are identical, and the only thing changing is the final estimate provided. Therefore, we refer to it here as “the detection function”, even if each was performed twice using school size or weight.

2.1.1 Covariates for the detection function

Detection functions were fitted to the perpendicular distance data to estimate the effective strip half-width, *esw*. Multi-Covariate Distance Sampling (MCDS) methods were used to allow detection probability to be modelled as a function of covariates additional to perpendicular distance from the transect line. These covariates were defined in the survey design phase and included sea state, air haziness, water turbidity, glare and subjective (a factor indicating whether the sighting conditions were good, moderate or poor). **Table 2.1.1** shows the covariates tested in the models (see section 2.1.4 for some comments on group size).

Table 2.1.1. Covariates tested in the models and their ranges or factor levels

Covariate	Type	Levels
Sighting related		
School size	numeric	
Log school size	numeric	
School size class	factor	1-50 60-400 401-1000 >1000
Weight	numeric	
Log Weight	numeric	
Weight class	factor	8-1000 1001-10000 10001-100000 >100000
Observer Type	factor	SS – Scientific spotter PS – Professional spotter
Effort related		
Beaufort sea state	factor & numeric	0 (calm) 1 (very light) 2 (light breeze) 2.5 (isolated whitecaps) 3 (gentle breeze) 4 (moderate breeze)
Seastate2	factor	0-1 2-3 4
Air haziness	factor & numeric	0 (clear) 1 (slight) 2 (moderate) 3 (heavy)
Air haziness2	factor	0-1 2-3
Water turbidity	factor & numeric	0 (clear) 1 (moderately clear) 2 (moderately turbid) 3 (turbid)
Water turbidity2	factor	0-1 2-3
Block	factor	A - C – E - G
Glare intensity	factor & numeric	0 (null) 1 (slight) 2 (moderate) 3 (strong)
Glare2	factor	0-1 2-3
Clouds	numeric	0 to 8 from clear to totally Cloudy
Clouds2	factor	0-2 3-5 6-8

2.1.2. Left and right truncation

It is common practice to right truncate perpendicular distance data to eliminate sightings at large distances that have no influence on the fit of the detection function close to the transect line (the quantity of interest) but may adversely affect the fit. Equally, a left truncation is applied when it is not possible to search underneath the airplane (i.e. along the track line and close to it), for example due to the use of flat instead of bubble windows.

After visual inspection of the data and test of different left and right truncation distances, the following truncations were applied:

- 2010-2013: left truncation at 109m and right truncation at 5.6km for all sizes and 5.4km for adults only.
- 2015-2019: right truncation at 5.15km

2.1.3. Model diagnostics and selection

The best functional form (Half Normal or Hazard Rate model) of the detection function and the covariates retained by the best fitting models were selected based on model fitting diagnostics: AIC, goodness of fit tests, Q-Q plots, and inspection of plots of fitted functions.

Q-Q plots (quantile-quantile plots) compare the distribution of two variables; if they follow the same distribution, a plot of the quantiles of the first variable against the quantiles of the second should follow a straight line. To compare the fit of a detection function model to the data, we used a Q-Q plot of the fitted cumulative distribution function (cdf) against the empirical distribution function (edf).

For goodness of fit tests, we used the Cramer-von Mises statistics (that focus on the squared differences between cdf and edf).

2.1.4. Mean and expected school sizes

An issue aroused within this revision process that was not that obvious in previous years. In a line transect methodology, the density of groups is estimated, and then multiplied by the school size to get the density of animals. In software DISTANCE, under the MCDS engine (Multiple Covariate Distance Sampling), the school size may be taken in two ways: the mean school size and the expected school size. The expected school size is calculated with what is called the “size-bias regression”. This is based on the fact that, in general, there might be a bias for larger groups to be detected at larger distances while small groups remain undetected at such large distances, yielding an overestimated mean group size. Where the size-bias regression line (a regression line plotted in a graph of school sizes against distances) intercepts perpendicular distance 0, it is considered the “expected school size”, a bias-corrected average school size. Usually, this expected school size is taken into the Distance calculations when it is significant at an alpha level of 0.15, otherwise, the mean group size is used.

There was much discussion within Alnilam, and between Alnilam and ICCAT about the use of this approach for the re-analysis, allowing Distance software to choose between the mean school size or the expected one depending on the significance of the regression line. However, given the, sometimes, large difference in results depending in the use of mean or expected group size, the Distance Team at CREEM at the University of St Andrews (developers of the software) were consulted, both through mail and in person at a meeting in December 2019, in order to make sure we chose the right method to analyze the BFT data, with its peculiarities.

The conclusion after this long period of consultation was that it was better to switch to “Distance in R” and to add the group size or even the logarithm of group sizes as covariates in the model of the detection

function. If it was selected by the model, it would correct by itself the potential bias of detection according to group size. If it was not selected by the model as significant covariate, then the effect of group size was not important. Therefore, final abundance estimate now is always estimated by the MCDS engine with the mean school size (or weight), having the size bias been accounted for within the detection function itself.

3. Results of the Re-analysis of all sizes together: detection functions

3.1 Effect of each covariate

In all datasets, the Hazard-rate key function performed much better than the Half-normal one. Therefore, only plots for the Hazard-rate are presented in this report. Also, only the plots for the area configuration 2010-2018 are presented, as they are virtually identical for the three areas configurations. These plots are submitted in Annex 1 to avoid the excess volume in the main report.

The effects of the covariates on the detection functions are commented in the Discussion section.

3.2 Selected best detection functions

In Annex 2 we present the plots of the selected best detection functions for each dataset, together with their respective qq-plot. See Annex 1 if interested in seeing the individual effect of each covariate in the final detection functions. Table 3.2.1 shows the selected detection functions for each dataset together with some parameters.

In the Discussion section some comments are given about the covariates usually selected in most detection functions.

Table 3.2.1. Final models for the detection functions. GOF CvM p value = Goodness of fit test Cramer von Misses p value. Average p = average probability of detection averaged over all covariates. CV p = Coefficient of Variation of the Average p. Esw = effective strip width derived from the detection function. Num.obs = final number of observations in the detection function after truncation. Loss obs. Trunc = number of observations lost after truncation, from the total number of observations in the dataset. % Loss obs. Trunc = % of the observations that were lost due to truncation.

Areas configuration	Period	Size class/ variable	Covariates	GOF CvM p value	Average p	CV p	Esw (km)	Num. obs	Loss obs. Trunc.	% Loss obs. Trunc.
2010-2018	2010-2013	Size/All	airplane + turbidity + size.log	0.783677	0.243958	0.1137	1.366	185	15	5.03
		Size/Repr	airplane + turbidity + size.log	0.549962	0.217202	0.1260	1.173	146	11	4.87
		Weight/All	weightclass + bubble + airplane	0.786968	0.235072	0.1117	1.316	185	15	4.98
		Weight/Repr	glare2 + airplane + weight.log	0.587592	0.230373	0.1166	1.244	146	11	4.8
	2015-2019	Size/All	airplane + seastate + size.log	0.529133	0.194881	0.1021	1.004	215	7	2.01
		Size/Repr	airplane + turbidity + size.log	0.388551	0.161746	0.1163	0.833	159	1	0.39
		Weight/All	airplane + seastate + size.log	0.529133	0.194881	0.1021	1.004	215	7	2.01
		Weight/Repr	airplane + turbidity + size.log	0.388551	0.161746	0.1163	0.833	159	1	0.39

Table 3.2.1. Final models for the detection functions (continuation).

Areas configuration	Period	Size class/ variable	Covariates	GOF CvM p value	Average p	CV p	Esw (km)	Num. obs	Loss obs. Trunc.	% Loss obs. Trunc.
2019	2010-2013	Size/All	airplane + seastate + size.log	0.900444	0.247455	0.1146	1.341	184	15	5.03
		Size/Repr	glare2 + airplane + size.log	0.626037	0.221331	0.1225	1.195	145	11	4.87
		Weight/All	bubble + airplane + seastate	0.948784	0.241295	0.1149	1.351	184	15	4.98
		Weight/Repr	glare2 + airplane + weight.log	0.538015	0.231417	0.1174	1.25	145	11	4.8
	2015-2019	Size/All	airplane + seastate + size.log	0.548571	0.194552	0.1025	1.002	216	7	2.01
		Size/Repr	airplane + turbidity + size.log	0.463725	0.161845	0.1155	0.834	160	1	0.39
		Weight/All	airplane + seastate + size.log	0.548571	0.194552	0.1025	1.002	216	7	2.01
		Weight/Repr	airplane + turbidity + size.log	0.463725	0.161845	0.1155	0.834	160	1	0.39

Table 3.2.1. Final models for the detection functions (continuation).

Areas configuration	Period	Size class/ variable	Covariates	GOF CvM p value	Average p	CV p	Esw (km)	Num. obs	Loss obs. Trunc.	% Loss obs. Trunc.
2018-2019	2010-2013	Size/All	airplane + turbidity + size.log	0.778276	0.24897	0.1125	1.341	184	15	5.03
		Size/Repr	glare2 + airplane + size.log	0.636605	0.221281	0.1221	1.195	145	11	4.87
		Weight/All	airplane + turbidity + weight.log	0.63635	0.261069	0.1031	1.462	184	15	4.98
		Weight/Repr	glare2 + airplane + weight.log	0.550741	0.232474	0.1155	1.255	145	11	4.8
	2015-2019	Size/All	airplane + seastate + size.log	0.548571	0.194552	0.1025	1.002	211	7	2.01
		Size/Repr	airplane + turbidity + size.log	0.475357	0.161851	0.1148	0.834	155	1	0.39
		Weight/All	airplane + seastate + size.log	0.548571	0.194552	0.1025	1.002	211	7	2.01
		Weight/Repr	airplane + turbidity + size.log	0.475357	0.161851	0.1148	0.834	155	1	0.39

4. Results of the Re-analysis of all sizes together: abundance estimates

Summary tables were made for each dataset (overlap areas considered, all sizes/adult sizes). Results for number of animals and weight were compiled together in the tables for each dataset. Given the amount of years and areas, a table for each area, divided by years has been created, as well as a table with all areas together, divided by years too. They are presented in their corresponding subsections below.

Area G shows a discrepancy in 2010 between the data used for estimating the abundance of animals and for weight (given that some sightings that had weight information did not have enough information to recover an index on number of animals). Area G was not surveyed in 2011.

Even if only the shape of area A changed between the three “overlap area” criteria for the datasets and all the rest remaining identical as 2010-2018, as the detection functions were modelled for all areas together and the number of sightings and amount of effort varied slightly in area A (and therefore in the total dataset), the results are slightly different in all areas. Therefore, all are presented in each subsection.

4.1. Overlap area 2010-2018

Tables 4.1.1 to 4.1.5 show the results of the re-analysis for all sizes of BFT using the overlap areas between 2010 and 2018 (as in the previous reports until 2018), for each area by year and for all areas pooled together by year.

Table 4.1.1. Area A: Results of the re-analysis for all sizes of BFT, using the overlap areas between 2010-2018.

	Area A						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	61,837	61,837	61,837	61,837	61,837	61,837	61,837
Transect length (km)	6,093	7,818	6,667	4,293	4,949	6,093	5,574
Probability of detection	0.24396	0.24396	0.24396	0.19488	0.19488	0.19488	0.19488
Effective strip width x2 (km)	2.67917	2.67917	2.67917	2.00726	2.00726	2.00726	2.00726
Area searched (km2)	68,246	87,557	74,669	44,222	50,979	62,757	57,413
% coverage	110.4	141.6	120.8	71.5	82.4	101.5	92.8
Number of schools ON effort	8	10	14	8	22	28	20
Abundance of schools	10	13.31	21.84	35.69	323.57	248.39	224.3
%CV abundance of schools	55.00	39.14	52.00	51.98	36.96	30.83	32.48
Encounter rate of schools	0.00131	0.00128	0.00210	0.00186	0.00444	0.00460	0.00359
%CV encounter rate	54.27	33.82	46.85	35.49	25.66	19.73	23.96
Density of schools	0.00016	0.00022	0.00035	0.00058	0.00523	0.00402	0.00363
%CV density of schools	55.00	39.14	52.00	51.98	36.96	30.83	32.48
Expected weight (T)	1.877	0.629	0.505	79.361	29.060	43.745	29.709
%CV weight	11.33	37.19	33.46	49.29	50.53	38.20	41.45
Expected cluster size (animals)	1850.5	528.2	415.1	445.3	164.4	268.6	184.7
%CV abundance	10.55	40.03	30.06	48.36	49.82	38.41	40.55
Density of weight (km-2)	0.49	0.14	0.20	45.80	152.06	175.72	107.76
%CV density of weight	56.59	44.53	40.86	42.05	36.23	28.45	36.05
Density of animals (km-2)	0.299	0.114	0.147	0.257	0.860	1.079	0.670
%CV density of animals	55.74	41.54	41.11	41.32	35.08	28.74	35.72
Total weight (T)	2,119	963	1,946	2,832	9,403	10,866	6,664
%CV total weight	55.75	44.65	40.32	42.05	36.23	28.45	36.05
L 95% CI total weight	751	415	902	1,281	4,713	6,279	3,351
U 95% CI total weight	5,977	2,235	4,200	6,263	18,760	18,804	13,250
Total abundance (animals)	18,502	7,028	9,064	15,894	53,180	66,713	41,422
%CV total abundance	55.74	41.54	41.11	41.32	35.08	28.74	35.72
L 95% CI total abundance	6,549	3,195	4,136	7,280	27,210	38,349	20,957
U 95% CI total abundance	52,269	15,461	19,862	34,699	103,934	116,055	81,873

Table 4.1.2. Area C: Results of the re-analysis for all sizes of BFT, using the overlap areas between 2010-2018.

	Area C						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	51,821	51,821	51,821	51,821	51,821	51,821	51,821
Transect length (km)	8,354	8,684	2,750	2,718	4,791	4,890	4,780
Probability of detection	0.24396	0.24396	0.24396	0.19488	0.19488	0.19488	0.19488
Effective strip width x2 (km)	2.67917	2.67917	2.67917	2.00726	2.00726	2.00726	2.00726
Area searched (km2)	93,569	97,261	30,796	27,995	49,343	50,369	49,231
% coverage	180.6	187.7	59.4	54.0	95.2	97.2	95.0
Number of schools ON effort	6	9	10	2	14	8	4
Abundance of schools	7.65	9.19	24.54	11.86	51.61	39.58	15.59
%CV abundance of schools	47.28	34.97	34.62	73.87	27.28	40.17	54.33
Encounter rate of schools	0.00072	0.00104	0.00364	0.00074	0.00292	0.00164	0.00084
%CV encounter rate	44.42	33.16	33.20	73.06	24.61	36.00	51.68
Density of schools	0.00015	0.00018	0.00047	0.00023	0.00100	0.00076	0.00030
%CV density of schools	47.28	34.97	34.62	73.87	27.28	40.17	54.33
Expected weight (T)	0.733	0.257	1.328	157.358	177.112	97.119	153.998
%CV weight	38.44	40.80	16.77	18.14	25.50	47.14	39.62
Expected cluster size (animals)	462.3	243.6	1245.7	1280.2	1296.7	638.0	1238.6
%CV abundance	55.64	39.91	16.57	16.73	20.58	46.42	34.79
Density of weight (km-2)	0.09	0.05	0.86	36.02	176.40	74.18	46.33
%CV density of weight	61.46	50.91	37.88	74.84	32.62	49.45	60.86
Density of animals (km-2)	0.068	0.043	0.590	0.293	1.291	0.487	0.373
%CV density of animals	59.29	49.05	35.41	74.61	30.24	48.81	58.69
Total weight (T)	502	310	6,194	1,867	9,141	3,844	2,401
%CV total weight	64.27	63.70	39.83	74.84	32.62	49.45	60.86
L 95% CI total weight	154	97	2,862	483	4,858	1,503	780
U 95% CI total weight	1,633	991	13,405	7,208	17,201	9,832	7,393
Total abundance (animals)	3,535	2,239	30,571	15,188	66,927	25,255	19,309
%CV total abundance	59.29	49.05	35.41	74.61	30.24	48.81	58.69
L 95% CI total abundance	1,175	890	15,276	3,947	37,179	9,984	6,492
U 95% CI total abundance	10,632	5,637	61,179	58,443	120,478	63,883	57,431

Table 4.1.3. Area E: Results of the re-analysis for all sizes of BFT, using the overlap areas between 2010-2018.

	Area E						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	90,102	90,102	90,102	90,102	90,102	90,102	90,102
Transect length (km)	12,852	9,980	3,511	4,107	6,294	8,713	8,248
Probability of detection	0.24396	0.24396	0.24396	0.19488	0.19488	0.19488	0.19488
Effective strip width x2 (km)	2.67917	2.67917	2.67917	2.00726	2.00726	2.00726	2.00726
Area searched (km²)	143,941	111,776	39,320	42,305	64,828	89,741	84,955
% coverage	159.8	124.1	43.6	47.0	71.9	99.6	94.3
Number of schools ON effort	30	40	20	11	9	11	11
Abundance of schools	46.83	246.02	443.16	118.9	68.28	44.97	19.97
%CV abundance of schools	26.54	30.68	38.20	36.80	42.04	33.73	34.63
Encounter rate of schools	0.00233	0.00401	0.00570	0.00268	0.00143	0.00126	0.00133
%CV encounter rate	29.35	21.90	29.45	27.70	33.37	30.70	32.82
Density of schools	0.00052	0.00273	0.00492	0.00132	0.00076	0.00050	0.00022
%CV density of schools	26.54	30.68	38.20	36.80	42.04	33.73	34.63
Expected weight (T)	3.295	1.386	0.430	91.609	52.447	81.298	98.205
%CV weight	49.38	31.74	63.77	71.85	64.72	31.42	22.37
Expected cluster size (animals)	1378.0	753.3	198.8	470.0	468.9	887.7	933.8
%CV abundance	44.07	35.43	65.49	74.14	48.73	28.23	21.07
Density of weight (km⁻²)	1.87	3.71	1.79	120.89	39.75	40.57	21.77
%CV density of weight	70.95	36.32	61.03	63.72	60.15	39.89	38.21
Density of animals (km⁻²)	0.716	2.057	0.978	0.620	0.355	0.443	0.207
%CV density of animals	52.71	32.53	57.15	66.15	44.70	38.26	36.76
Total weight (T)	8,909	24,977	9,209	10,892	3,581	3,656	1,961
%CV total weight	64.31	36.57	73.61	63.72	60.15	39.89	38.21
L 95% CI total weight	2,777	12,367	2,499	3,415	1,200	1,706	947
U 95% CI total weight	28,579	50,443	33,937	34,736	10,686	7,832	4,063
Total abundance (animals)	64,525	185,316	88,079	55,886	32,015	39,916	18,652
%CV total abundance	52.71	32.53	57.15	66.15	44.70	38.26	36.76
L 95% CI total abundance	24,188	98,640	30,696	16,885	13,825	19,181	9,240
U 95% CI total abundance	172,129	348,157	252,738	184,975	74,137	83,064	37,651

Table 4.1.4. Area G: Results of the re-analysis for all sizes of BFT, using the overlap areas between 2010-2018.

	Area G						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	38,788		38,788	38,788	38,788	38,788	38,788
Transect length (km)	2,866		1,715	1,055	4,042	3,969	3,747
Probability of detection	0.24396		0.24396	0.19488	0.19488	0.19488	0.19488
Effective strip width x2 (km)	2.67917		2.67917	2.00726	2.00726	2.00726	2.00726
Area searched (km2)	32,096		19,212	10,863	41,631	40,877	38,598
% coverage	82.7		49.5	28.0	107.3	105.4	99.5
Number of schools ON effort	25		13	2	29	25	11
Abundance of schools	114.43		78.88	15.46	65.92	105.25	52.52
%CV abundance of schools	32.27		43.50	71.85	22.79	27.42	35.02
Encounter rate of schools	0.00872		0.00758	0.00190	0.00717	0.00630	0.00294
%CV encounter rate	29.66		37.80	70.48	19.86	21.97	29.31
Density of schools	0.00295		0.00203	0.00040	0.00170	0.00271	0.00135
%CV density of schools	32.27		43.50	71.85	22.79	27.42	35.02
Expected weight (T)	2.492		0.175	7.771	9.756	3.079	0.861
%CV weight	21.35		58.54	53.09	29.10	49.05	38.69
Expected cluster size (animals)	2072.7		228.9	518.1	449.3	91.3	45.3
%CV abundance	20.08		48.90	53.09	26.96	38.03	43.05
Density of weight (km-2)	7.38		0.65	3.10	16.58	8.36	1.17
%CV density of weight	39.44		56.57	82.53	32.50	46.45	39.75
Density of animals (km-2)	6.115		0.466	0.207	0.764	0.248	0.061
%CV density of animals	34.95		60.86	82.53	31.00	35.34	42.90
Total weight (T)	8,150		299	120	643	324	45
%CV total weight	39.36		60.65	82.53	32.50	46.45	39.75
L 95% CI total weight	3,822		96	28	344	135	21
U 95% CI total weight	17,377		929	519	1,203	777	96
Total abundance (animals)	237,188		18,059	8,011	29,617	9,612	2,377
%CV total abundance	34.95		60.86	82.53	31.00	35.34	42.90
L 95% CI total abundance	120,439		5,810	1,854	16,284	4,879	1,055
U 95% CI total abundance	467,108		56,134	34,607	53,865	18,938	5,355

Table 4.1.5. All areas together: Results of the re-analysis for all sizes of BFT, using the overlap areas between 2010-2018.

Area	Total: All areas together						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	242,548	203,760	242,548	242,548	242,548	242,548	242,548
Transect length (km)	30,165	26,482	14,643	12,173	20,076	23,664	22,349
Probability of detection	0.24396	0.24396	0.24396	0.19488	0.19488	0.19488	0.19488
Effective strip width x2 (km)	2.67917	2.67917	2.67917	2.00726	2.00726	2.00726	2.00726
Area searched (km2)	337,852	296,594	163,998	125,385	206,780	243,744	230,196
% coverage	139.3	145.6	67.6	51.7	85.3	100.5	94.9
Number of schools ON effort	69	59	57	23	74	72	46
Abundance of schools	178.9	268.52	568.43	181.92	509.38	438.19	312.38
%CV abundance of schools	22.46	28.28	30.65	27.54	24.94	20.04	24.60
Encounter rate of schools	0.00229	0.00223	0.00389	0.00189	0.00369	0.00304	0.00206
%CV encounter rate	18.67	17.70	18.82	20.46	12.47	13.01	15.87
Density of schools	0.00074	0.00132	0.00234	0.00075	0.00210	0.00181	0.00129
%CV density of schools	22.46	28.28	30.65	27.54	24.94	20.04	24.60
Expected weight (T)	2.597	0.400	0.422	86.368	44.697	42.653	35.442
%CV weight	22.60	0.00	44.63	50.79	31.85	26.29	31.05
Expected cluster size (animals)	1809.6	724.7	256.5	522.1	356.8	322.9	261.7
%CV abundance	17.25	33.35	44.58	46.79	28.96	25.22	29.60
Density of weight (km-2)	2.02	0.60	1.00	64.78	93.87	77.06	45.65
%CV density of weight	34.76	85.89	41.85	45.77	23.07	22.02	26.67
Density of animals (km-2)	1.335	0.955	0.601	0.392	0.749	0.583	0.337
%CV density of animals	28.29	31.05	36.43	42.02	18.90	20.73	24.77
Total weight (T)	19,679	26,250	17,648	15,712	22,768	18,690	11,071
%CV total weight	34.89	34.95	41.87	45.77	23.07	22.02	26.67
L 95% CI total weight	10,086	13,388	7,975	6,616	14,557	12,188	6,614
U 95% CI total weight	38,396	51,470	39,053	37,312	35,610	28,660	18,533
Total abundance (animals)	323,749	194,584	145,773	94,978	181,738	141,496	81,760
%CV total abundance	28.29	31.05	36.43	42.02	18.90	20.73	24.77
L 95% CI total abundance	186,649	106,440	72,504	42,740	125,791	94,568	50,602
U 95% CI total abundance	561,556	355,722	293,086	211,061	262,569	211,709	132,104

4.2. Area 2019

Tables 4.2.1 to 4.2.5 show the results of the re-analysis for all sizes of BFT using the new redesigned area A in 2019, for each area by year and for all areas pooled together by year.

Table 4.2.1. Area A: Results of the re-analysis for all sizes of BFT, using the new redesigned area A in 2019.

Area	Area A						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	62,745	62,745	62,745	62,745	62,745	62,745	62,745
Transect length (km)	5,097	6,779	5,942	3,762	4,233	5,263	6,538
Probability of detection	0.24746	0.24746	0.24746	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.71761	2.71761	2.71761	2.00387	2.00387	2.00387	2.00387
Area searched (km²)	57,087	75,922	66,554	38,745	43,603	54,212	67,339
% coverage	91.0	121.0	106.1	61.7	69.5	86.4	107.3
Number of schools ON effort	8	10	13	8	20	26	25
Abundance of schools	12.73	16.31	22.71	41.16	334.07	284.73	220.15
%CV abundance of schools	55.29	40.29	48.86	51.59	40.83	31.62	29.85
Encounter rate of schools	0.00157	0.00148	0.00219	0.00213	0.00472	0.00494	0.00382
%CV encounter rate	54.00	34.02	43.72	35.55	27.78	20.51	21.10
Density of schools	0.00020	0.00026	0.00036	0.00066	0.00532	0.00454	0.00351
%CV density of schools	55.29	40.29	48.86	51.59	40.83	31.62	29.85
Expected weight (T)	1.831	0.651	0.565	80.226	33.871	41.833	42.136
%CV weight	10.97	32.78	29.26	48.69	53.15	39.92	37.59
Expected cluster size (animals)	1832.5	510.6	426.6	450.0	191.6	256.5	254.8
%CV abundance	10.76	41.62	33.66	47.76	52.50	40.16	36.81
Density of weight (km⁻²)	0.57	0.15	0.20	52.63	180.34	189.84	147.84
%CV density of weight	56.28	43.14	39.80	42.15	36.33	29.92	31.09
Density of animals (km⁻²)	0.372	0.133	0.154	0.295	1.020	1.164	0.894
%CV density of animals	55.46	41.79	38.85	41.42	35.23	30.24	30.68
Total weight (T)	2,586	1,063	1,901	3,302	11,315	11,911	9,276
%CV total weight	56.47	43.09	41.72	42.15	36.33	29.92	31.09
L 95% CI total weight	902	470	857	1,490	5,659	6,697	5,106
U 95% CI total weight	7,412	2,405	4,214	7,317	22,627	21,187	16,852
Total abundance (animals)	23,320	8,330	9,691	18,523	64,005	73,023	56,098
%CV total abundance	55.46	41.79	38.85	41.42	35.23	30.24	30.68
L 95% CI total abundance	8,263	3,767	4,597	8,466	32,650	40,814	31,112
U 95% CI total abundance	65,813	18,421	20,431	40,525	125,471	130,648	101,149

Table 4.2.2. Area C: Results of the re-analysis for all sizes of BFT, using the new redesigned area A in 2019.

	Area C						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	51,821	51,821	51,821	51,821	51,821	51,821	51,821
Transect length (km)	8,354	8,684	2,750	2,718	4,791	4,890	4,780
Probability of detection	0.24746	0.24746	0.24746	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.71761	2.71761	2.71761	2.00387	2.00387	2.00387	2.00387
Area searched (km2)	93,569	97,261	30,796	27,995	49,343	50,369	49,231
% coverage	180.6	187.7	59.4	54.0	95.2	97.2	95.0
Number of schools ON effort	6	9	10	2	14	8	4
Abundance of schools	7.76	9.01	27.08	11.86	51.47	39.57	15.36
%CV abundance of schools	48.19	35.38	35.15	73.88	27.29	40.18	54.34
Encounter rate of schools	0.00072	0.00104	0.00364	0.00074	0.00292	0.00164	0.00084
%CV encounter rate	44.42	33.16	33.20	73.06	24.61	36.00	51.68
Density of schools	0.00015	0.00017	0.00052	0.00023	0.00099	0.00076	0.00030
%CV density of schools	48.19	35.38	35.15	73.88	27.29	40.18	54.34
Expected weight (T)	0.768	0.274	1.265	157.362	176.979	97.175	154.066
%CV weight	34.98	33.98	17.03	18.14	25.57	47.14	39.60
Expected cluster size (animals)	436.1	231.7	1238.6	1280.2	1294.6	638.4	1239.1
%CV abundance	58.59	37.79	16.62	16.73	20.68	46.42	34.78
Density of weight (km-2)	0.08	0.04	0.96	36.03	175.78	74.20	45.67
%CV density of weight	61.44	48.34	37.39	74.85	32.64	49.47	60.88
Density of animals (km-2)	0.065	0.040	0.647	0.293	1.286	0.487	0.367
%CV density of animals	58.87	46.83	35.81	74.62	30.25	48.83	58.71
Total weight (T)	462	250	6,663	1,867	9,109	3,845	2,367
%CV total weight	63.41	60.44	38.41	74.85	32.64	49.47	60.88
L 95% CI total weight	144	82	3,159	483	4,839	1,503	768
U 95% CI total weight	1,483	757	14,055	7,210	17,147	9,837	7,291
Total abundance (animals)	3,382	2,088	33,536	15,189	66,632	25,260	19,035
%CV total abundance	58.87	46.83	35.81	74.62	30.25	48.83	58.71
L 95% CI total abundance	1,132	862	16,649	3,947	37,015	9,983	6,398
U 95% CI total abundance	10,104	5,062	67,549	58,457	119,948	63,918	56,637

Table 4.2.3. Area E: Results of the re-analysis for all sizes of BFT, using the new redesigned area A in 2019.

	Area E						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	90,102	90,102	90,102	90,102	90,102	90,102	90,102
Transect length (km)	12,852	9,980	3,511	4,107	6,294	8,713	8,248
Probability of detection	0.24746	0.24746	0.24746	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.71761	2.71761	2.71761	2.00387	2.00387	2.00387	2.00387
Area searched (km2)	143,941	111,776	39,320	42,305	64,828	89,741	84,955
% coverage	159.8	124.1	43.6	47.0	71.9	99.6	94.3
Number of schools ON effort	30	40	20	11	9	11	11
Abundance of schools	54.3	252.76	337.82	118.88	69.28	44.67	20.12
%CV abundance of schools	28.65	33.31	38.43	36.79	42.04	33.76	34.65
Encounter rate of schools	0.00233	0.00401	0.00570	0.00268	0.00143	0.00126	0.00133
%CV encounter rate	29.35	21.90	29.45	27.70	33.37	30.70	32.82
Density of schools	0.00060	0.00281	0.00375	0.00132	0.00077	0.00050	0.00022
%CV density of schools	28.65	33.31	38.43	36.79	42.04	33.76	34.65
Expected weight (T)	2.700	1.766	0.503	91.627	51.874	81.197	97.913
%CV weight	47.13	25.88	58.31	71.81	64.72	31.35	22.46
Expected cluster size (animals)	1730.5	791.6	204.6	470.2	466.3	886.1	931.3
%CV abundance	47.75	36.20	65.98	74.10	48.62	28.16	21.03
Density of weight (km-2)	1.97	4.71	1.39	120.89	39.89	40.25	21.87
%CV density of weight	69.60	37.79	60.56	63.67	60.05	39.85	38.19
Density of animals (km-2)	1.043	2.221	0.767	0.620	0.359	0.439	0.208
%CV density of animals	62.82	34.17	57.92	66.09	44.55	38.21	36.69
Total weight (T)	9,348	30,293	6,649	10,892	3,594	3,627	1,970
%CV total weight	63.05	36.84	69.80	63.67	60.05	39.85	38.19
L 95% CI total weight	2,970	14,927	1,908	3,418	1,206	1,694	951
U 95% CI total weight	29,426	61,474	23,168	34,708	10,708	7,765	4,081
Total abundance (animals)	93,966	200,085	69,127	55,898	32,303	39,578	18,741
%CV total abundance	62.82	34.17	57.92	66.09	44.55	38.21	36.69
L 95% CI total abundance	29,956	103,382	23,805	16,902	13,988	19,037	9,296
U 95% CI total abundance	294,750	387,241	200,734	184,862	74,601	82,285	37,783

Table 4.2.4. Area G: Results of the re-analysis for all sizes of BFT, using the new redesigned area A in 2019.

	Area G						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	38,788		38,788	38,788	38,788	38,788	38,788
Transect length (km)	2,866		1,715	1,055	4,042	3,969	3,747
Probability of detection	0.24746		0.24746	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.71761		2.71761	2.00387	2.00387	2.00387	2.00387
Area searched (km2)	32,096		19,212	10,863	41,631	40,877	38,598
% coverage	82.7		49.5	28.0	107.3	105.4	99.5
Number of schools ON effort	25		13	2	29	25	11
Abundance of schools	104.94		125.98	15.37	66.02	105.39	52.71
%CV abundance of schools	31.58		40.70	71.84	22.76	27.45	34.94
Encounter rate of schools	0.00872		0.00758	0.00190	0.00717	0.00630	0.00294
%CV encounter rate	29.66		37.80	70.48	19.86	21.97	29.31
Density of schools	0.00271		0.00325	0.00040	0.00170	0.00272	0.00136
%CV density of schools	31.58		40.70	71.84	22.76	27.45	34.94
Expected weight (T)	2.371		0.270	7.776	9.751	3.089	0.865
%CV weight	19.35		47.40	53.07	29.11	49.10	38.55
Expected cluster size (animals)	2119.1		222.5	518.4	448.0	91.5	45.5
%CV abundance	19.91		51.50	53.07	26.90	38.02	42.88
Density of weight (km-2)	8.62		0.77	3.08	16.60	8.39	1.18
%CV density of weight	38.63		60.40	82.55	32.52	46.52	39.75
Density of animals (km-2)	5.733		0.723	0.205	0.763	0.249	0.062
%CV density of animals	35.53		61.59	82.55	30.94	35.33	42.87
Total weight (T)	9,703		353	119	644	325	46
%CV total weight	38.89		64.36	82.55	32.52	46.52	39.75
L 95% CI total weight	4,587		107	28	344	136	21
U 95% CI total weight	20,525		1,164	516	1,204	781	97
Total abundance (animals)	222,371		28,032	7,966	29,578	9,641	2,397
%CV total abundance	35.53		61.59	82.55	30.94	35.33	42.87
L 95% CI total abundance	111,697		8,873	1,843	16,279	4,895	1,065
U 95% CI total abundance	442,704		88,563	34,425	53,741	18,990	5,398

Table 4.2.5. All areas together: Results of the re-analysis for all sizes of BFT, using the new redesigned area A in 2019.

	Total: All areas together						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	243,456	204,668	243,456	243,456	243,456	243,456	243,456
Transect length (km)	29,169	25,443	13,918	11,642	19,360	22,835	23,313
Probability of detection	0.24746	0.24746	0.24746	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.71761	2.71761	2.71761	2.00387	2.00387	2.00387	2.00387
Area searched (km2)	326,693	284,959	155,883	119,907	199,404	235,199	240,123
% coverage	134.2	139.2	64.0	49.3	81.9	96.6	98.6
Number of schools ON effort	69	59	56	23	72	70	51
Abundance of schools	179.72	278.09	513.59	187.27	520.84	474.35	308.35
%CV abundance of schools	21.39	30.52	28.32	27.33	27.49	21.13	22.72
Encounter rate of schools	0.00237	0.00232	0.00402	0.00198	0.00372	0.00307	0.00219
%CV encounter rate	18.65	17.68	18.25	20.48	12.74	13.24	15.01
Density of schools	0.00074	0.00136	0.00211	0.00077	0.00214	0.00195	0.00127
%CV density of schools	21.39	30.52	28.32	27.33	27.49	21.13	22.72
Expected weight (T)	2.379	0.417	0.516	86.405	47.350	41.548	44.297
%CV weight	19.74	0.00	35.25	49.58	33.98	27.77	29.09
Expected cluster size (animals)	1908.8	757.0	273.3	521.1	369.6	311.0	312.2
%CV abundance	18.53	33.96	38.90	45.80	31.25	26.58	27.70
Density of weight (km-2)	2.26	0.78	0.89	66.46	101.30	80.95	56.10
%CV density of weight	33.41	105.09	37.41	44.63	23.37	22.80	24.73
Density of animals (km-2)	1.409	1.029	0.577	0.401	0.791	0.606	0.395
%CV density of animals	29.82	32.55	32.89	41.08	19.13	21.27	23.07
Total weight (T)	22,099	31,605	15,567	16,181	24,662	19,708	13,659
%CV total weight	33.21	35.32	34.68	44.63	23.37	22.80	24.73
L 95% CI total weight	11,678	16,010	8,003	6,950	15,678	12,664	8,464
U 95% CI total weight	41,819	62,394	30,280	37,672	38,794	30,671	22,041
Total abundance (animals)	343,038	210,503	140,386	97,576	192,519	147,502	96,271
%CV total abundance	29.82	32.55	32.89	41.08	19.13	21.27	23.07
L 95% CI total abundance	192,717	112,062	74,567	44,649	132,679	97,585	61,540
U 95% CI total abundance	610,612	395,421	264,303	213,242	279,347	222,951	150,604

4.3. Overlap area 2010-2019

Tables 4.3.1 to 4.3.5 show the results of the re-analysis for all sizes of BFT using an overlap between the previous 2010-2018 areas and the new redesigned area A in 2019, for each area by year and for all areas pooled together by year.

Table 4.3.1. Area A: Results of the re-analysis for all sizes of BFT, using the overlap areas between 2010 and 2019.

Area	Area A						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	53,388	53,388	53,388	53,388	53,388	53,388	53,388
Transect length (km)	5,094	6,778	5,910	3,754	4,230	5,258	5,549
Probability of detection	0.24897	0.24897	0.24897	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.73419	2.73419	2.73419	2.00387	2.00387	2.00387	2.00387
Area searched (km²)	57,053	75,913	66,194	38,670	43,566	54,152	57,159
% coverage	106.9	142.2	124.0	72.4	81.6	101.4	107.1
Number of schools ON effort	8	10	13	8	20	26	20
Abundance of schools	10.52	13.4	20.3	35.09	284.49	242.54	195.77
%CV abundance of schools	54.79	39.32	49.47	51.59	40.83	31.62	32.37
Encounter rate of schools	0.00157	0.00148	0.00220	0.00213	0.00473	0.00495	0.00360
%CV encounter rate	54.00	34.02	43.76	35.55	27.78	20.51	23.96
Density of schools	0.00020	0.00025	0.00038	0.00066	0.00533	0.00454	0.00367
%CV density of schools	54.79	39.32	49.47	51.59	40.83	31.62	32.37
Expected weight (T)	1.864	0.552	0.441	80.226	33.871	41.833	30.002
%CV weight	10.55	38.40	31.34	48.69	53.15	39.92	41.62
Expected cluster size (animals)	1850.6	531.4	408.4	450.0	191.6	256.5	186.3
%CV abundance	10.56	39.83	33.75	47.76	52.50	40.16	40.71
Density of weight (km⁻²)	0.37	0.13	0.15	52.73	180.49	190.05	110.01
%CV density of weight	56.02	41.94	40.57	42.15	36.33	29.92	36.17
Density of animals (km⁻²)	0.364	0.133	0.155	0.296	1.021	1.165	0.683
%CV density of animals	55.54	41.66	38.94	41.42	35.23	30.24	35.82
Total weight (T)	1,401	757	1,137	2,815	9,636	10,146	5,873
%CV total weight	54.70	43.16	40.69	42.15	36.33	29.92	36.17
L 95% CI total weight	503	334	522	1,270	4,819	5,704	2,947
U 95% CI total weight	3,903	1,715	2,478	6,238	19,269	18,047	11,704
Total abundance (animals)	19,459	7,121	8,288	15,791	54,507	62,202	36,480
%CV total abundance	55.54	41.66	38.94	41.42	35.23	30.24	35.82
L 95% CI total abundance	6,886	3,227	3,925	7,218	27,805	34,766	18,423
U 95% CI total abundance	54,990	15,712	17,500	34,548	106,851	111,290	72,234

Table 4.3.2. Area C: Results of the re-analysis for all sizes of BFT using the overlap areas between 2010 and 2019.

	Area C						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	51,821	51,821	51,821	51,821	51,821	51,821	51,821
Transect length (km)	8,354	8,684	2,750	2,718	4,791	4,890	4,780
Probability of detection	0.24897	0.24897	0.24897	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.73419	2.73419	2.73419	2.00387	2.00387	2.00387	2.00387
Area searched (km2)	93,569	97,261	30,796	27,995	49,343	50,369	49,231
% coverage	180.6	187.7	59.4	54.0	95.2	97.2	95.0
Number of schools ON effort	6	9	10	2	14	8	4
Abundance of schools	7.68	9.3	24.97	11.86	51.47	39.57	15.36
%CV abundance of schools	47.21	35.04	34.69	73.88	27.29	40.18	54.34
Encounter rate of schools	0.00072	0.00104	0.00364	0.00074	0.00292	0.00164	0.00084
%CV encounter rate	44.42	33.16	33.20	73.06	24.61	36.00	51.68
Density of schools	0.00015	0.00018	0.00048	0.00023	0.00099	0.00076	0.00030
%CV density of schools	47.21	35.04	34.69	73.88	27.29	40.18	54.34
Expected weight (T)	0.569	0.231	1.252	157.362	176.979	97.175	154.066
%CV weight	46.86	40.34	16.68	18.14	25.57	47.14	39.60
Expected cluster size (animals)	468.2	244.5	1246.2	1280.2	1294.6	638.4	1239.1
%CV abundance	55.19	39.90	16.57	16.73	20.68	46.42	34.78
Density of weight (km-2)	0.07	0.04	0.58	36.03	175.78	74.20	45.67
%CV density of weight	60.12	48.46	35.90	74.85	32.64	49.47	60.88
Density of animals (km-2)	0.069	0.044	0.601	0.293	1.286	0.487	0.367
%CV density of animals	59.34	49.16	35.49	74.62	30.25	48.83	58.71
Total weight (T)	366	253	4,036	1,867	9,109	3,845	2,367
%CV total weight	59.77	60.66	37.42	74.85	32.64	49.47	60.88
L 95% CI total weight	121	83	1,945	483	4,839	1,503	768
U 95% CI total weight	1,108	769	8,377	7,210	17,147	9,837	7,291
Total abundance (animals)	3,597	2,275	31,120	15,189	66,632	25,260	19,035
%CV total abundance	59.34	49.16	35.49	74.62	30.25	48.83	58.71
L 95% CI total abundance	1,195	902	15,531	3,947	37,015	9,983	6,398
U 95% CI total abundance	10,828	5,736	62,359	58,457	119,948	63,918	56,637

Table 4.3.3. Area E: Results of the re-analysis for all sizes of BFT using the overlap areas between 2010 and 2019.

	Area E						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	90,102	90,102	90,102	90,102	90,102	90,102	90,102
Transect length (km)	12,852	9,980	3,511	4,107	6,294	8,713	8,248
Probability of detection	0.24897	0.24897	0.24897	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.73419	2.73419	2.73419	2.00387	2.00387	2.00387	2.00387
Area searched (km2)	143,941	111,776	39,320	42,305	64,828	89,741	84,955
% coverage	159.8	124.1	43.6	47.0	71.9	99.6	94.3
Number of schools ON effort	30	40	20	11	9	11	11
Abundance of schools	48.89	236.47	424.4	118.88	69.28	44.67	20.12
%CV abundance of schools	26.77	30.68	38.24	36.79	42.04	33.76	34.65
Encounter rate of schools	0.00233	0.00401	0.00570	0.00268	0.00143	0.00126	0.00133
%CV encounter rate	29.35	21.90	29.45	27.70	33.37	30.70	32.82
Density of schools	0.00054	0.00262	0.00471	0.00132	0.00077	0.00050	0.00022
%CV density of schools	26.77	30.68	38.24	36.79	42.04	33.76	34.65
Expected weight (T)	1.695	1.043	0.312	91.627	51.874	81.197	97.913
%CV weight	46.28	32.77	62.34	71.81	64.72	31.35	22.46
Expected cluster size (animals)	1500.2	773.7	204.6	470.2	466.3	886.1	931.3
%CV abundance	45.33	35.30	65.44	74.10	48.62	28.16	21.03
Density of weight (km-2)	0.91	2.50	1.19	120.89	39.89	40.25	21.87
%CV density of weight	57.58	33.86	57.99	63.67	60.05	39.85	38.19
Density of animals (km-2)	0.814	2.030	0.964	0.620	0.359	0.439	0.208
%CV density of animals	56.17	32.67	57.27	66.09	44.55	38.21	36.69
Total weight (T)	4,510	15,894	5,677	10,892	3,594	3,627	1,970
%CV total weight	54.23	33.54	67.81	63.67	60.05	39.85	38.19
L 95% CI total weight	1,650	8,307	1,676	3,418	1,206	1,694	951
U 95% CI total weight	12,332	30,409	19,221	34,708	10,708	7,765	4,081
Total abundance (animals)	73,346	182,948	86,841	55,898	32,303	39,578	18,741
%CV total abundance	56.17	32.67	57.27	66.09	44.55	38.21	36.69
L 95% CI total abundance	25,983	97,135	30,208	16,902	13,988	19,037	9,296
U 95% CI total abundance	207,042	344,572	249,648	184,862	74,601	82,285	37,783

Table 4.3.4. Area G: Results of the re-analysis for all sizes of BFT using the overlap areas between 2010 and 2019.

	Area G						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	38,788		38,788	38,788	38,788	38,788	38,788
Transect length (km)	2,866		1,715	1,055	4,042	3,969	3,747
Probability of detection	0.24897		0.24897	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.73419		2.73419	2.00387	2.00387	2.00387	2.00387
Area searched (km²)	32,096		19,212	10,863	41,631	40,877	38,598
% coverage	82.7		49.5	28.0	107.3	105.4	99.5
Number of schools ON effort	25		13	2	29	25	11
Abundance of schools	112.55		102.02	15.37	66.02	105.39	52.71
%CV abundance of schools	32.36		42.50	71.84	22.76	27.45	34.94
Encounter rate of schools	0.00872		0.00758	0.00190	0.00717	0.00630	0.00294
%CV encounter rate	29.66		37.80	70.48	19.86	21.97	29.31
Density of schools	0.00290		0.00263	0.00040	0.00170	0.00272	0.00136
%CV density of schools	32.36		42.50	71.84	22.76	27.45	34.94
Expected weight (T)	2.156		0.254	7.776	9.751	3.089	0.865
%CV weight	20.01		47.27	53.07	29.11	49.10	38.55
Expected cluster size (animals)	2077.3		227.1	518.4	448.0	91.5	45.5
%CV abundance	20.08		48.99	53.07	26.90	38.02	42.88
Density of weight (km⁻²)	7.77		0.66	3.08	16.60	8.39	1.18
%CV density of weight	35.56		61.59	82.55	32.52	46.52	39.75
Density of animals (km⁻²)	6.028		0.597	0.205	0.763	0.249	0.062
%CV density of animals	35.09		60.09	82.55	30.94	35.33	42.87
Total weight (T)	8,913		285	119	644	325	46
%CV total weight	36.70		70.85	82.55	32.52	46.52	39.75
L 95% CI total weight	4,384		78	28	344	136	21
U 95% CI total weight	18,121		1,035	516	1,204	781	97
Total abundance (animals)	233,798		23,166	7,966	29,578	9,641	2,397
%CV total abundance	35.09		60.09	82.55	30.94	35.33	42.87
L 95% CI total abundance	118,431		7,534	1,843	16,279	4,895	1,065
U 95% CI total abundance	461,544		71,232	34,425	53,741	18,990	5,398

Table 4.3.5. All areas together: Results of the re-analysis for all sizes of BFT using the overlap areas between 2010 and 2019.

	Total: All areas together						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	234,099	195,311	234,099	234,099	234,099	234,099	234,099
Transect length (km)	29,166	25,442	13,886	11,634	19,356	22,829	22,325
Probability of detection	0.24897	0.24897	0.24897	0.19455	0.19455	0.19455	0.19455
Effective strip width x2 (km)	2.73419	2.73419	2.73419	2.00387	2.00387	2.00387	2.00387
Area searched (km²)	326,658	284,950	155,523	119,833	199,367	235,139	229,942
% coverage	139.5	145.9	66.4	51.2	85.2	100.4	98.2
Number of schools ON effort	69	59	56	23	72	70	46
Abundance of schools	179.64	259.17	571.68	181.2	471.27	432.16	283.97
%CV abundance of schools	22.29	28.19	29.78	27.54	26.25	20.35	23.88
Encounter rate of schools	0.00237	0.00232	0.00403	0.00198	0.00372	0.00307	0.00206
%CV encounter rate	18.65	17.68	18.26	20.48	12.74	13.24	15.87
Density of schools	0.00077	0.00133	0.00244	0.00077	0.00201	0.00185	0.00121
%CV density of schools	22.29	28.19	29.78	27.54	26.25	20.35	23.88
Expected weight (T)	1.983	0.307	0.352	86.612	48.768	41.520	36.118
%CV weight	17.51	0.00	41.75	50.80	32.71	27.03	30.57
Expected cluster size (animals)	1838.2	742.1	261.4	523.4	388.4	316.3	269.9
%CV abundance	17.47	33.18	43.10	46.82	29.88	25.84	29.14
Density of weight (km⁻²)	1.74	0.39	0.73	67.04	98.18	76.65	43.81
%CV density of weight	29.35	63.71	38.27	45.78	23.13	22.63	26.48
Density of animals (km⁻²)	1.411	0.985	0.638	0.405	0.782	0.584	0.327
%CV density of animals	28.50	31.16	35.65	42.05	18.94	21.18	24.66
Total weight (T)	15,190	16,903	11,135	15,694	22,983	17,943	10,256
%CV total weight	28.07	31.69	37.79	45.78	23.13	22.63	26.48
L 95% CI total weight	8,819	9,142	5,408	6,607	14,675	11,566	6,147
U 95% CI total weight	26,166	31,253	22,927	37,278	35,993	27,838	17,111
Total abundance (animals)	330,200	192,344	149,415	94,844	183,021	136,681	76,654
%CV total abundance	28.50	31.16	35.65	42.05	18.94	21.18	24.66
L 95% CI total abundance	189,821	105,027	75,389	42,659	126,573	90,563	47,536
U 95% CI total abundance	574,394	352,252	296,126	210,866	264,642	206,286	123,607

5. Results of the Re-analysis of adults (reproductive) only: abundance estimates

5.1. Overlap area 2010-2018

Tables 5.1.1 to 5.1.5 show the results of the re-analysis for adult individuals of BFT using the overlap areas between 2010 and 2018 (as in the previous reports until 2018), for each area by year and for all areas pooled together by year.

Table 5.1.1. Area A: Results of the re-analysis for adult individuals of BFT, using the overlap areas between 2010-2018.

	Area A						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	61,837	61,837	61,837	61,837	61,837	61,837	61,837
Transect length (km)	6,093	7,818	6,667	4,293	4,949	6,093	5,574
Probability of detection	0.21404	0.21404	0.21404	0.16175	0.16175	0.16175	0.16175
Effective strip width x2 (km)	2.26497	2.26497	2.26497	1.66603	1.66603	1.66603	1.66603
Area searched (km2)	65,808	84,430	72,003	44,222	50,979	62,757	57,413
% coverage	106.4	136.5	116.4	71.5	82.4	101.5	92.8
Number of schools ON effort	8	7	9	8	22	28	20
Abundance of schools	12.68	11.51	18.3	32.51	325.48	255.91	235.22
%CV abundance of schools	55.22	41.78	37.20	47.00	36.44	30.28	31.62
Encounter rate of schools	0.00131	0.00090	0.00135	0.00186	0.00444	0.00460	0.00359
%CV encounter rate	54.27	37.74	34.37	35.49	25.66	19.73	23.96
Density of schools	0.00021	0.00019	0.00030	0.00053	0.00526	0.00414	0.00380
%CV density of schools	55.22	41.78	37.20	47.00	36.44	30.28	31.62
Expected weight (T)	1.863	0.781	0.588	90.978	38.373	51.207	37.279
%CV weight	10.39	32.58	33.21	41.07	49.68	37.28	42.28
Expected cluster size (animals)	1846.0	767.8	600.3	509.1	217.8	313.0	230.8
%CV abundance	10.51	32.25	29.57	40.05	48.89	37.51	41.39
Density of weight (km-2)	0.42	0.14	0.16	47.84	201.97	211.91	141.80
%CV density of weight	56.89	44.58	39.74	42.50	36.44	28.97	37.22
Density of animals (km-2)	0.379	0.143	0.178	0.268	1.146	1.295	0.878
%CV density of animals	55.87	43.73	39.61	41.74	35.28	29.26	36.79
Total weight (T)	1,830	1,026	1,843	2,958	12,489	13,104	8,769
%CV total weight	55.53	43.81	38.41	42.50	36.44	28.97	37.22
L 95% CI total weight	651	448	883	1,327	6,236	7,501	4,319
U 95% CI total weight	5,146	2,347	3,845	6,592	25,015	22,894	17,804
Total abundance (animals)	23,409	8,836	10,985	16,554	70,876	80,087	54,284
%CV total abundance	55.87	43.73	39.61	41.74	35.28	29.26	36.79
L 95% CI total abundance	8,272	3,867	5,152	7,527	36,133	45,598	26,941
U 95% CI total abundance	66,248	20,190	23,421	36,405	139,025	140,664	109,381

Table 5.1.2. Area C: Results of the re-analysis for adult individuals of BFT, using the overlap areas between 2010-2018.

Area	Area C						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	51,821	51,821	51,821	51,821	51,821	51,821	51,821
Transect length (km)	8,354	8,684	2,750	2,718	4,791	4,890	4,780
Probability of detection	0.21404	0.21404	0.21404	0.16175	0.16175	0.16175	0.16175
Effective strip width x2 (km)	2.26497	2.26497	2.26497	1.66603	1.66603	1.66603	1.66603
Area searched (km2)	90,227	93,788	29,696	27,995	49,343	50,369	49,231
% coverage	174.1	181.0	57.3	54.0	95.2	97.2	95.0
Number of schools ON effort	6	3	10	2	11	8	4
Abundance of schools	10.95	3.33	36.06	14.2	43.65	44.79	17.04
%CV abundance of schools	49.67	59.47	35.52	73.88	31.61	39.63	53.31
Encounter rate of schools	0.00072	0.00035	0.00364	0.00074	0.00230	0.00164	0.00084
%CV encounter rate	44.42	57.88	33.20	73.06	28.94	36.00	51.68
Density of schools	0.00021	0.00006	0.00070	0.00027	0.00084	0.00086	0.00033
%CV density of schools	49.67	59.47	35.52	73.88	31.61	39.63	53.31
Expected weight (T)	0.407	0.609	1.230	157.650	247.675	102.763	157.238
%CV weight	61.02	35.38	17.43	18.13	19.88	46.85	38.63
Expected cluster size (animals)	415.2	598.2	1229.1	1282.4	1643.2	678.1	1261.6
%CV abundance	59.85	32.67	16.99	16.71	18.80	46.08	34.04
Density of weight (km-2)	0.11	0.04	0.86	43.20	208.60	88.82	51.71
%CV density of weight	61.52	66.95	36.71	74.98	32.96	50.21	60.52
Density of animals (km-2)	0.088	0.038	0.855	0.351	1.384	0.586	0.415
%CV density of animals	59.43	65.03	35.99	74.74	32.57	49.60	58.40
Total weight (T)	561	335	5,726	2,239	10,810	4,603	2,680
%CV total weight	59.46	62.37	38.05	74.98	32.96	50.21	60.52
L 95% CI total weight	186	107	2,731	579	5,708	1,777	874
U 95% CI total weight	1,691	1,047	12,005	8,661	20,472	11,925	8,217
Total abundance (animals)	4,548	1,995	44,319	18,211	71,720	30,374	21,503
%CV total abundance	59.43	65.03	35.99	74.74	32.57	49.60	58.40
L 95% CI total abundance	1,509	612	21,946	4,724	38,144	11,848	7,256
U 95% CI total abundance	13,704	6,499	89,500	70,200	134,852	77,868	63,724

Table 5.1.3. Area E: Results of the re-analysis for adult individuals of BFT, using the overlap areas between 2010-2018.

	Area E						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	90,102	90,102	90,102	90,102	90,102	90,102	90,102
Transect length (km)	12,852	9,980	3,511	4,107	6,294	8,713	8,248
Probability of detection	0.21404	0.21404	0.21404	0.16175	0.16175	0.16175	0.16175
Effective strip width x2 (km)	2.26497	2.26497	2.26497	1.66603	1.66603	1.66603	1.66603
Area searched (km2)	138,800	107,784	37,916	42,305	64,828	89,741	84,955
% coverage	154.0	119.6	42.1	47.0	71.9	99.6	94.3
Number of schools ON effort	22	38	20	8	4	9	11
Abundance of schools	38.39	224.37	485.08	134.47	14.64	37.02	24.74
%CV abundance of schools	33.09	31.64	38.67	47.47	54.26	36.02	37.07
Encounter rate of schools	0.00171	0.00381	0.00570	0.00195	0.00064	0.00103	0.00133
%CV encounter rate	36.65	21.47	29.45	33.18	49.96	34.06	32.82
Density of schools	0.00043	0.00249	0.00538	0.00149	0.00016	0.00041	0.00028
%CV density of schools	33.09	31.64	38.67	47.47	54.26	36.02	37.07
Expected weight (T)	2.066	0.737	0.209	138.960	183.629	112.638	97.909
%CV weight	43.85	37.02	64.02	74.25	47.01	24.34	20.68
Expected cluster size (animals)	1609.8	789.5	209.9	704.0	1477.6	1180.9	904.5
%CV abundance	41.52	37.52	65.16	77.11	20.81	23.19	19.89
Density of weight (km-2)	0.86	1.84	0.84	207.39	29.84	46.28	26.88
%CV density of weight	64.34	33.87	57.41	63.36	61.75	39.82	39.97
Density of animals (km-2)	0.686	1.966	1.130	1.051	0.240	0.485	0.248
%CV density of animals	53.40	33.13	57.44	66.31	53.46	39.31	37.72
Total weight (T)	3,423	11,488	3,318	18,686	2,688	4,169	2,422
%CV total weight	54.56	33.30	70.62	63.36	61.75	39.82	39.97
L 95% CI total weight	1,245	6,031	940	5,905	879	1,948	1,134
U 95% CI total weight	9,409	21,882	11,711	59,132	8,221	8,926	5,174
Total abundance (animals)	61,799	177,146	101,825	94,665	21,631	43,712	22,378
%CV total abundance	53.40	33.13	57.44	66.31	53.46	39.31	37.72
L 95% CI total abundance	22,930	93,289	35,329	28,590	8,069	20,605	10,905
U 95% CI total abundance	166,554	336,385	293,477	313,443	57,986	92,731	45,923

Table 5.1.4. Area G: Results of the re-analysis for adult individuals of BFT, using the overlap areas between 2010-2018.

	Area G						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	38,788		38,788	38,788	38,788	38,788	38,788
Transect length (km)	2,866		1,715	1,055	4,042	3,969	3,747
Probability of detection	0.21404		0.21404	0.16175	0.16175	0.16175	0.16175
Effective strip width x2 (km)	2.26497		2.26497	1.66603	1.66603	1.66603	1.66603
Area searched (km2)	30,950		18,526	10,863	41,631	40,877	38,598
% coverage	79.8		47.8	28.0	107.3	105.4	99.5
Number of schools ON effort	23		0	0	12	8	4
Abundance of schools	101.65		0	0	33.58	37.72	45.37
%CV abundance of schools	34.89		0.00	0.00	35.27	42.68	54.99
Encounter rate of schools	0.00803		0.00000	0.00000	0.00297	0.00202	0.00107
%CV encounter rate	32.18		0.00	0.00	28.02	35.15	50.34
Density of schools	0.00262		0.00000	0.00000	0.00087	0.00097	0.00117
%CV density of schools	34.89		0.00	0.00	35.27	42.68	54.99
Expected weight (T)	2.100		0.000	0.000	10.802	7.151	0.509
%CV weight	22.00		0.00	0.00	47.03	66.38	44.66
Expected cluster size (animals)	2060.3		0.0	0.0	252.7	138.2	20.1
%CV abundance	21.77		0.0	0.00	30.83	55.34	52.32
Density of weight (km-2)	5.69		0.00	0.00	9.35	6.95	0.60
%CV density of weight	37.92		0.00	0.00	51.51	64.27	63.60
Density of animals (km-2)	5.400		0.000	0.000	0.219	0.134	0.023
%CV density of animals	37.76		0.00	0.00	38.00	54.63	68.92
Total weight (T)	6,878		0	0	363	270	23
%CV total weight	37.69		0.00	0.00	51.51	64.27	63.60
L 95% CI total weight	3,322		0	0	139	84	7
U 95% CI total weight	14,240		0	0	945	862	73
Total abundance (animals)	209,437		0	0	8,487	5,214	910
%CV total abundance	37.76		0.00	0.00	38.00	54.63	68.92
L 95% CI total abundance	101,052		0	0	4,112	1,899	265
U 95% CI total abundance	434,071		0	0	17,517	14,316	3,118

Table 5.1.5. All areas together: Results of the re-analysis for adult individuals of BFT, using the overlap areas between 2010-2018.

Area	Total: All areas together						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	242,548	203,760	242,548	242,548	242,548	242,548	242,548
Transect length (km)	30,165	26,482	14,643	12,173	20,076	23,664	22,349
Probability of detection	0.21404	0.21404	0.21404	0.16175	0.16175	0.16175	0.16175
Effective strip width x2 (km)	2.26497	2.26497	2.26497	1.66603	1.66603	1.66603	1.66603
Area searched (km2)	325,785	286,001	158,141	125,385	206,780	243,744	230,196
% coverage	134.3	140.4	65.2	51.7	85.3	100.5	94.9
Number of schools ON effort	59	48	39	18	49	53	39
Abundance of schools	163.68	239.21	539.44	181.19	417.34	375.43	322.38
%CV abundance of schools	23.95	29.82	34.95	36.82	29.00	22.50	25.09
Encounter rate of schools	0.00196	0.00181	0.00266	0.00148	0.00244	0.00224	0.00175
%CV encounter rate	20.83	19.81	19.09	23.29	15.70	14.62	17.41
Density of schools	0.00068	0.00117	0.00222	0.00075	0.00172	0.00155	0.00133
%CV density of schools	23.95	29.82	34.95	36.82	29.00	22.50	25.09
Expected weight (T)	1.936	0.738	0.314	131.814	63.139	58.988	43.099
%CV weight	18.61	34.88	44.45	57.84	35.09	27.16	32.15
Expected cluster size (animals)	1828.0	785.8	291.3	714.3	413.8	424.5	307.3
%CV abundance	17.76	35.41	48.58	57.64	33.87	26.65	30.62
Density of weight (km-2)	1.36	0.87	0.53	98.47	108.64	91.31	57.28
%CV density of weight	30.28	31.86	35.67	50.47	24.02	22.66	27.72
Density of animals (km-2)	1.234	0.923	0.648	0.534	0.712	0.657	0.408
%CV density of animals	29.34	31.33	38.96	50.08	22.26	21.96	25.92
Total weight (T)	12,692	12,849	10,887	23,883	26,350	22,146	13,894
%CV total weight	26.99	30.00	30.34	50.47	24.02	22.66	27.72
L 95% CI total weight	7,519	7,171	6,057	9,293	16,547	14,269	8,141
U 95% CI total weight	21,421	23,022	19,567	61,378	41,963	34,371	23,713
Total abundance (animals)	299,192	187,978	157,129	129,429	172,715	159,387	99,074
%CV total abundance	29.34	31.33	38.96	50.08	22.26	21.96	25.92
L 95% CI total abundance	169,168	102,356	74,682	50,711	112,107	104,059	60,027
U 95% CI total abundance	529,155	345,221	330,596	330,344	266,089	244,131	163,523

5.2. Area 2019

Tables 5.2.1 to 5.2.5 show the results of the re-analysis for adult individuals of BFT using the new redesigned area A in 2019, for each area by year and for all areas pooled together by year.

Table 5.2.1. Area A: Results of the re-analysis for adult individuals of BFT, using the new redesigned area A in 2019.

	Area A						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	62,745	62,745	62,745	62,745	62,745	62,745	62,745
Transect length (km)	5,097	6,779	5,942	3,762	4,233	5,263	6,538
Probability of detection	0.22133	0.22133	0.22133	0.16184	0.16184	0.16184	0.16184
Effective strip width x2 (km)	2.34211	2.34211	2.34211	1.66695	1.66695	1.66695	1.66695
Area searched (km²)	55,048	73,210	64,178	38,745	43,603	54,212	67,339
% coverage	87.7	116.7	102.3	61.7	69.5	86.4	107.3
Number of schools ON effort	8	7	8	8	20	26	25
Abundance of schools	14.95	12.39	20.34	37.47	332.72	286.71	227.73
%CV abundance of schools	55.60	42.00	42.18	46.86	39.98	31.12	29.06
Encounter rate of schools	0.00157	0.00103	0.00135	0.00213	0.00472	0.00494	0.00382
%CV encounter rate	54.00	37.85	36.77	35.55	27.78	20.51	21.10
Density of schools	0.00024	0.00020	0.00032	0.00060	0.00530	0.00457	0.00363
%CV density of schools	55.60	42.00	42.18	46.86	39.98	31.12	29.06
Expected weight (T)	1.863	0.778	0.579	91.305	44.341	49.395	51.575
%CV weight	10.40	32.81	37.74	40.85	51.96	39.14	37.35
Expected cluster size (animals)	1845.4	792.2	545.3	511.0	251.5	301.4	311.4
%CV abundance	10.52	30.66	39.68	39.82	51.22	39.42	36.64
Density of weight (km⁻²)	0.49	0.16	0.16	54.53	235.13	225.71	187.19
%CV density of weight	56.65	44.60	42.58	42.55	36.55	30.59	31.73
Density of animals (km⁻²)	0.440	0.156	0.177	0.305	1.334	1.377	1.130
%CV density of animals	56.24	44.40	42.05	41.79	35.41	30.93	31.33
Total weight (T)	2,141	1,158	1,842	3,421	14,753	14,162	11,745
%CV total weight	55.27	43.82	41.20	42.55	36.55	30.59	31.73
L 95% CI total weight	762	506	838	1,533	7,350	7,864	6,390
U 95% CI total weight	6,015	2,651	4,046	7,634	29,615	25,505	21,589
Total abundance (animals)	27,593	9,814	11,093	19,146	83,680	86,428	70,925
%CV total abundance	56.24	44.40	42.05	41.79	35.41	30.93	31.33
L 95% CI total abundance	9,666	4,243	4,973	8,695	42,545	47,693	38,870
U 95% CI total abundance	78,767	22,698	24,743	42,158	164,590	156,620	129,413

Table 5.2.2. Area C: Results of the re-analysis for adult individuals of BFT, using the new redesigned area A in 2019.

	Area C						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	51,821	51,821	51,821	51,821	51,821	51,821	51,821
Transect length (km)	8,354	8,684	2,750	2,718	4,791	4,890	4,780
Probability of detection	0.22133	0.22133	0.22133	0.16184	0.16184	0.16184	0.16184
Effective strip width x2 (km)	2.34211	2.34211	2.34211	1.66695	1.66695	1.66695	1.66695
Area searched (km2)	90,227	93,788	29,696	27,995	49,343	50,369	49,231
% coverage	174.1	181.0	57.3	54.0	95.2	97.2	95.0
Number of schools ON effort	6	3	10	2	11	8	4
Abundance of schools	13.46	3.32	37.42	14.17	43.54	44.55	16.99
%CV abundance of schools	50.73	59.86	35.90	73.88	31.59	39.60	53.29
Encounter rate of schools	0.00072	0.00035	0.00364	0.00074	0.00230	0.00164	0.00084
%CV encounter rate	44.42	57.88	33.20	73.06	28.94	36.00	51.68
Density of schools	0.00026	0.00006	0.00072	0.00027	0.00084	0.00086	0.00033
%CV density of schools	50.73	59.86	35.90	73.88	31.59	39.60	53.29
Expected weight (T)	0.406	0.609	1.228	157.665	247.883	103.068	157.400
%CV weight	61.13	35.40	17.45	18.13	19.84	46.83	38.58
Expected cluster size (animals)	419.1	592.6	1251.6	1282.5	1644.6	680.3	1262.8
%CV abundance	59.88	36.03	16.83	16.71	18.75	46.06	34.00
Density of weight (km-2)	0.11	0.04	0.86	43.10	208.25	88.61	51.61
%CV density of weight	61.56	66.94	36.67	74.98	32.95	50.24	60.53
Density of animals (km-2)	0.109	0.038	0.904	0.351	1.382	0.585	0.414
%CV density of animals	60.01	66.10	36.72	74.74	32.56	49.63	58.41
Total weight (T)	564	323	5,748	2,234	10,792	4,592	2,675
%CV total weight	59.42	62.36	37.99	74.98	32.95	50.24	60.53
L 95% CI total weight	187	103	2,745	577	5,699	1,771	872
U 95% CI total weight	1,698	1,010	12,038	8,641	20,434	11,903	8,202
Total abundance (animals)	5,642	1,967	46,837	18,168	71,600	30,309	21,459
%CV total abundance	60.01	66.10	36.72	74.74	32.56	49.63	58.41
L 95% CI total abundance	1,857	594	22,903	4,713	38,086	11,817	7,239
U 95% CI total abundance	17,144	6,512	95,786	70,036	134,605	77,744	63,605

Table 5.2.3. Area E: Results of the re-analysis for adult individuals of BFT, using the new redesigned area A in 2019.

	Area E						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	90,102	90,102	90,102	90,102	90,102	90,102	90,102
Transect length (km)	12,852	9,980	3,511	4,107	6,294	8,713	8,248
Probability of detection	0.22133	0.22133	0.22133	0.16184	0.16184	0.16184	0.16184
Effective strip width x2 (km)	2.34211	2.34211	2.34211	1.66695	1.66695	1.66695	1.66695
Area searched (km²)	138,800	107,784	37,916	42,305	64,828	89,741	84,955
% coverage	154.0	119.6	42.1	47.0	71.9	99.6	94.3
Number of schools ON effort	22	38	20	8	4	9	11
Abundance of schools	37.09	233.73	390.74	138.63	14.22	36.91	24.73
%CV abundance of schools	34.04	31.52	37.60	47.40	54.69	36.00	37.27
Encounter rate of schools	0.00171	0.00381	0.00570	0.00195	0.00064	0.00103	0.00133
%CV encounter rate	36.65	21.47	29.45	33.18	49.96	34.06	32.82
Density of schools	0.00041	0.00259	0.00434	0.00154	0.00016	0.00041	0.00027
%CV density of schools	34.04	31.52	37.60	47.40	54.69	36.00	37.27
Expected weight (T)	2.042	0.723	0.205	139.698	180.978	112.737	98.017
%CV weight	43.36	37.12	63.97	74.16	47.93	24.33	20.75
Expected cluster size (animals)	1950.6	732.6	191.8	707.6	1470.4	1181.9	901.8
%CV abundance	43.65	36.82	64.72	77.03	20.85	23.19	19.85
Density of weight (km⁻²)	0.84	1.82	0.80	214.94	28.57	46.18	26.90
%CV density of weight	63.55	33.92	57.31	63.44	61.91	39.83	40.22
Density of animals (km⁻²)	0.803	1.900	0.832	1.089	0.232	0.484	0.247
%CV density of animals	62.72	33.41	57.22	66.40	53.60	39.32	37.75
Total weight (T)	3,309	11,403	3,172	19,366	2,574	4,161	2,424
%CV total weight	53.96	33.29	70.46	63.44	61.91	39.83	40.22
L 95% CI total weight	1,216	5,987	901	6,113	840	1,943	1,130
U 95% CI total weight	9,009	21,720	11,171	61,358	7,892	8,908	5,201
Total abundance (animals)	72,341	171,223	74,964	98,100	20,916	43,618	22,300
%CV total abundance	62.72	33.41	57.22	66.40	53.60	39.32	37.75
L 95% CI total abundance	23,103	89,684	26,106	29,593	7,785	20,559	10,861
U 95% CI total abundance	226,515	326,898	215,256	325,203	56,194	92,541	45,785

Table 5.2.4. Area G: Results of the re-analysis for adult individuals of BFT, using the new redesigned area A in 2019.

	Area G						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	38,788		38,788	38,788	38,788	38,788	38,788
Transect length (km)	2,866		1,715	1,055	4,042	3,969	3,747
Probability of detection	0.22133		0.22133	0.16184	0.16184	0.16184	0.16184
Effective strip width x2 (km)	2.34211		2.34211	1.66695	1.66695	1.66695	1.66695
Area searched (km2)	30,950		18,526	10,863	41,631	40,877	38,598
% coverage	79.8		47.8	28.0	107.3	105.4	99.5
Number of schools ON effort	23		0	0	12	8	4
Abundance of schools	101.83		0	0	33.15	38.31	46.79
%CV abundance of schools	35.44		0.00	0.00	35.43	43.00	54.97
Encounter rate of schools	0.00803		0.00000	0.00000	0.00297	0.00202	0.00107
%CV encounter rate	32.18		0.00	0.00	28.02	35.15	50.34
Density of schools	0.00263		0.00000	0.00000	0.00086	0.00099	0.00121
%CV density of schools	35.44		0.00	0.00	35.43	43.00	54.97
Expected weight (T)	2.098		0.000	0.000	10.815	6.988	0.509
%CV weight	22.02		0.00	0.00	46.89	66.68	44.63
Expected cluster size (animals)	2061.5		0.0	0.0	253.3	135.5	20.1
%CV abundance	21.87		0.00	0.00	30.59	55.50	52.27
Density of weight (km-2)	5.70		0.00	0.00	9.24	6.90	0.61
%CV density of weight	37.87		0.00	0.00	51.56	64.20	63.62
Density of animals (km-2)	5.412		0.000	0.000	0.217	0.134	0.024
%CV density of animals	38.04		0.00	0.00	38.13	54.48	68.93
Total weight (T)	6,882		0	0	359	268	24
%CV total weight	37.64		0.00	0.00	51.56	64.20	63.62
L 95% CI total weight	3,327		0	0	137	84	8
U 95% CI total weight	14,236		0	0	935	855	75
Total abundance (animals)	209,914		0	0	8,398	5,191	939
%CV total abundance	38.04		0.00	0.00	38.13	54.48	68.93
L 95% CI total abundance	100,793		0	0	4,060	1,895	274
U 95% CI total abundance	437,175		0	0	17,372	14,218	3,219

Table 5.2.5. All areas together: Results of the re-analysis for adult individuals of BFT, using the new redesigned area A in 2019.

	Total: All areas together						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	243,456	204,668	243,456	243,456	243,456	243,456	243,456
Transect length (km)	29,169	25,443	13,918	11,642	19,360	22,835	23,313
Probability of detection	0.22133	0.22133	0.22133	0.16184	0.16184	0.16184	0.16184
Effective strip width x2 (km)	2.34211	2.34211	2.34211	1.66695	1.66695	1.66695	1.66695
Area searched (km2)	315,025	274,782	150,316	119,907	199,404	235,199	240,123
% coverage	129.4	134.3	61.7	49.3	81.9	96.6	98.6
Number of schools ON effort	59	48	38	18	47	51	44
Abundance of schools	167.33	249.44	448.51	190.27	423.63	406.48	316.24
%CV abundance of schools	23.90	29.57	32.96	36.31	31.93	23.53	23.26
Encounter rate of schools	0.00202	0.00189	0.00273	0.00155	0.00243	0.00223	0.00189
%CV encounter rate	20.82	19.77	19.43	23.32	16.18	14.93	16.30
Density of schools	0.00069	0.00122	0.00184	0.00078	0.00174	0.00167	0.00130
%CV density of schools	23.90	29.57	32.96	36.31	31.93	23.53	23.26
Expected weight (T)	1.927	0.725	0.313	131.505	67.223	57.032	53.337
%CV weight	18.24	34.79	43.96	57.14	37.61	28.73	29.62
Expected cluster size (animals)	1885.5	733.7	296.3	711.7	435.7	407.3	365.6
%CV abundance	18.22	34.60	44.75	56.96	36.41	28.10	28.29
Density of weight (km-2)	1.37	0.86	0.52	102.78	116.97	95.22	69.28
%CV density of weight	29.82	31.72	35.13	50.02	24.51	23.50	25.36
Density of animals (km-2)	1.296	0.894	0.546	0.556	0.758	0.680	0.475
%CV density of animals	30.05	31.36	34.89	49.65	22.62	22.59	23.90
Total weight (T)	12,896	12,884	10,762	25,021	28,478	23,182	16,867
%CV total weight	26.59	29.75	30.12	50.02	24.51	23.50	25.36
L 95% CI total weight	7,698	7,225	6,012	9,811	17,718	14,700	10,329
U 95% CI total weight	21,604	22,976	19,266	63,815	45,773	36,559	27,543
Total abundance (animals)	315,491	183,004	132,894	135,415	184,594	165,546	115,622
%CV total abundance	30.05	31.36	34.89	49.65	22.62	22.59	23.90
L 95% CI total abundance	176,306	99,567	67,993	53,445	119,011	106,812	72,776
U 95% CI total abundance	564,556	336,362	259,743	343,104	286,320	256,576	183,695

5.3. Overlap area 2018-2019

Tables 5.3.1 to 5.3.5 show the results of the re-analysis for adult individuals of BFT using an overlap between the previous 2010-2018 areas and the new redesigned area A in 2019, for each area by year and for all areas pooled together by year.

Table 5.3.1. Area A: Results of the re-analysis for adult individuals of BFT, using the overlap areas between 2010 and 2019.

Area	Area A						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km²)	53,388	53,388	53,388	53,388	53,388	53,388	53,388
Transect length (km)	5,094	6,778	5,910	3,754	4,230	5,258	5,549
Probability of detection	0.22128	0.22128	0.22128	0.16185	0.16185	0.16185	0.16185
Effective strip width x2 (km)	2.34158	2.34158	2.34158	1.66706	1.66706	1.66706	1.66706
Area searched (km²)	55,015	73,202	63,830	38,670	43,566	54,152	57,159
% coverage	103.0	137.1	119.6	72.4	81.6	101.4	107.1
Number of schools ON effort	8	7	8	8	20	26	20
Abundance of schools	13.39	11.04	16.79	31.78	282.42	243.45	201.11
%CV abundance of schools	55.70	42.09	41.69	46.69	39.91	31.03	31.52
Encounter rate of schools	0.00157	0.00103	0.00135	0.00213	0.00473	0.00495	0.00360
%CV encounter rate	54.00	37.85	36.87	35.55	27.78	20.51	23.96
Density of schools	0.00025	0.00021	0.00031	0.00060	0.00529	0.00456	0.00377
%CV density of schools	55.70	42.09	41.69	46.69	39.91	31.03	31.52
Expected weight (T)	1.863	0.783	0.590	91.628	44.777	49.779	37.961
%CV weight	10.41	32.42	36.82	40.62	51.88	39.05	42.18
Expected cluster size (animals)	1845.5	795.3	557.4	512.7	254.0	303.8	235.0
%CV abundance	10.52	30.40	38.64	39.59	51.14	39.34	41.28
Density of weight (km⁻²)	0.51	0.17	0.16	54.54	236.87	226.99	143.00
%CV density of weight	56.74	44.72	42.72	42.52	36.55	30.62	37.25
Density of animals (km⁻²)	0.463	0.164	0.175	0.305	1.343	1.385	0.885
%CV density of animals	56.34	44.54	42.15	41.77	35.42	30.96	36.82
Total weight (T)	1,899	1,027	1,551	2,912	12,646	12,118	7,634
%CV total weight	55.37	43.94	41.17	42.52	36.55	30.62	37.25
L 95% CI total weight	675	447	706	1,306	6,299	6,725	3,758
U 95% CI total weight	5,345	2,356	3,407	6,494	25,389	21,836	15,510
Total abundance (animals)	24,708	8,778	9,359	16,295	71,726	73,952	47,263
%CV total abundance	56.34	44.54	42.15	41.77	35.42	30.96	36.82
L 95% CI total abundance	8,643	3,787	4,188	7,403	36,461	40,785	23,443
U 95% CI total abundance	70,636	20,347	20,913	35,863	141,099	134,088	95,286

Table 5.3.2. Area C: Results of the re-analysis for adult individuals of BFT using the overlap areas between 2010 and 2019.

	Area C						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	51,821	51,821	51,821	51,821	51,821	51,821	51,821
Transect length (km)	8,354	8,684	2,750	2,718	4,791	4,890	4,780
Probability of detection	0.22128	0.22128	0.22128	0.16185	0.16185	0.16185	0.16185
Effective strip width x2 (km)	2.34158	2.34158	2.34158	1.66706	1.66706	1.66706	1.66706
Area searched (km2)	90,227	93,788	29,696	27,995	49,343	50,369	49,231
% coverage	174.1	181.0	57.3	54.0	95.2	97.2	95.0
Number of schools ON effort	6	3	10	2	11	8	4
Abundance of schools	12.95	3.48	36.19	14.25	43.8	44.7	17.09
%CV abundance of schools	50.40	59.96	35.80	73.88	31.57	39.57	53.28
Encounter rate of schools	0.00072	0.00035	0.00364	0.00074	0.00230	0.00164	0.00084
%CV encounter rate	44.42	57.88	33.20	73.06	28.94	36.00	51.68
Density of schools	0.00025	0.00007	0.00070	0.00028	0.00085	0.00086	0.00033
%CV density of schools	50.40	59.96	35.80	73.88	31.57	39.57	53.28
Expected weight (T)	0.407	0.610	1.230	157.679	248.068	103.346	157.543
%CV weight	61.02	35.37	17.38	18.13	19.80	46.81	38.54
Expected cluster size (animals)	419.8	593.3	1252.3	1282.6	1645.9	682.3	1263.8
%CV abundance	59.69	35.99	16.79	16.71	18.71	46.03	33.97
Density of weight (km-2)	0.10	0.04	0.83	43.37	209.65	89.15	51.95
%CV density of weight	61.42	67.04	36.57	74.98	32.95	50.27	60.54
Density of animals (km-2)	0.105	0.040	0.874	0.353	1.391	0.589	0.417
%CV density of animals	59.98	66.23	36.66	74.74	32.56	49.66	58.42
Total weight (T)	542	337	5,562	2,247	10,864	4,620	2,692
%CV total weight	59.42	62.46	37.91	74.98	32.95	50.27	60.54
L 95% CI total weight	180	108	2,659	581	5,738	1,781	878
U 95% CI total weight	1,633	1,053	11,633	8,694	20,573	11,983	8,257
Total abundance (animals)	5,438	2,066	45,317	18,281	72,083	30,502	21,597
%CV total abundance	59.98	66.23	36.66	74.74	32.56	49.66	58.42
L 95% CI total abundance	1,790	623	22,182	4,742	38,342	11,885	7,285
U 95% CI total abundance	16,517	6,851	92,581	70,472	135,517	78,279	64,029

Table 5.3.3. Area E: Results of the re-analysis for adult individuals of BFT using the overlap areas between 2010 and 2019.

Area	Area E						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	90,102	90,102	90,102	90,102	90,102	90,102	90,102
Transect length (km)	12,852	9,980	3,511	4,107	6,294	8,713	8,248
Probability of detection	0.22128	0.22128	0.22128	0.16185	0.16185	0.16185	0.16185
Effective strip width x2 (km)	2.34158	2.34158	2.34158	1.66706	1.66706	1.66706	1.66706
Area searched (km2)	138,800	107,784	37,916	42,305	64,828	89,741	84,955
% coverage	154.0	119.6	42.1	47.0	71.9	99.6	94.3
Number of schools ON effort	22	38	20	8	4	9	11
Abundance of schools	39.17	227.23	406.76	140.78	14.08	37.11	24.73
%CV abundance of schools	34.39	31.13	38.12	47.21	54.80	35.99	37.36
Encounter rate of schools	0.00171	0.00381	0.00570	0.00195	0.00064	0.00103	0.00133
%CV encounter rate	36.65	21.47	29.45	33.18	49.96	34.06	32.82
Density of schools	0.00044	0.00252	0.00451	0.00156	0.00016	0.00041	0.00028
%CV density of schools	34.39	31.13	38.12	47.21	54.80	35.99	37.36
Expected weight (T)	2.072	0.745	0.212	140.768	179.330	112.824	98.090
%CV weight	43.87	37.02	64.10	74.06	48.45	24.31	20.81
Expected cluster size (animals)	1976.7	752.9	198.8	713.1	1465.9	1182.8	900.2
%CV abundance	44.15	36.65	64.83	76.94	20.86	23.18	19.83
Density of weight (km-2)	0.89	1.83	0.86	219.95	28.03	46.47	26.93
%CV density of weight	64.51	33.68	57.66	63.45	61.69	39.83	40.35
Density of animals (km-2)	0.859	1.899	0.897	1.114	0.229	0.487	0.247
%CV density of animals	63.64	33.24	57.60	66.40	53.47	39.33	37.70
Total weight (T)	3,540	11,425	3,421	19,817	2,526	4,187	2,426
%CV total weight	54.61	33.13	70.86	63.45	61.69	39.83	40.35
L 95% CI total weight	1,287	6,016	966	6,255	827	1,955	1,128
U 95% CI total weight	9,739	21,698	12,117	62,789	7,716	8,966	5,218
Total abundance (animals)	77,428	171,079	80,847	100,386	20,645	43,895	22,266
%CV total abundance	63.64	33.24	57.60	66.40	53.47	39.33	37.70
L 95% CI total abundance	24,385	89,900	27,990	30,280	7,701	20,686	10,853
U 95% CI total abundance	245,856	325,562	233,523	332,812	55,348	93,145	45,678

Table 5.3.4. Area G: Results of the re-analysis for adult individuals of BFT using the overlap areas between 2010 and 2019.

	Area G						
Area	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	38,788		38,788	38,788	38,788	38,788	38,788
Transect length (km)	2,866		1,715	1,055	4,042	3,969	3,747
Probability of detection	0.22128		0.22128	0.16185	0.16185	0.16185	0.16185
Effective strip width x2 (km)	2.34158		2.34158	1.66706	1.66706	1.66706	1.66706
Area searched (km2)	30,950		18,526	10,863	41,631	40,877	38,598
% coverage	79.8		47.8	28.0	107.3	105.4	99.5
Number of schools ON effort	23		0	0	12	8	4
Abundance of schools	100.42		0	0	32.87	38.61	47.52
%CV abundance of schools	35.32		0.00	0.00	35.34	43.16	54.86
Encounter rate of schools	0.00803		0.00000	0.00000	0.00297	0.00202	0.00107
%CV encounter rate	32.18		0.00	0.00	28.02	35.15	50.34
Density of schools	0.00259		0.00000	0.00000	0.00085	0.00100	0.00123
%CV density of schools	35.32		0.00	0.00	35.34	43.16	54.86
Expected weight (T)	2.100		0.000	0.000	10.833	6.900	0.510
%CV weight	21.98		0.00	0.00	46.78	66.77	44.60
Expected cluster size (animals)	2064.5		0.0	0.0	254.0	134.1	20.1
%CV abundance	21.83		0.00	0.00	30.42	55.51	52.22
Density of weight (km-2)	5.63		0.00	0.00	9.18	6.87	0.62
%CV density of weight	37.82		0.00	0.00	51.49	64.11	63.55
Density of animals (km-2)	5.345		0.000	0.000	0.215	0.133	0.025
%CV density of animals	38.05		0.00	0.00	38.10	54.36	68.85
Total weight (T)	6,797		0	0	356	266	24
%CV total weight	37.58		0.00	0.00	51.49	64.11	63.55
L 95% CI total weight	3,289		0	0	137	84	8
U 95% CI total weight	14,047		0	0	928	850	77
Total abundance (animals)	207,311		0	0	8,347	5,176	955
%CV total abundance	38.05		0.00	0.00	38.10	54.36	68.85
L 95% CI total abundance	99,517		0	0	4,037	1,894	279
U 95% CI total abundance	431,864		0	0	17,260	14,148	3,270

Table 5.3.5. All areas together: Results of the re-analysis for adult individuals of BFT using the overlap areas between 2010 and 2019.

Area	Total: All areas together						
	2010	2011	2013	2015	2017	2018	2019
Survey area (km2)	234,099	195,311	234,099	234,099	234,099	234,099	234,099
Transect length (km)	29,166	25,442	13,886	11,634	19,356	22,829	22,325
Probability of detection	0.22128	0.22128	0.22128	0.16185	0.16185	0.16185	0.16185
Effective strip width x2 (km)	2.34158	2.34158	2.34158	1.66706	1.66706	1.66706	1.66706
Area searched (km2)	314,992	274,774	149,969	119,833	199,367	235,139	229,942
% coverage	134.6	140.7	64.1	51.2	85.2	100.4	98.2
Number of schools ON effort	59	48	38	18	47	51	39
Abundance of schools	165.93	241.75	459.74	186.81	373.17	363.87	290.45
%CV abundance of schools	23.84	29.32	33.86	37.00	30.86	22.72	24.48
Encounter rate of schools	0.00202	0.00189	0.00274	0.00155	0.00243	0.00223	0.00175
%CV encounter rate	20.82	19.77	19.44	23.32	16.18	14.93	17.41
Density of schools	0.00071	0.00124	0.00196	0.00080	0.00159	0.00155	0.00124
%CV density of schools	23.84	29.32	33.86	37.00	30.86	22.72	24.48
Expected weight (T)	1.941	0.745	0.311	133.699	70.724	58.240	43.990
%CV weight	18.61	34.86	45.43	58.46	36.29	27.84	31.46
Expected cluster size (animals)	1897.7	752.5	294.8	722.4	463.1	421.9	317.0
%CV abundance	18.59	34.57	46.24	58.34	35.11	27.24	29.99
Density of weight (km-2)	1.41	0.90	0.55	106.69	112.74	90.53	54.58
%CV density of weight	30.22	31.67	36.73	51.16	24.10	23.33	27.38
Density of animals (km-2)	1.345	0.931	0.579	0.577	0.738	0.656	0.393
%CV density of animals	30.45	31.34	36.51	50.84	22.33	22.53	25.71
Total weight (T)	12,779	12,788	10,534	24,977	26,392	21,192	12,777
%CV total weight	26.98	29.84	31.25	51.16	24.10	23.33	27.38
L 95% CI total weight	7,574	7,158	5,764	9,609	16,546	13,480	7,532
U 95% CI total weight	21,561	22,847	19,253	64,924	42,098	33,316	21,673
Total abundance (animals)	314,885	181,923	135,523	134,961	172,801	153,524	92,081
%CV total abundance	30.45	31.34	36.51	50.84	22.33	22.53	25.71
L 95% CI total abundance	174,720	99,018	67,334	52,216	111,998	99,147	55,999
U 95% CI total abundance	567,495	334,241	272,767	348,832	266,613	237,726	151,413

6. Changes over time

Figures 6.1 to 6.5 show the abundance estimates for each area and in total, both for all sizes classes and for adults only. The lines indicating the 95%CI are also displayed. Figures 6.6 to 6.10 show the same plots but for weight.

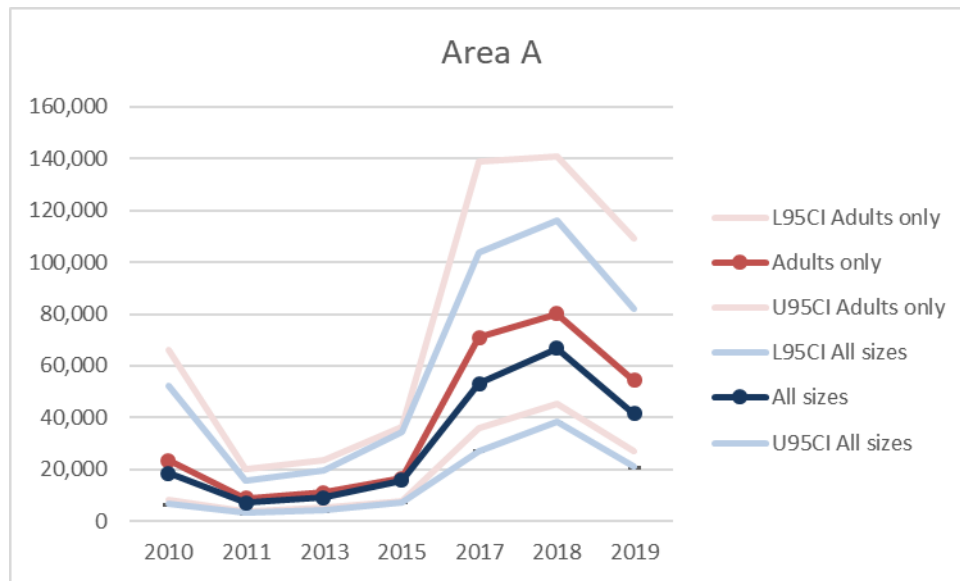


Figure 6.1. Abundance estimates per year for all sizes (blue) and for adults only (red) in Area A. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

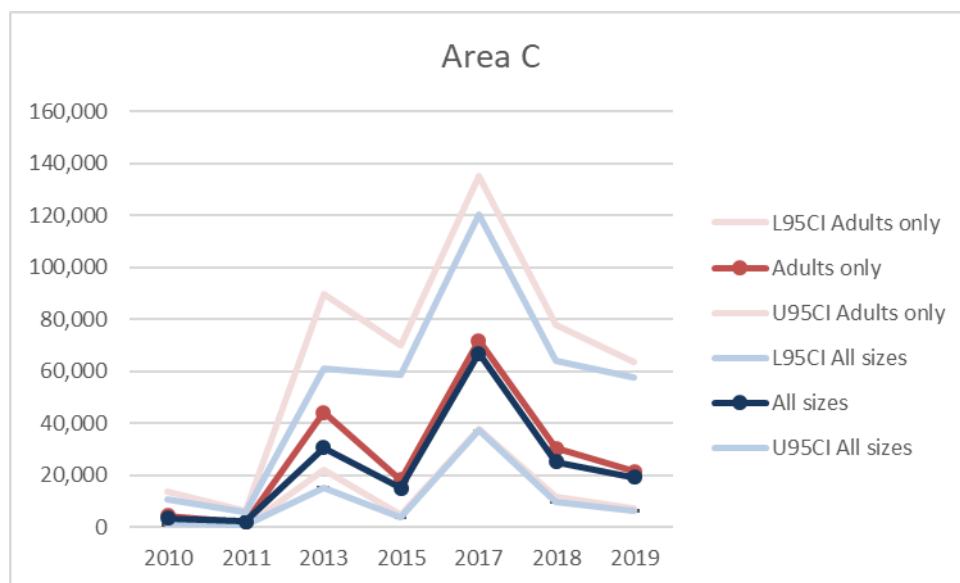


Figure 6.2. Abundance estimates per year for all sizes (blue) and for adults only (red) in Area C. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

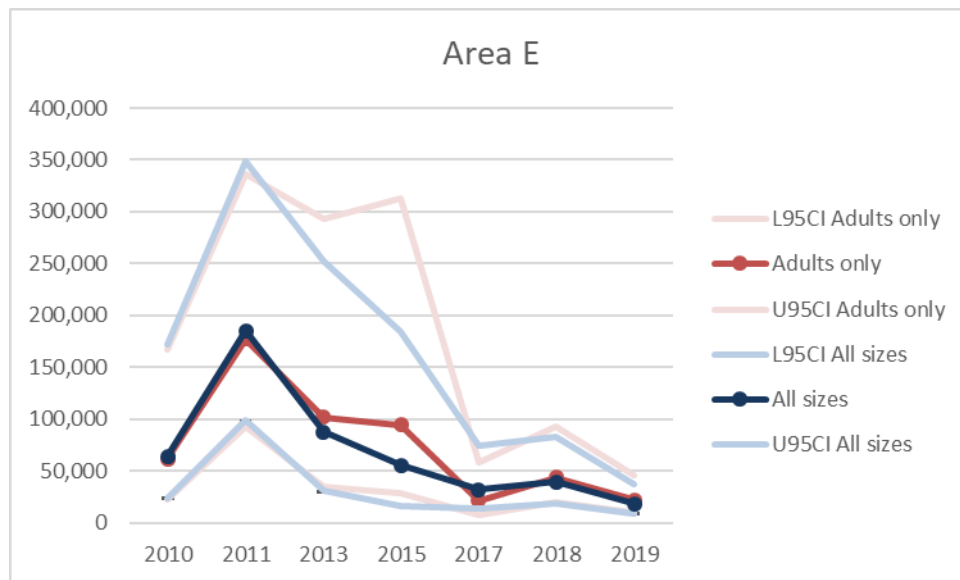


Figure 6.3. Abundance estimates per year for all sizes (blue) and for adults only (red) in Area E. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

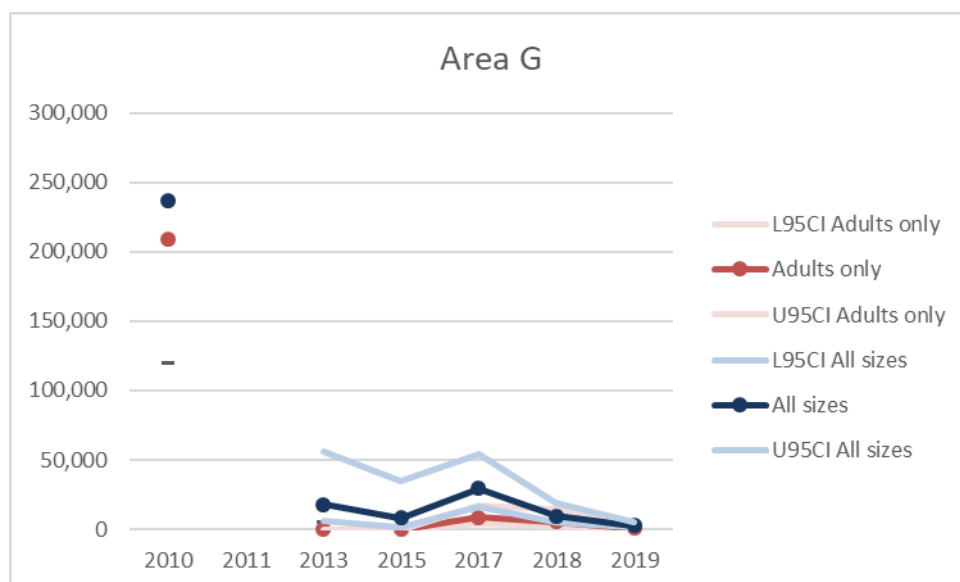


Figure 6.4. Abundance estimates per year for all sizes (blue) and for adults only (red) in Area G. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

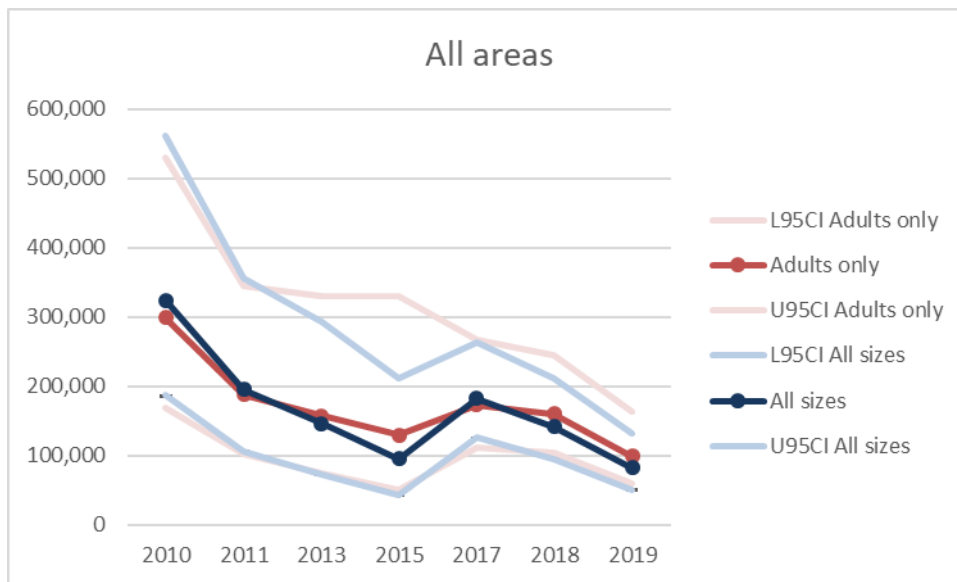


Figure 6.5. Abundance estimates per year for all sizes (blue) and for adults only (red) in all areas pooled together. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

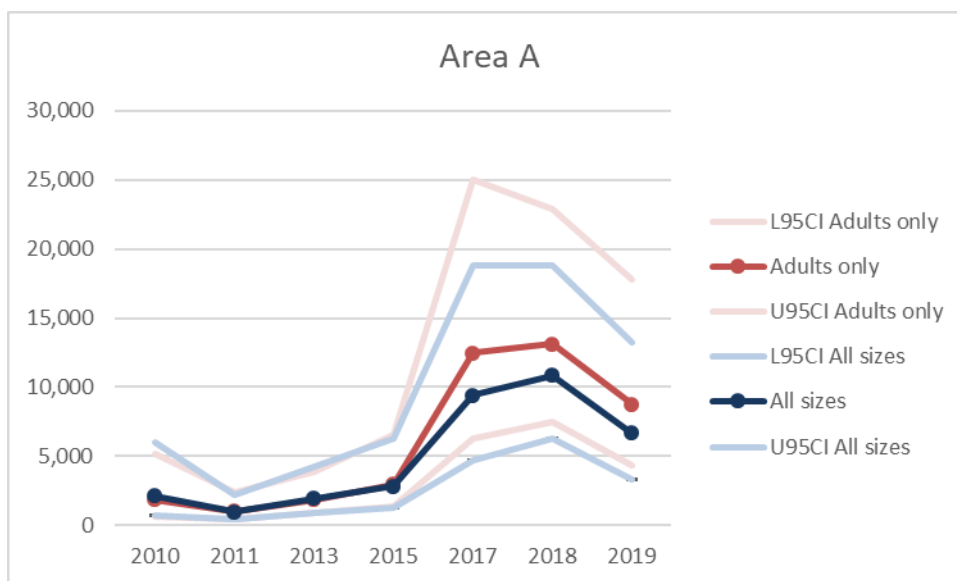


Figure 6.6. Weight estimates per year for all sizes (blue) and for adults only (red) in Area A. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

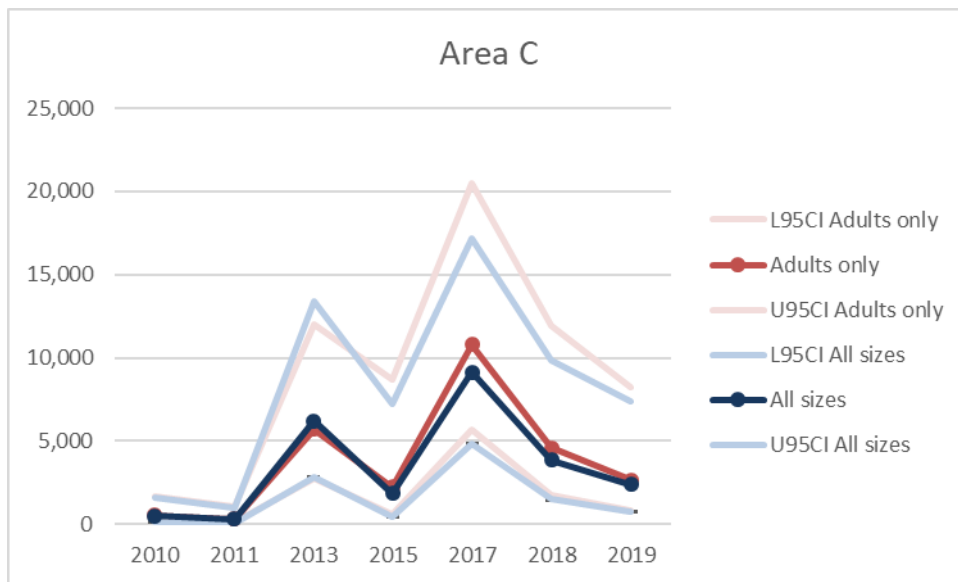


Figure 6.7. Weight estimates per year for all sizes (blue) and for adults only (red) in Area C. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

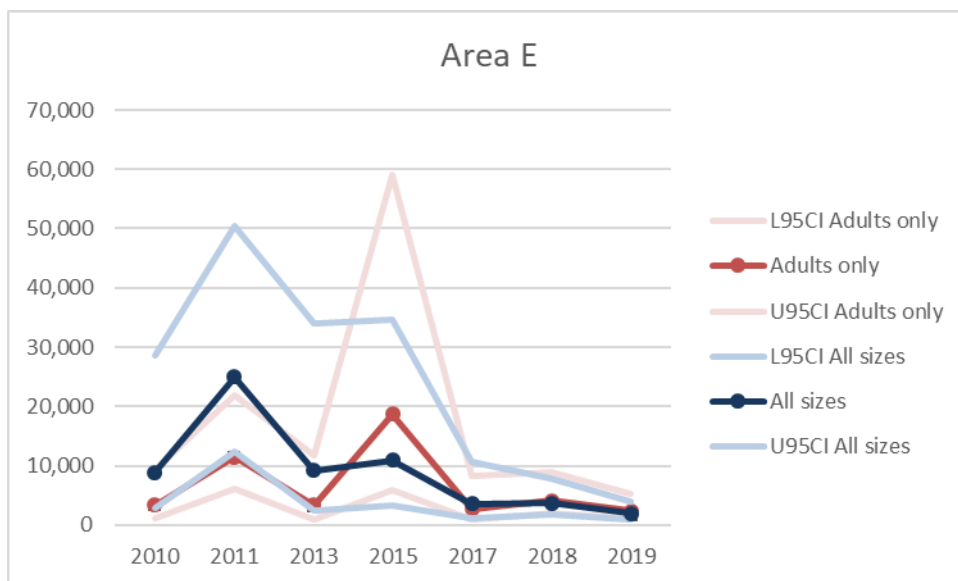


Figure 6.8. Weight estimates per year for all sizes (blue) and for adults only (red) in Area E. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

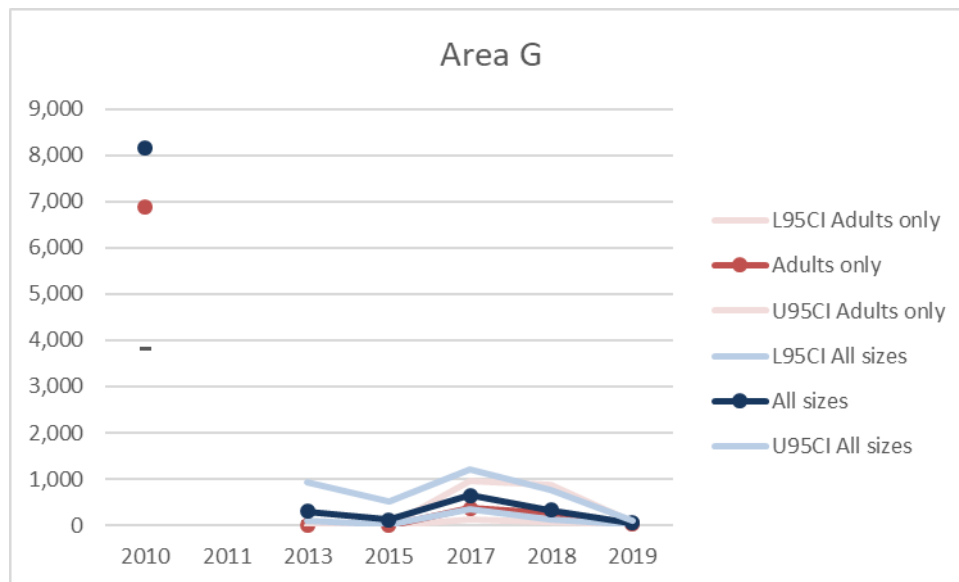


Figure 6.9. Weight estimates per year for all sizes (blue) and for adults only (red) in Area G. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

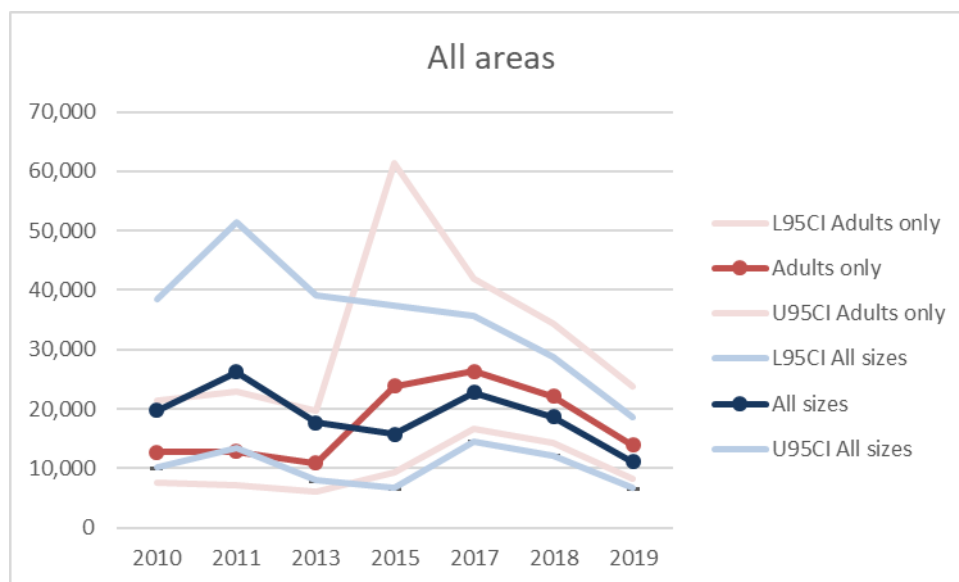


Figure 6.10. Weight estimates per year for all sizes (blue) and for adults only (red) in all areas pooled together. Dark colors indicate the point estimates. Light colors indicate the 95% Confidence intervals.

7. Discussion

7.1 Expected and mean school size and weight

In previous years, sometimes the mean and sometimes the expected school sizes were considered, but they were usually similar. In 2019, there were large differences between both in all areas except G, both for all animals and for reproductive adults only. The same issue occurred with weight, although only in areas A and C. Areas E and G had very similar mean and expected weight, both for all animals and for reproductive adults only, as was the case for the overall estimate with all areas together for all animals (a bit more different for adults, but not for much).

For re-analysis of the whole series, the approach discussed with the Distance developers (described above in section 2.4.1) was undertaken. The variables `size.log` (logarithm of the school size) and `weight.log` (logarithm of the weight) were introduced as advised by the Distance developers during our conversations, as it is usually easier for the detection function to handle this when the range of school sizes is very wide, as is the case of the BFT sightings.

When redoing all detection functions allowing for school size (or weight) or their logs to be used as a covariate, almost all detection functions chose the logarithm of size (and weight in a few cases) as one of the main covariates in the model. This is a good thing as it then incorporates the variability in detection probability according to the size of the schools, solving the troubles we had previously with mean/expected school size and the size bias issue. Now the final abundance estimate is calculated by the MCDS engine using the mean, being the size bias already accounted for in the detection function.

7.2 Juveniles and adults

This year is the first time that a distinction has been made in the analysis between juveniles not reproducing (those recorded as “small”) and reproductive adults (medium, large and giant sizes). As seen in the tables above, the difference in total abundance and weight between all Bluefin tuna and reproductive adults only is minimal and therefore not significant (well within their respective 95% Confidence Intervals), being the juveniles a tiny proportion of the whole. This is true for areas A, C and E and for the all. However, in area G most of the animals are juveniles, and a difference in estimates is much more obvious. Nevertheless, the proportion of the number of animals and weight in area G with respect to the other three areas is minimum, so it hardly makes any difference in the total estimate.

7.3 Effects of the covariates in the detection functions

See Annex 1 for the plots to follow the discussion. In each plot, the observations corresponding to each level of the factor covariate are shown in a different color. For continuous covariates a different gradient of color is shown.

- *Airplane and company:*

It is interesting to see the big change in effect of airplane on the detection function between the two periods. This variable is highly correlated with Company. Cessna was used always by ActionAir and Perigod, Partenavia always by AirMed and Unimar, and Partenavia Observer only by AirMed in 2015.

The main difference between the two periods corresponds to the Partenavia/AirMed. In 2010-2013 the plot shows a very different pattern for Partenavia and Cessna (equally a very different pattern by ActionAir/Perigod, almost identical between them, and AirMed/Unimar, although with some difference between them). The sightings by Cessna (ActionAir/Perigod) are much closer to the line transect, at shorter distances, while Partenavia (AirMed/Unimar) have much more distant observations.

However, the pattern gets inverted in the period 2015-2019, except for Partenavia Observer (AirMed 2015) which still follows the same pattern as 2010-2013. In the plot for companies, it is also clear how in the second period AirMed observations got much closer to the line transect compared to ActionAir and even Unimar (using the same airplane as AirMed).

Only looking at the plots for 2010-2013, one could think that the difference is due to the different configuration of the airplanes. However, the shift in pattern in 2015-2019 shows that this is not the case,

but it is an issue of the company observers. In 2015, with the Partenavia-Observer, AirMed still had the same pattern as in 2010-2013. However, after 2015, their whole pattern changed, probably due to the insistence that they should concentrate closer to the transect line than away from it. So they seem to have changed their searching behavior. All the other companies seem to have remain more or less with the same searching behavior all the time.

- Effort state

There is very little effect of the effort state (on or off) in terms of distances of detection. If anything, slightly closer to the transect line while On effort (probably because they are making more effort into following the searching protocol more strictly).

- Bubble window

Against expectation, the observations made with bubble window (brown dots in the plots) in the period of 2010-2013 are further in average than the observations made without bubble window (green dots in the plots). One would expect to have more observations further from the transect line when not using bubble window. However, these plots do not say that with bubble windows all observations are further away, but rather that they disperse more from close ranges to further away, while the observations without bubble windows for some reason do not extend that further away.

A possible explanation is that it was mainly AirMed the company who did not have bubble windows until mid 2011, and we have seen that during the first years AirMed tended to search much further away than the other companies. Therefore, this could be a confounding effect of being AirMed the company without bubble windows for long time during 2010-2013.

However, in the period of 2015-2019 (when also AirMed changed their searching behavior), there is no effect at all of observations made with or without bubble windows in terms of how far they were detected.

- Clouds and Clouds2

Clouds coverage was not recorded during 2010-2013, so it could only be tested during 2015-2019. These years, there is a pattern where the less clouds, the further away the observations are detected, with the clear skies (0 clouds) having the longest range of detections. The reasons are not clear for the difference. However, the effect is not too large.

- Glare and Glare 2

Glare did not converge for the period 2010-2013, but Glare2 did. In 2010-2013, the absence of glare (green dots in the plot of Glare2) had a strong effect in extending the range of observations very far into the distance, as compared with the other categories where glare was present. A similar effect is observed for Glare in 2015-2019 although much more subtle. When using Glare2 in 2015-2019 the effect is not so straightforward, although still lower intensities of glare (1_2) extend further than stronger intensities (3_5).

- Haze2

Contrary as expected, in both periods observations made when there is no or little haze (0_1) concentrate closer to the transect line, while they extend further away when there is more haze (2_4). The effect is not strong, and it is possible caused by the difficulties of detecting groups even underneath the plain when there is haze, so the observers tend to extend their search further away too.

- Observer type

In the period of 2010-2013, contrary to what we were expecting according to previous analysis, the observations done by SS (Scientific spotters) extend further away than those by PS (professional spotters). Maybe the fact that all the furthest observations (usually made by PS) were truncated for the modeling of the detection function has something to do with this pattern, and also because in those years, the SS most probably did not look properly under the plane either.

In the period 2015-2019 there are no differences between both observer types.

- On Track

There is no difference in detectability either being on track or off track.

- Seastate and seastate2

There is basically no effect of sea state in none of the periods. When grouped by classes in seastate2, there are almost no differences either, especially between 0_1 and 2_3, but there seems to be a pattern of extended distances for higher seastates (4_6), although very few observations were made in such sea state, especially in 2015-2019. Also in this period there is a slight difference with sea states 2_3 having a bit more extended distances than calmer sea states (0_1). Maybe it is easier to concentrate in the shorter distances when there are calmer seas, and when the sea state increases, the observers try to look also further away.

- School size and log of school size

The variable school size has such a large range of values, that it was not possible to run in most cases, as it crashed the detection function. Only in one case was possible to obtain a plot to look at the effect and cause of the problem, in 2010-2013 for all sizes. The problem is obvious in this plot, where only the small school sizes are scattered over the histogram of distances, while most of the observations (including the large school sizes) form a straight line at probability of detection=1. Therefore, we worked with the logarithm of school size.

In the plots of size.log, it is very clear the strong effect it has on detectability, on both periods, with the smaller groups (black dots in the plots) closer to the transect line, and the larger groups (from purple to orange dots in the plots) extending increasingly further away.

- Size classes

In the size classes, the pattern is not so clear in both periods, although the small school sizes (1_50) are clearly all much closer to the transect line than all the others with larger sizes. Maybe the three other classes do not have the adequate breaks and so they are confounding. But in any case, the difference between small (less than 50 animals) and larger than that is very strong.

- Subjective

Subjective was not recorded during the 2010-2013 surveys. In 2015-2019, the pattern is clear: the good conditions in both sides (GG, green dots) or on one side only (GM, brown dots) have much closer detections than the observations made with poor (PP and MP) and moderate (MM) conditions. This pattern, as happened with several others above, goes against intuition. But maybe the same effect is happening in all cases: when the conditions are good, observers tend to concentrate more closer to the track line, while they extend further away their search when the conditions are not so good, and therefore maybe not so easy to detect the animals.

- Turbidity and Turbidity2

In both covariates occur the same pattern just commented. With clear waters (turbidity 0), observations tend to concentrate closer to the transect line, while they extend further when there is some turbidity in the water (values 1 to 3). With clear waters it is expected to see animals clearer from a vertical position (from the airplane down to close to the track line) when they are even underwater, so probably observers focus more on this area where there is no turbidity.

- Weight classes

This variable presented some problems in 2010-2013, as can be seen for all sizes with a failed function. In 2015-2019, a similar effect is observed as for the size classes, with the small ones (8-1000Kgs) much closer to the transect line than all the others which are more confounded among them.

- Logarithm of weight

This variable did not work in 2010-2013. In 2015-2019 the same effect as with size.log can be observed, with the observations with smaller total weight (black dots) closer to the track line and the observations with increasing weight (purple to orange dots) getting further away from the track line.

7.4. Selected detection functions

Almost all detection functions, in the three areas configuration, selected a measure of school size or weight (usually size.log), airplane, seastate, turbidity and in a few cases glare2 and bubble (see table 3.2.1). Annex 2 shows the resulting plots of the detection functions pooling together the three covariates selected by each one. The qq-plot in all of them, as well as the goodness of fit tests (table 3.2.1) are very good, indicating a very good fit of the detection function to the field observations.

In Annex 1, looking at the plots, as well as what was discussed in the previous section 7.3, it seems obvious that those were the covariates with stronger effects and clearer distinguishable patterns, except for seastate, which by itself didn't show any particular patterns, but maybe when put together with turbidity or size.log, it actually produced some noticeable effect.

7.5 Precision of estimates

The CV of abundance is determined by the CVs of estimated density of schools and expected/mean school sizes/weight in each sub-area. The CV of estimated density of schools is determined by the CVs of encounter rate (number of schools seen per survey km) and effective strip half width (*esw*). All of these quantities are functions of the number of schools seen, as well as the distribution of the data.

Looking into all sizes (taking areas 2010-2018 as example), CVs for density of schools in Area A varied between 31% and 55% depending on the year. In area C it varied between 27% and 54%. In area E it varied between 26% and 42%. In area G it varied between 23% and 72%. And pooling all areas together, it varied between 20% and 31%.

The variation in CVs for density of schools when looking into adults only (also areas 2010-2018 as example), was of 30-55% for area A, 32-74% for area C, 31-54% for area E, 35-55% for area G, and 23-37% for all areas together.

The precision of mean school size, also looking at the same dataset, for all sizes, varied between 11 and 50% for area A, 17 to 56% in area C, 21 to 74% in area E, 20 to 53% in area G, and 17 to 47% for all areas together.

The precision of mean school size for only adults was 11-49% for area A, 17-60% for area C, 20-77% for area E, 22-55% for area G, and 18-58% for all areas together.

The CVs generally increase slightly for the adults only datasets because the number of observations is smaller.

The number of schools seen in most of the areas per year was insufficient to estimate an independent *esw* per area/year so data from all sub-areas and periods of years were pooled together. This is acceptable as long as differences in conditions in each area (such as sea state, air haziness, water turbidity, observers) or the differences in searching patterns (team, observer type) can be investigated as a covariate in fitting the detection function, as was done here. Using the same *esw* for multiple areas generates correlation in the estimates which was taken into account in estimating the CV of total abundance by stratifying by area.

The main way to reduce the estimated CVs in future surveys is to increase the number of sightings, to reduce the CVs of the encounter rate. This can be achieved partly by more efficient searching and partly by increasing the amount of searching effort (transect length). For example, exclude in future surveys the very shallow waters (e.g. 0-100m) where no animals are seen, excluding area G, or to adequate better the seasonality of the survey in each area with information derived from satellite tagging or sea surface temperature or other means (although all this might be logistically very difficult) to maximize effort in the areas with maximum density. However, the sample size is also a consequence of the study year real density of animals. So, sometimes little can be done to improve it.

Nevertheless, another component of the overall CV, the mean school size, varies considerably and is relatively independent of sample size.

7.5. Changes over time

Figures 6.1 to 6.5 show how, in all areas, there is little difference between the estimates with all sizes included or with only adults, and even in many cases the latter yields slightly larger estimates. However, none of these differences are statistically significant, as they all fall inside the 95% confidence intervals of each other. The reason why the estimates including only adults are in general higher than those including all individuals is the effect on the effective strip width (*esw*). The *esw* obtained when considering only adults are smaller in all scenarios than considering all individuals (see table 3.2.1) suggesting that groups with juveniles are proportionally detected at longer distances than adults (maybe because the group size is larger considering all animals and therefore easier to detect at longer distances). The positive effect of the decrease

in *esw* over the density is stronger than the negative effect of the decrease in number of observations. Even the interannual differences have the same issue, the uncertainty around the estimates (CVs and 95% Confidence intervals) is so large, that it is not possible to determine if the differences among years are real trends or not. Only in a few cases there seems to be some indication, like in 2011 for areas A and C (and even 2010 for area C), when the estimates and the uncertainty around them fall outside (under) those of other years like 2017, 2018 and 2019 in area A and 2017 in area C.

When looking at each area separately, there doesn't seem to be a clear pattern downwards or upwards. It seems to be a negative correlation between areas C and E with opposite trends when comparing consecutive years. This could indicate that the spawners in these two areas should be potentially considered as only one area in the analysis. But when looking at Figure 6.5 with all areas together, there seems to be a downward trend, although there is not enough power in the data (because of the large uncertainty) to determine if it is real or not, and the contradictory shapes of the different areas makes it more confusing to interpret.

The same plots for weight (Figures 6.5 to 6.10) show practically the same pattern as for abundance of animals. The only differences to highlight are, first, the even larger uncertainty around the weight estimate on area E for 2015. And second, in Figure 6.10 with all areas together, there seems to be no trend at all, with a much flatter plot than for abundance of animals estimates, although with a small (not significant) downward line from 2017 to 2019.

7.6 Considerations of the Re-analysis and comparison with previous estimates

To produce the most reliable re-analysis and comparison, several points needed to be considered:

1. Create a new overlap area for Area A with the new edges created in 2019, so all years were using the same area.
2. Recalculate the surface area of all blocks with the more adequate updated projection used in 2019, specific for the Mediterranean (ETRS_1989_LAEA).
3. Pool together as much data as possible for detection functions to increase sample size, joining all areas in two different periods due to differences in the use or not of bubble windows and therefore the need or not of using left truncation.
4. Restructure the data from all previous years, as far as available information allowed, to discriminate between juveniles and adults and analyze the reproductive adults only separately as was done in 2019.
5. Include school size in the detection functions to ensure that the size bias in the detectability is taking into account.

Finally, the whole series was analyzed using the same criteria, in a more objective way. This same procedure will be used for future surveys.

Acknowledgements

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References

Buckland, ST, Anderson, DR, Burnham, KP, Laake, JL, Borchers, DL & Thomas, L (2001). *Introduction to distance sampling: estimating abundance of biological populations*. Oxford University Press, Oxford.

Cañadas, A. and Vázquez, J.A. 2016. Atlantic-wide research programme on bluefin tuna (ICCAT GBYP – PHASE 5 - 2015). Elaboration of data from the aerial surveys on spawning aggregations. Report available from ICCAT.

Gerrodette, T (1987). A power analysis for detecting trends. *Ecology* 68: 1364-72. Software TRENDS available from <http://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=228&id=4740>.

ANNEX 1

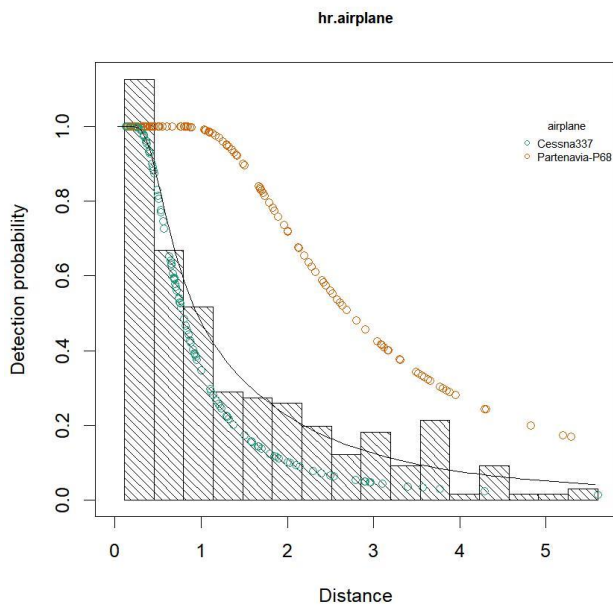
Effect of each covariate in the detection functions

The same covariate is presented for four datasets in each box:

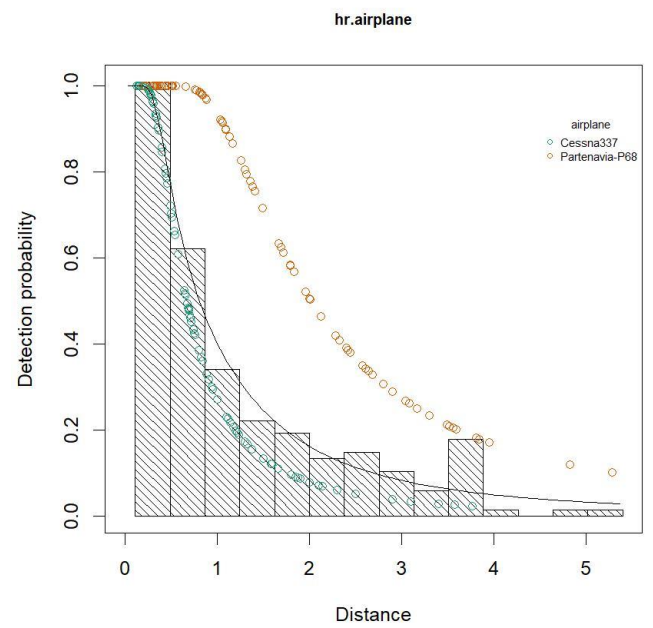
- Period 2010-2013 all size classes
- Period 2010-2013 adults only
- Period 2015-2019 all size classes
- Period 2015-2019 adults only

If a plot is missing from a box, it means that it did not converge or yielded any other problem, so it could not be used or plotted, or did not exist for that period of years.

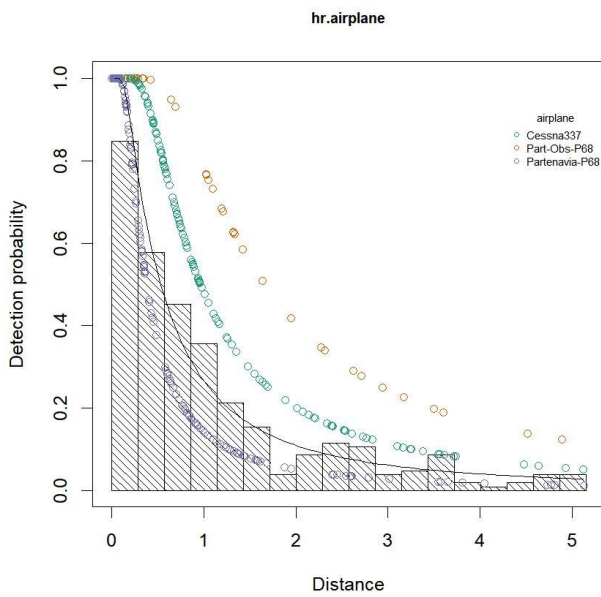
Airplane



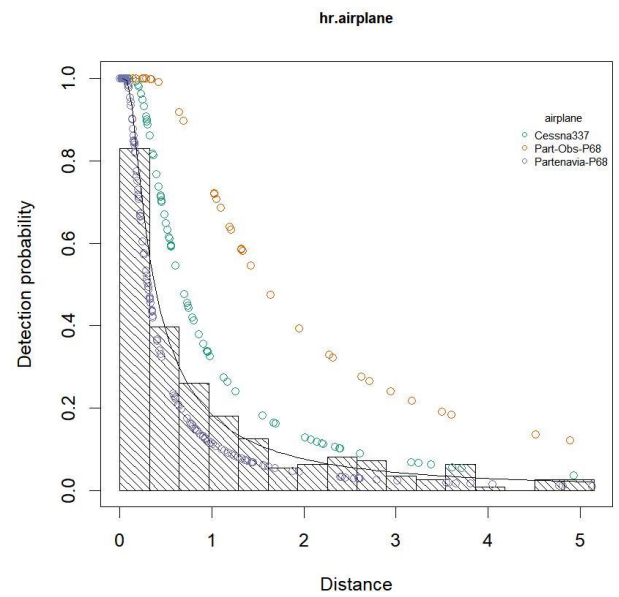
Period 2010-2013 all size classes



Period 2010-2013 adults only

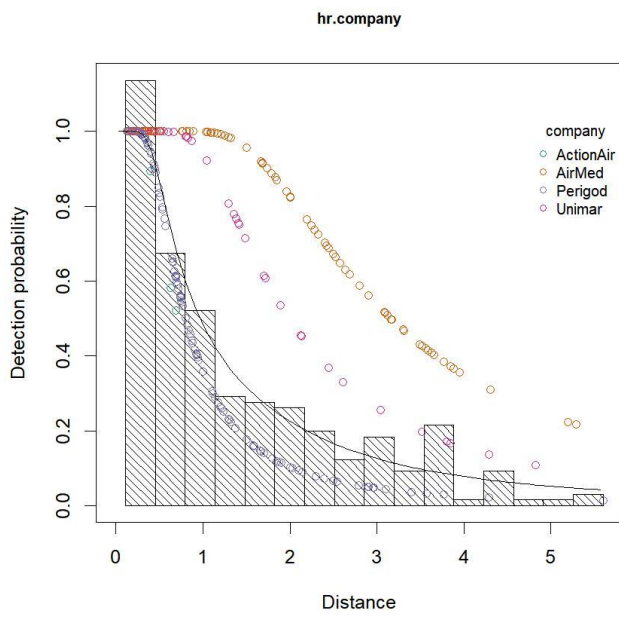


Period 2015-2019 all size classes

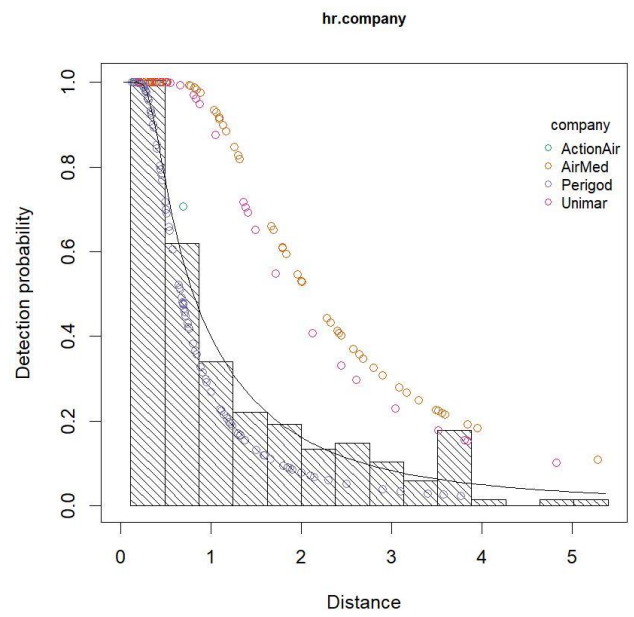


Period 2015-2019 adults only

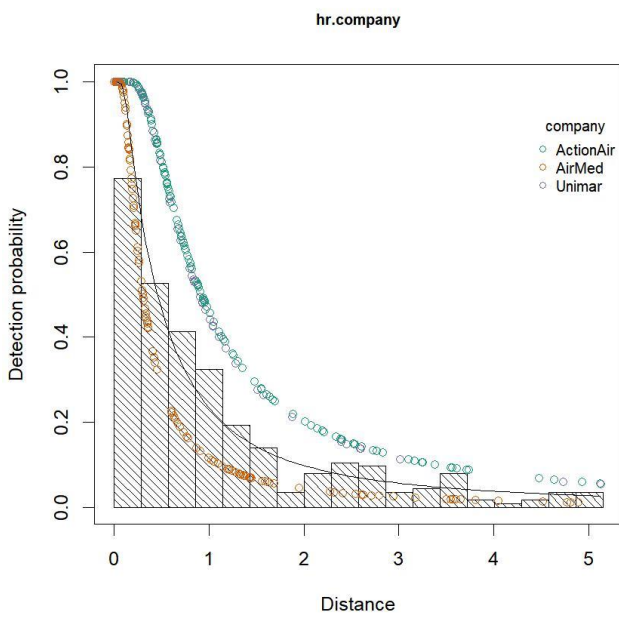
Company



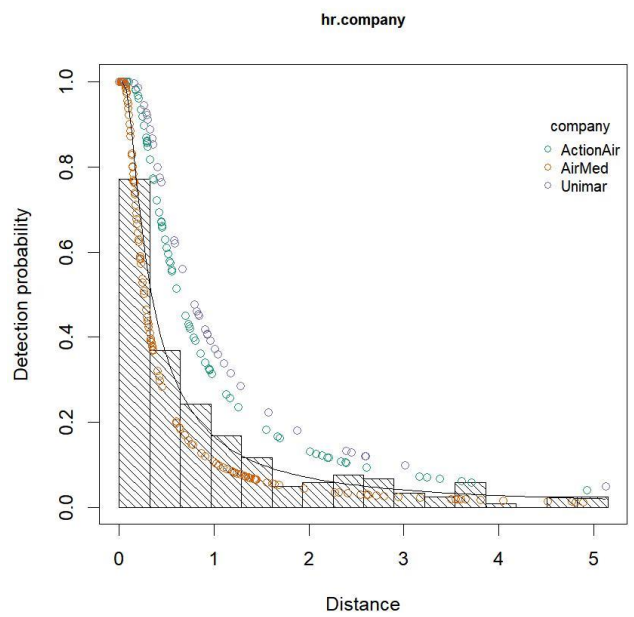
Period 2010-2013 all size classes



Period 2010-2013 adults only

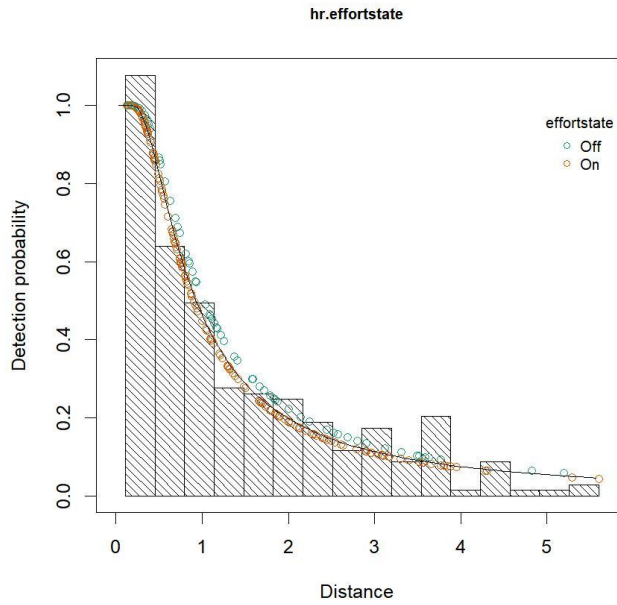


Period 2015-2019 all size classes

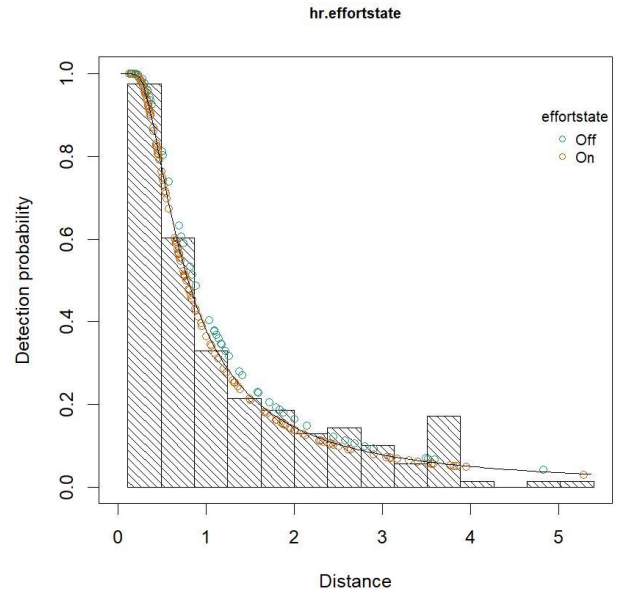


Period 2015-2019 adults only

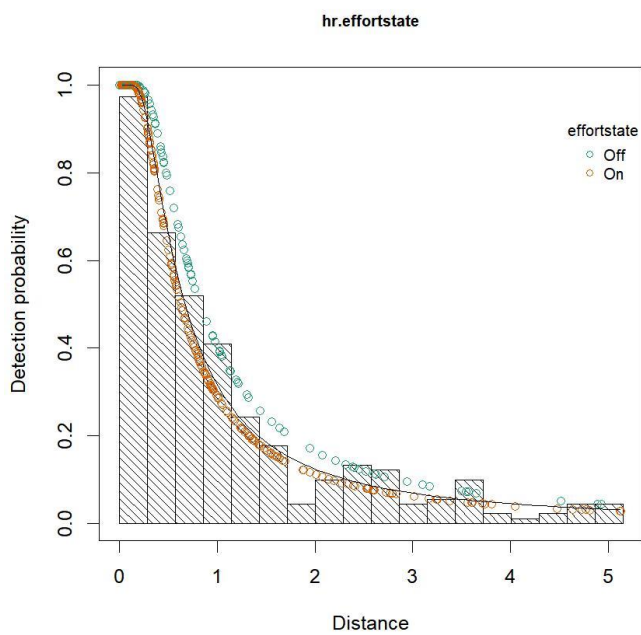
Effortstate



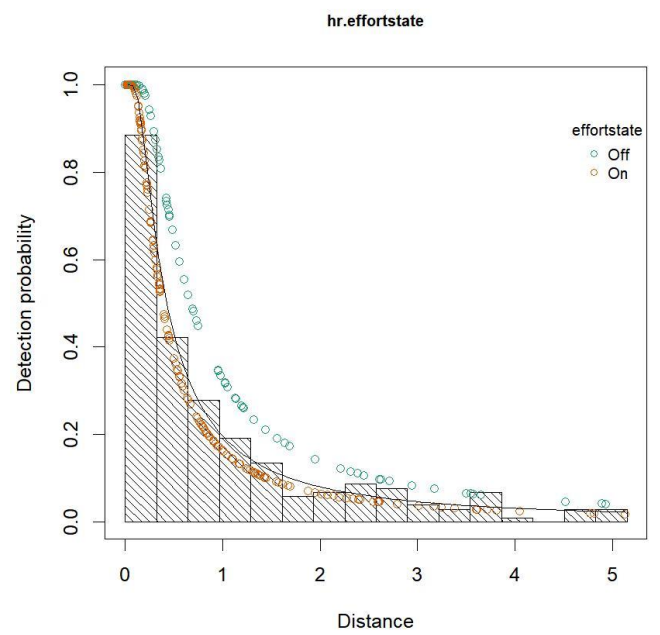
Period 2010-2013 all size classes



Period 2010-2013 adults only

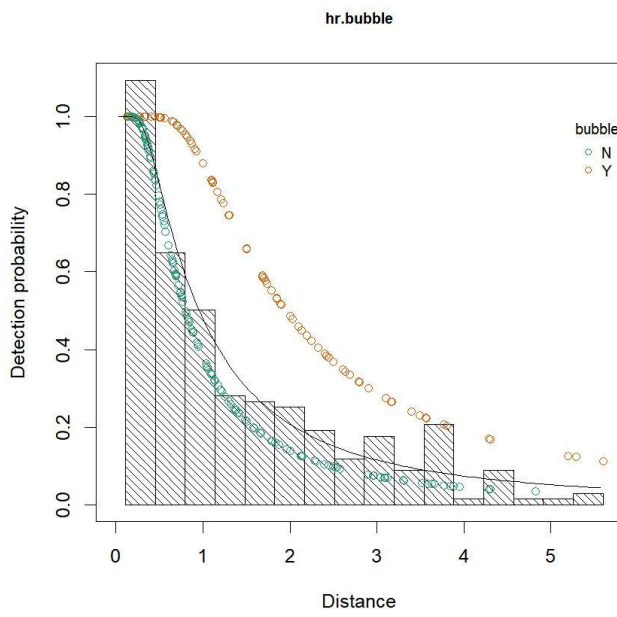


Period 2015-2019 all size classes

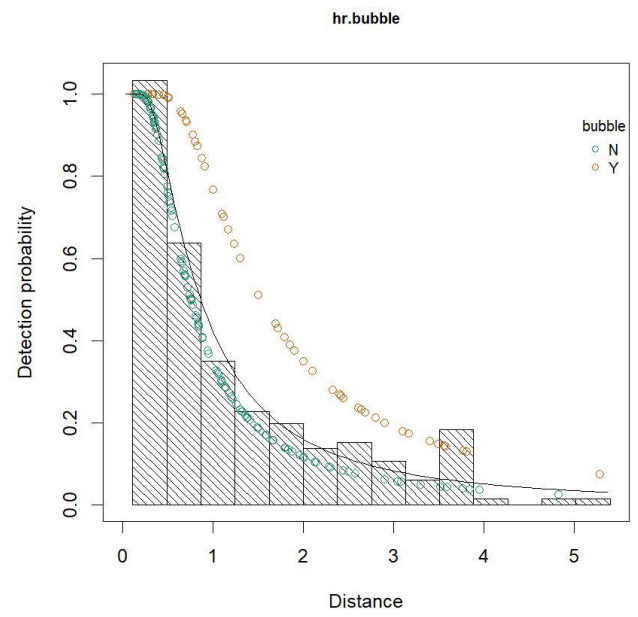


Period 2015-2019 adults only

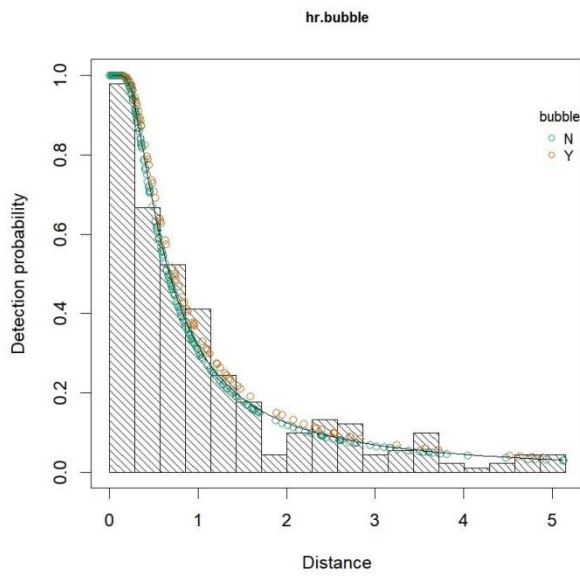
Bubble window



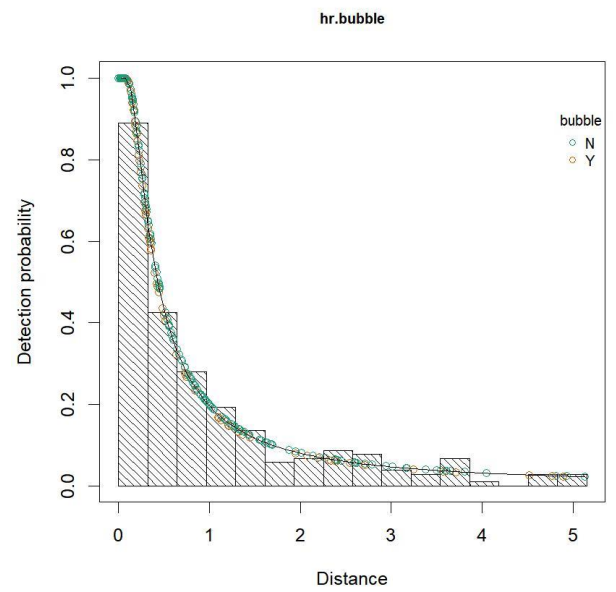
Period 2010-2013 all size classes



Period 2010-2013 adults only



Period 2015-2019 all size classes

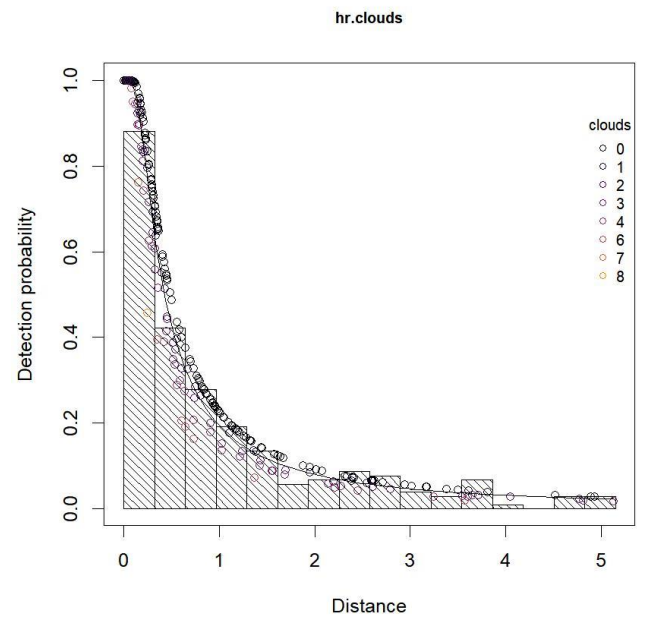
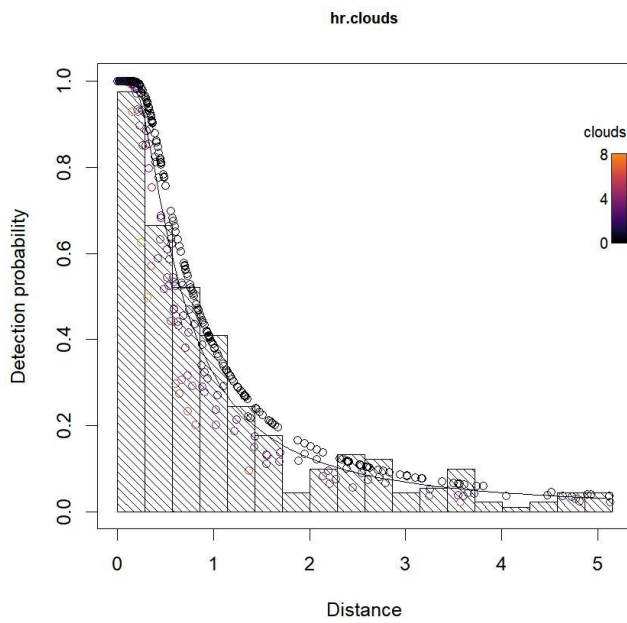


Period 2015-2019 adults only

Clouds

Period 2010-2013 all size classes

Period 2010-2013 adults only



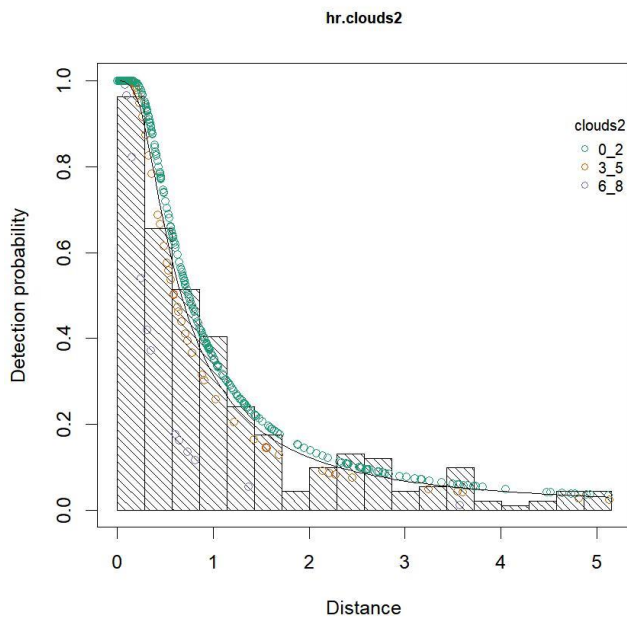
Period 2015-2019 all size classes

Period 2015-2019 adults only

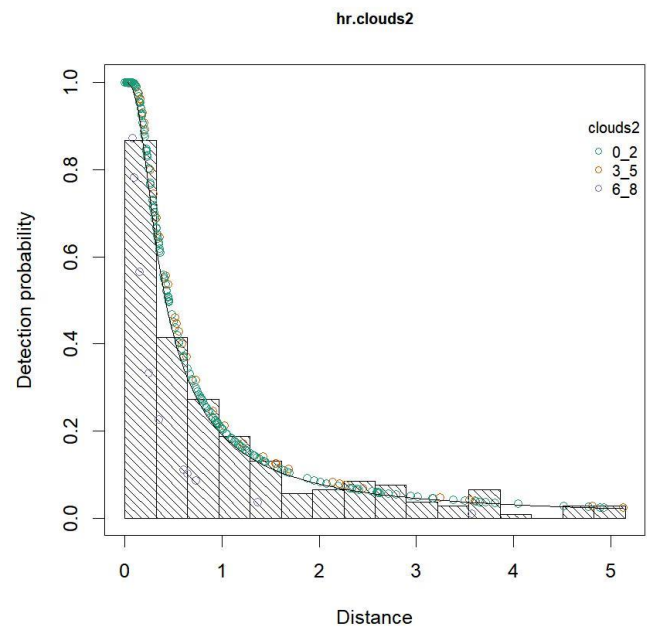
Clouds2

Period 2010-2013 all size classes

Period 2010-2013 adults only



Period 2015-2019 all size classes

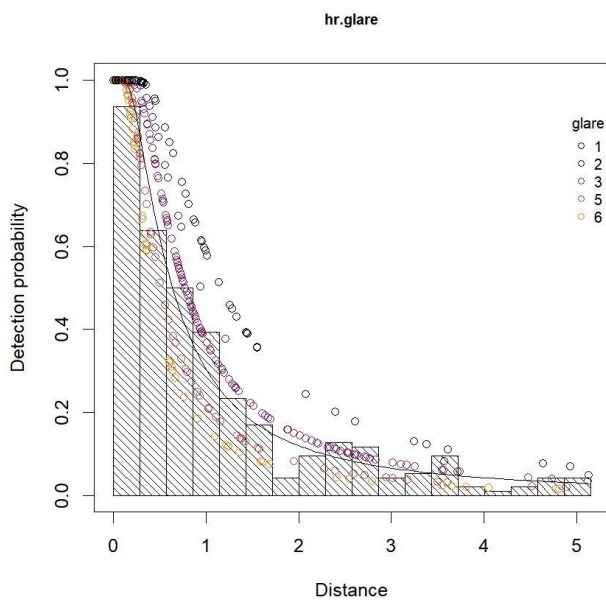


Period 2015-2019 adults only

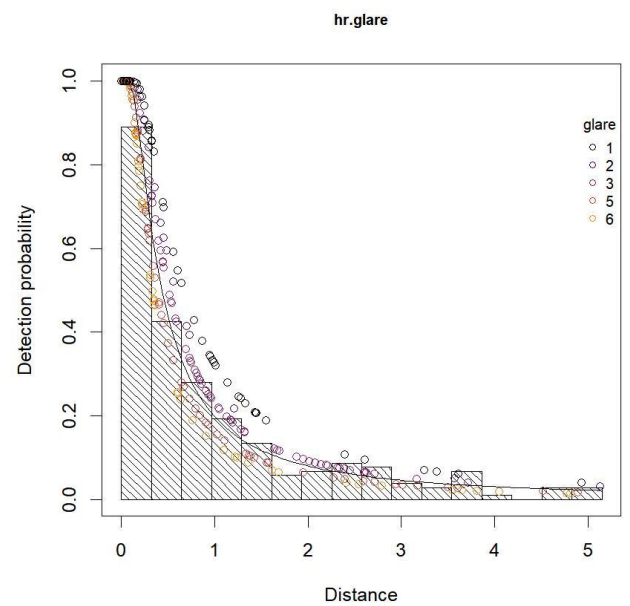
Glare

Period 2010-2013 all size classes

Period 2010-2013 adults only

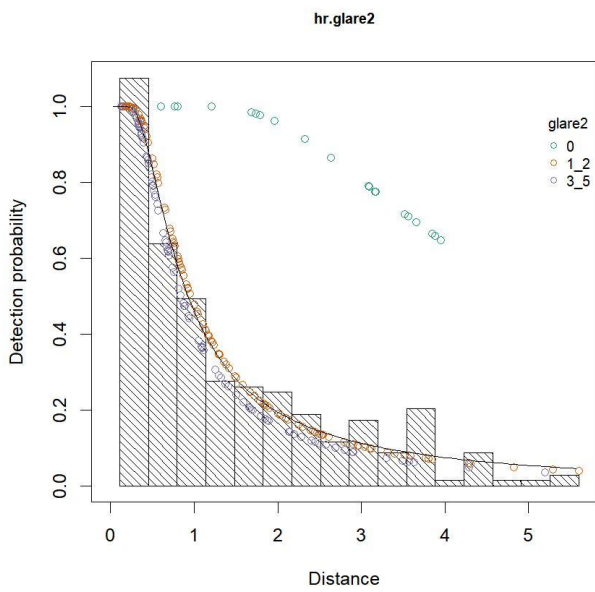


Period 2015-2019 all size classes

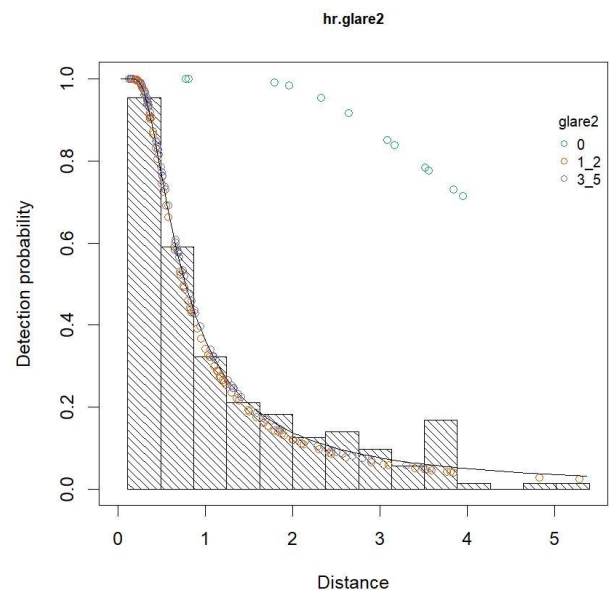


Period 2015-2019 adults only

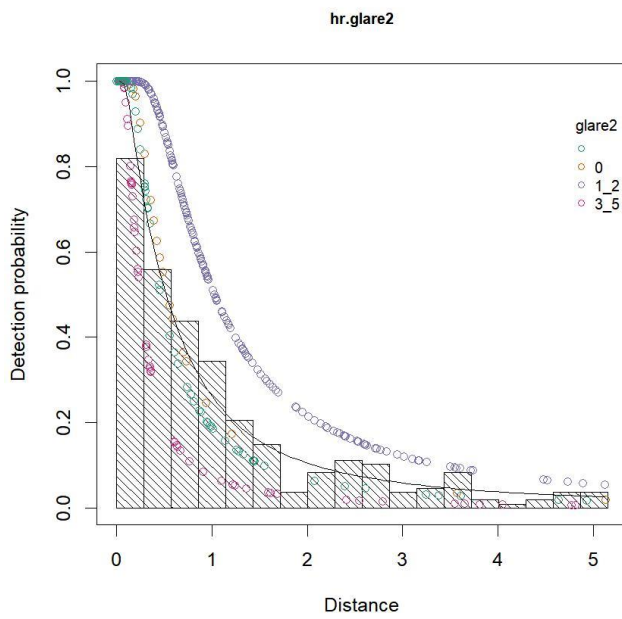
Glare2



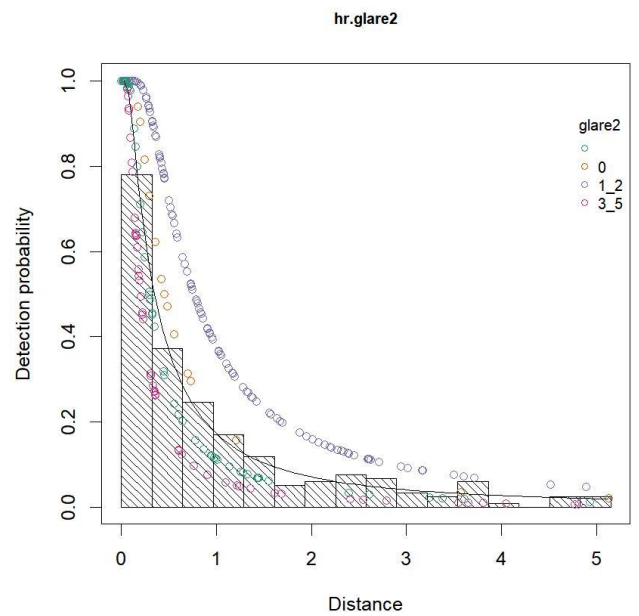
Period 2010-2013 all size classes



Period 2010-2013 adults only

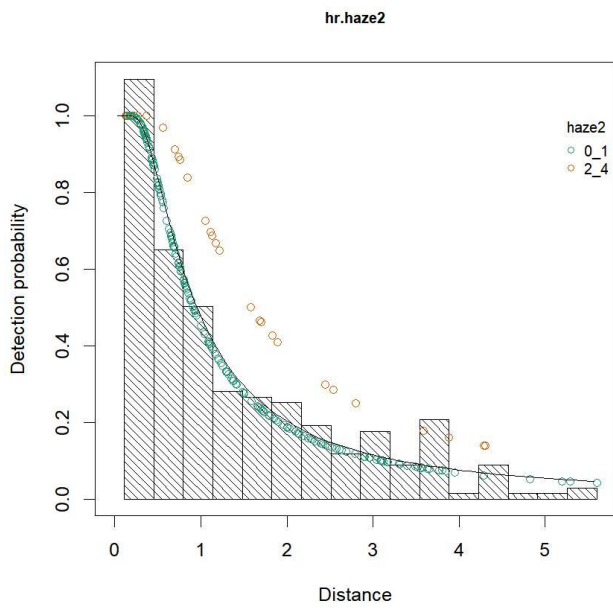


Period 2015-2019 all size classes

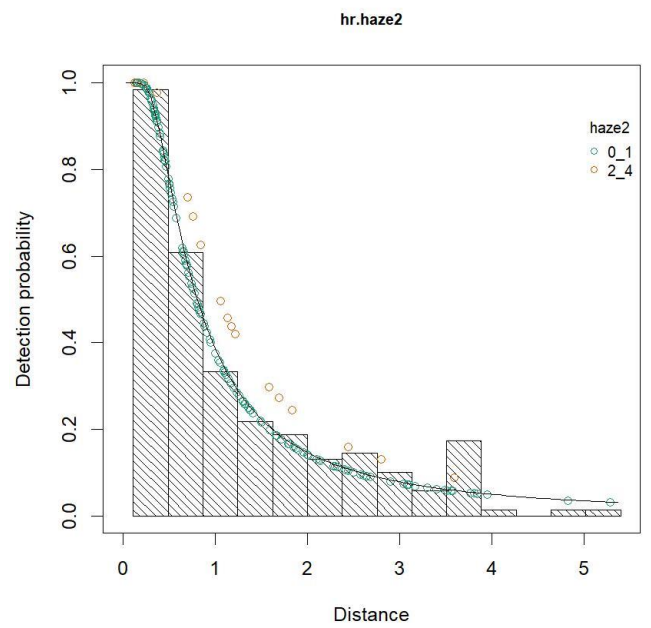


Period 2015-2019 adults only

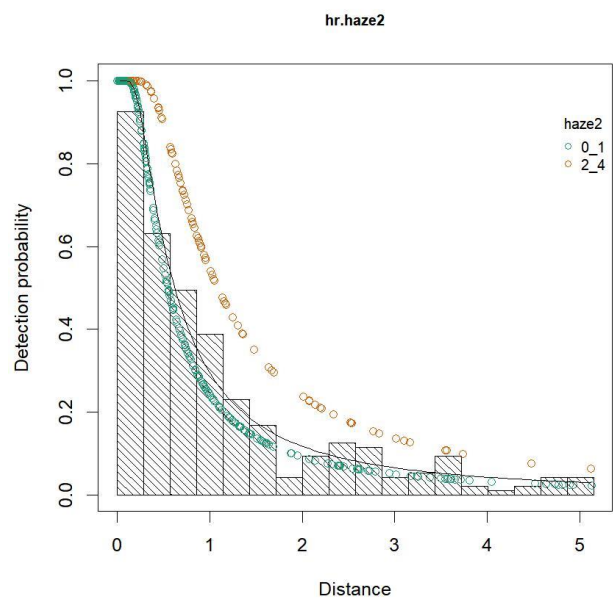
Haze2



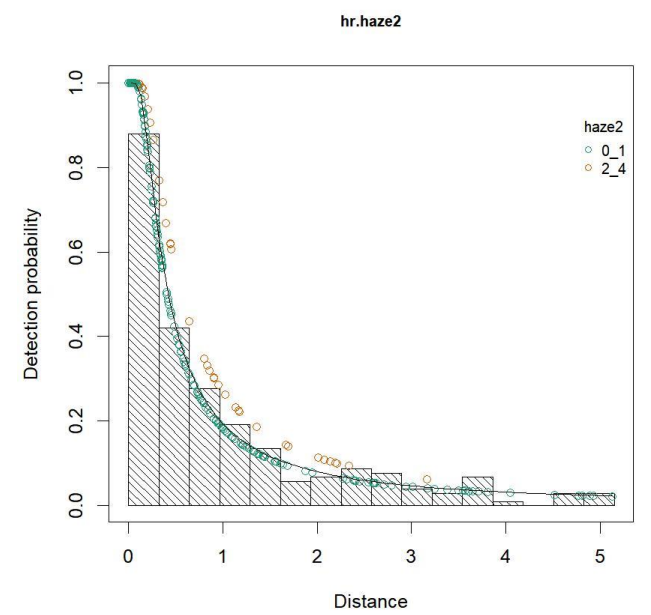
Period 2010-2013 all size classes



Period 2010-2013 adults only

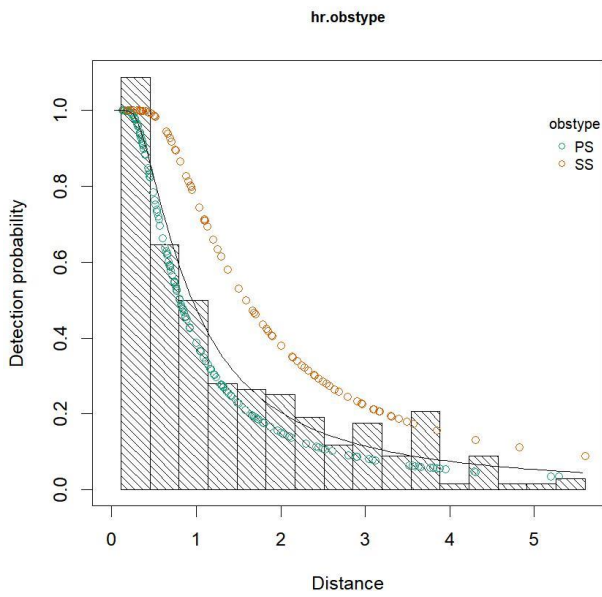


Period 2015-2019 all size classes

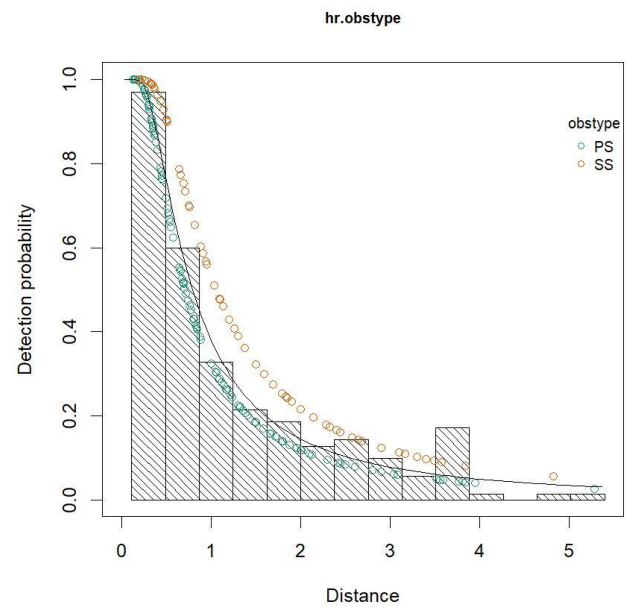


Period 2015-2019 adults only

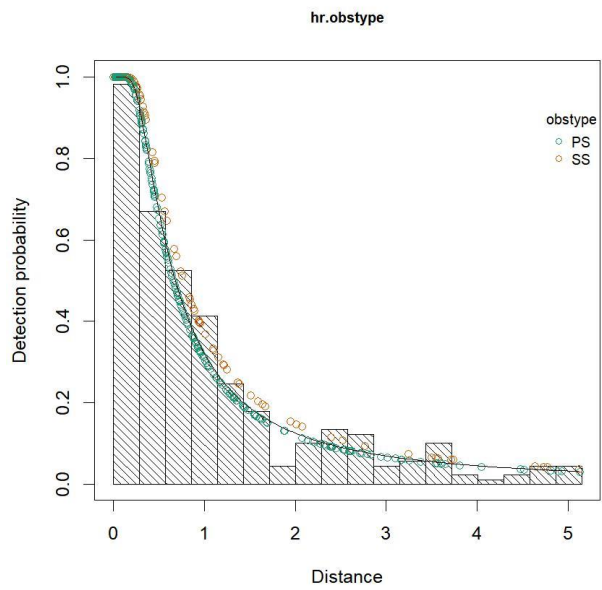
Observer type



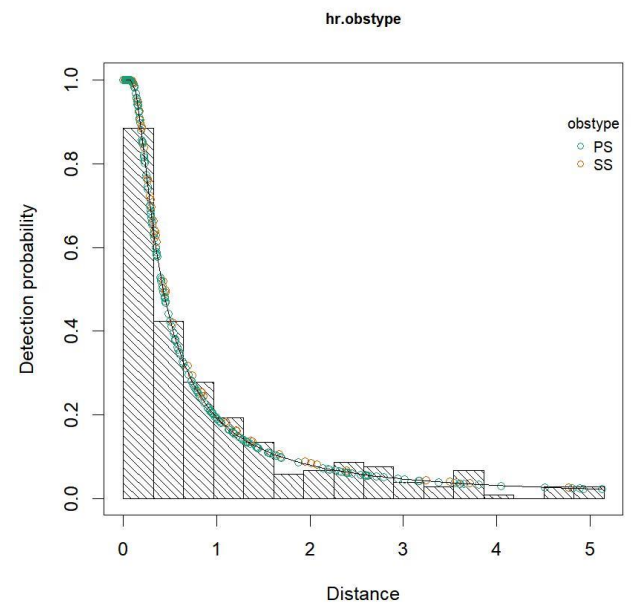
Period 2010-2013 all size classes



Period 2010-2013 adults only

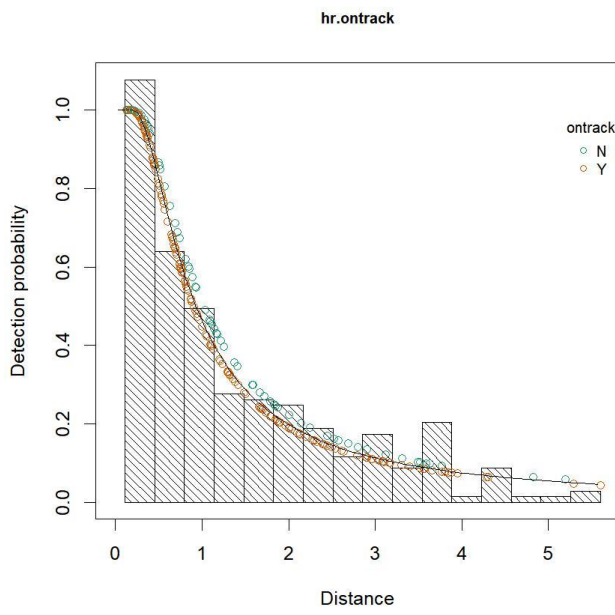


Period 2015-2019 all size classes

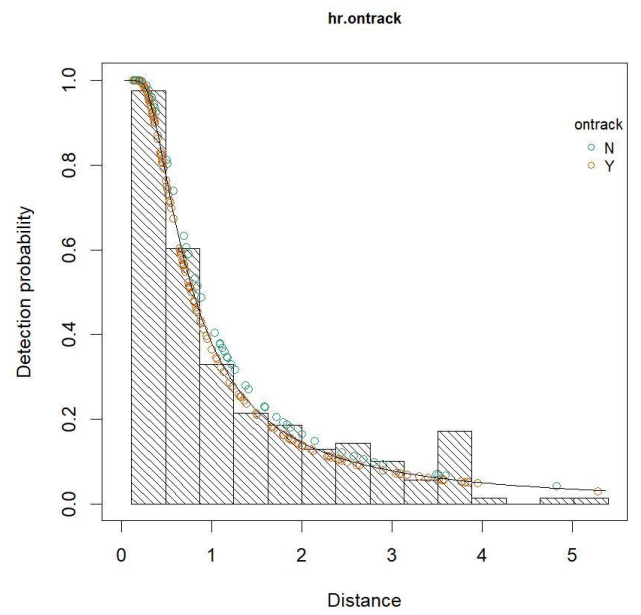


Period 2015-2019 adults only

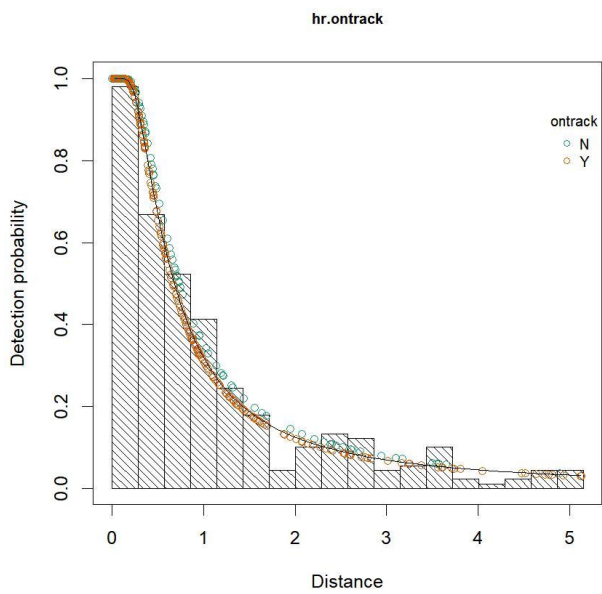
On Track



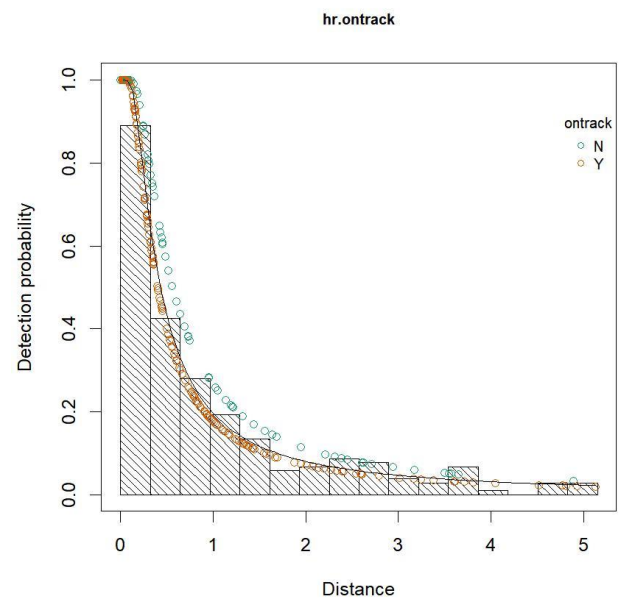
Period 2010-2013 all size classes



Period 2010-2013 adults only

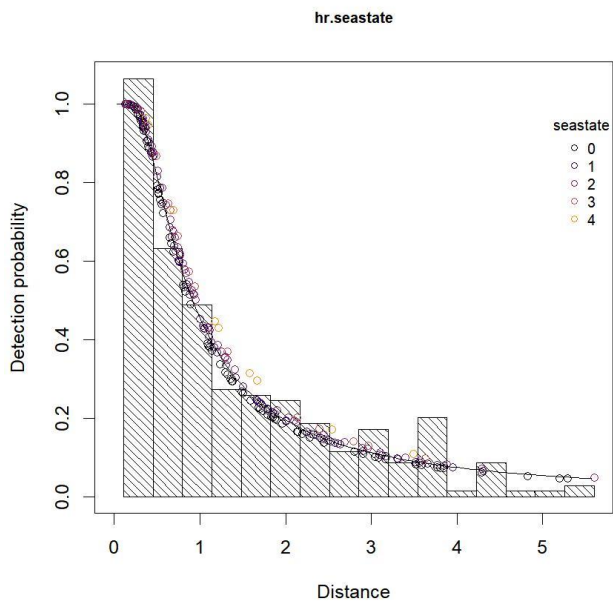


Period 2015-2019 all size classes

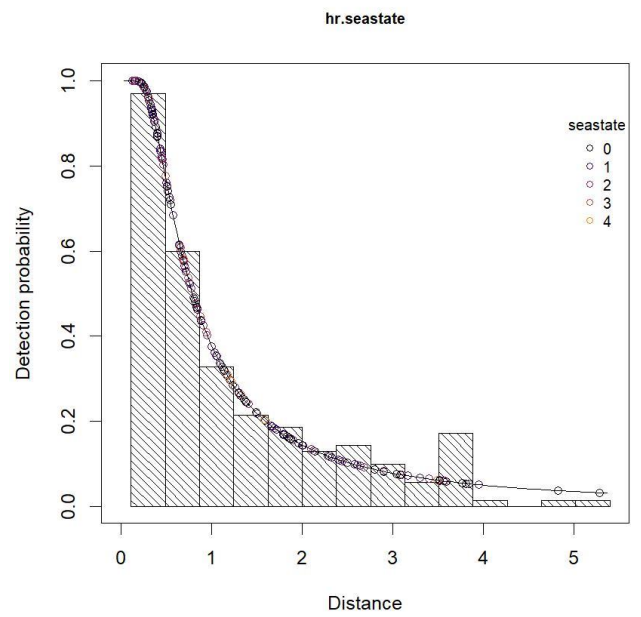


Period 2015-2019 adults only

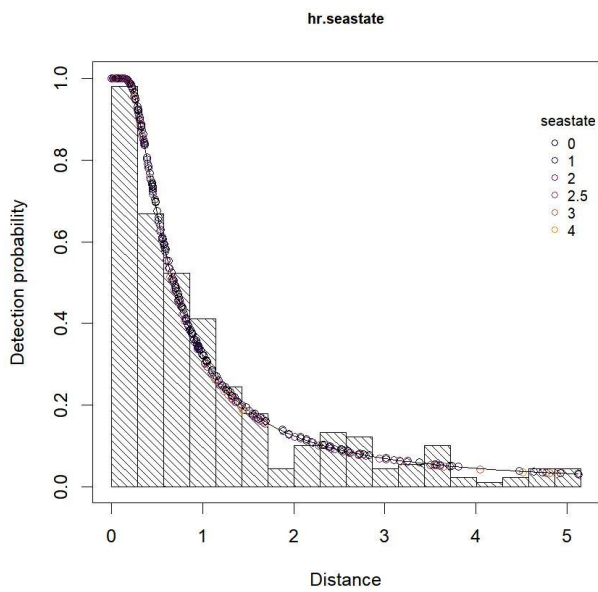
Seastate



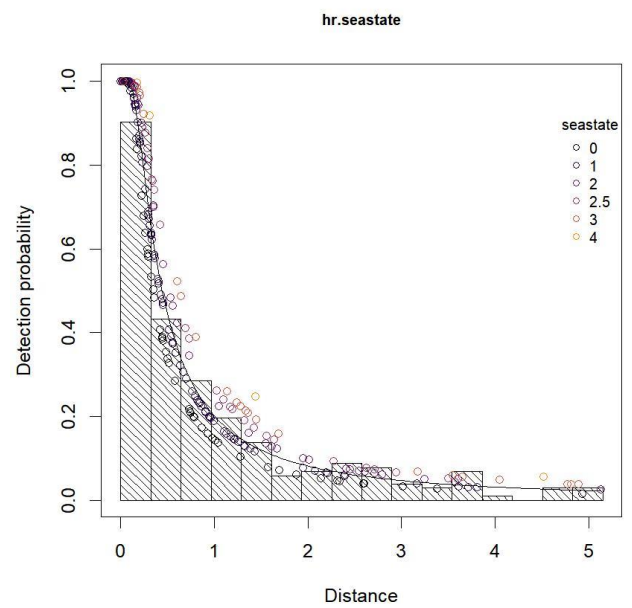
Period 2010-2013 all size classes



Period 2010-2013 adults only

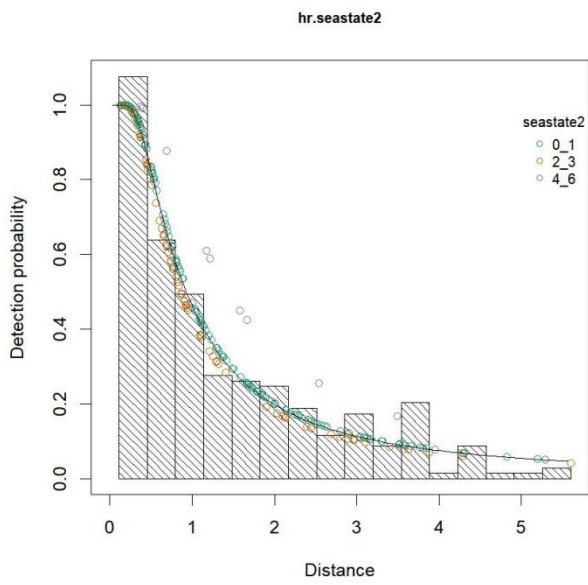


Period 2015-2019 all size classes

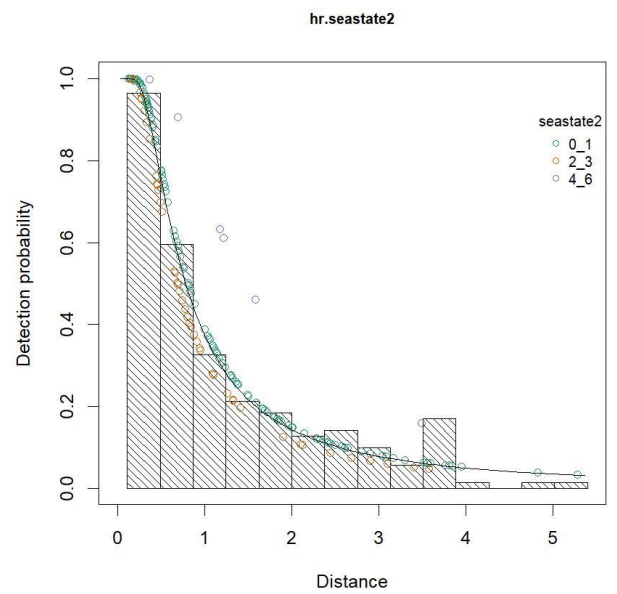


Period 2015-2019 adults only

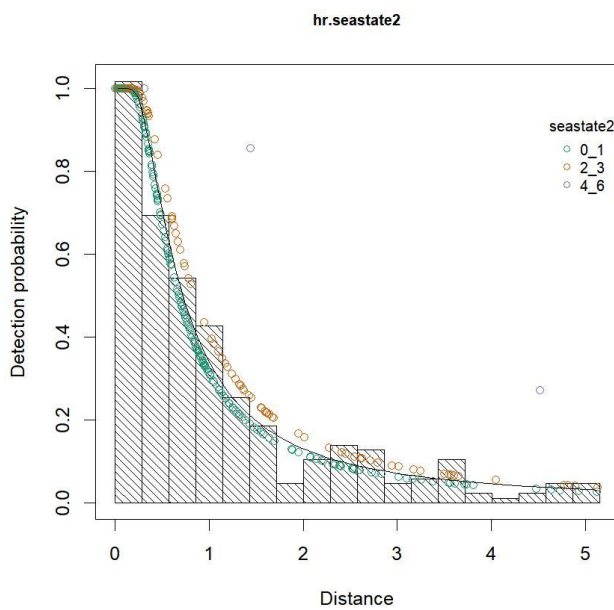
Seastate2



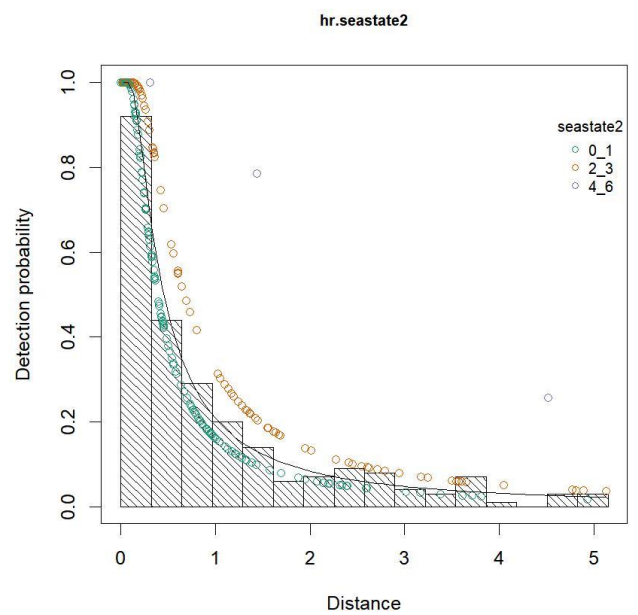
Period 2010-2013 all size classes



Period 2010-2013 adults only

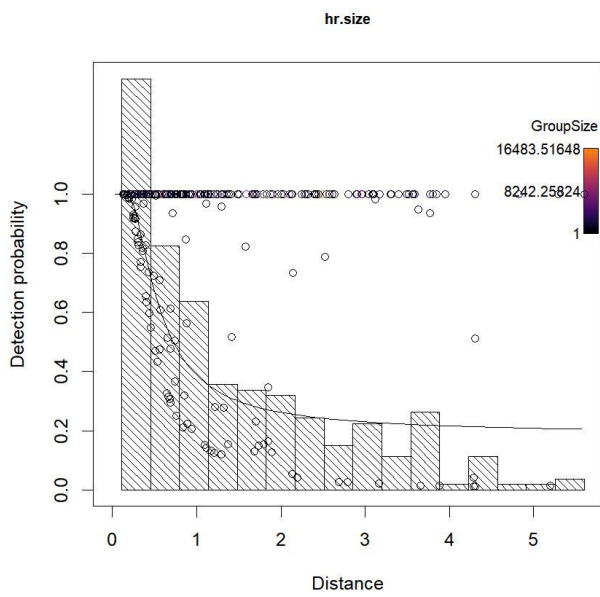


Period 2015-2019 all size classes



Period 2015-2019 adults only

School size



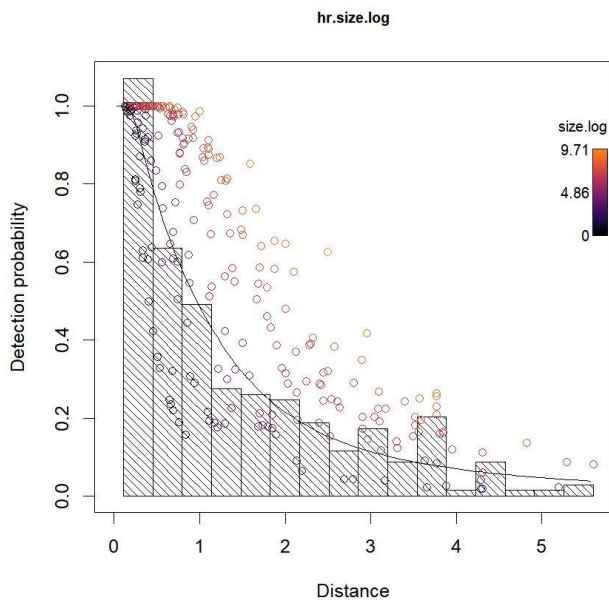
Period 2010-2013 all size classes

Period 2010-2013 adults only

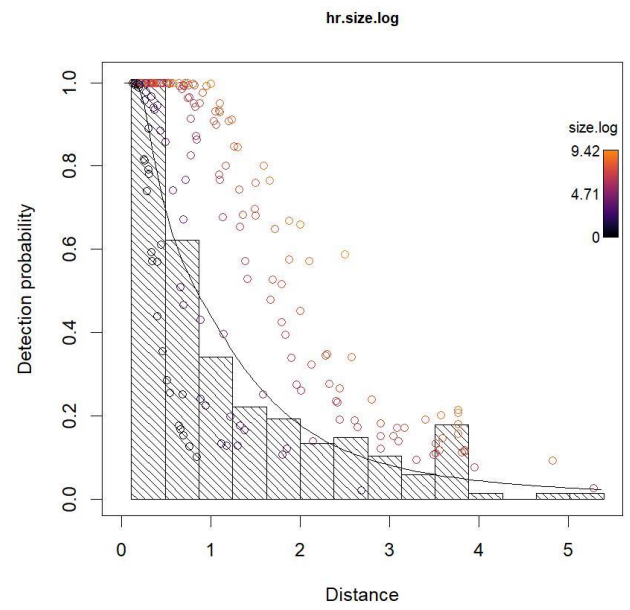
Period 2015-2019 all size classes

Period 2015-2019 adults only

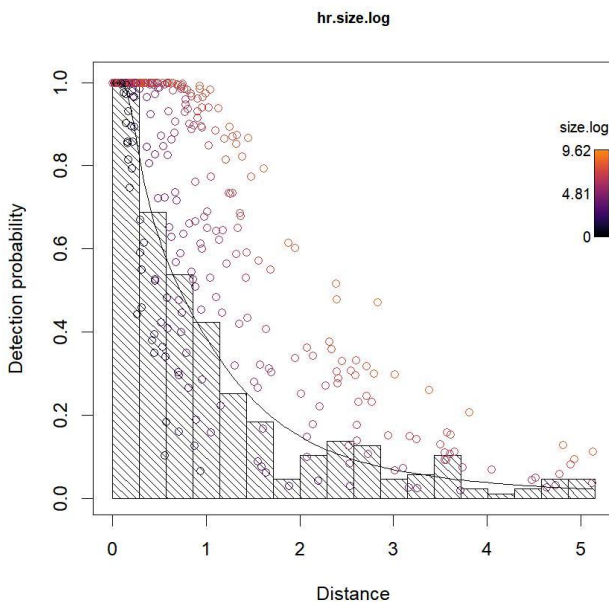
Log of school size



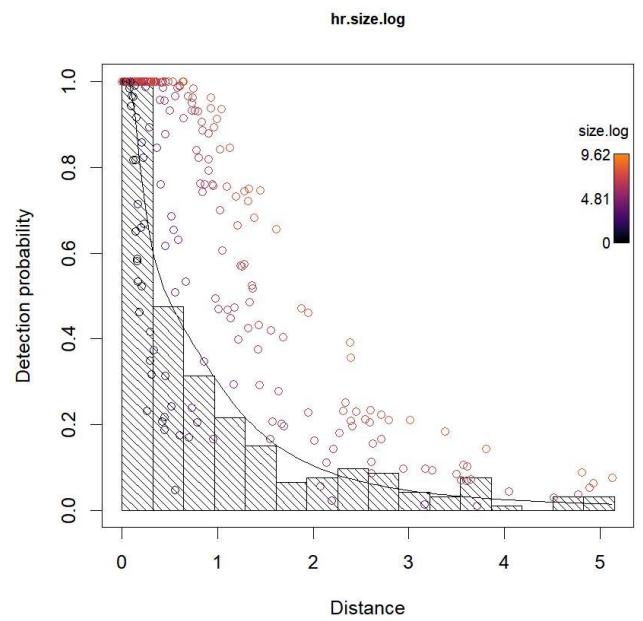
Period 2010-2013 all size classes



Period 2010-2013 adults only

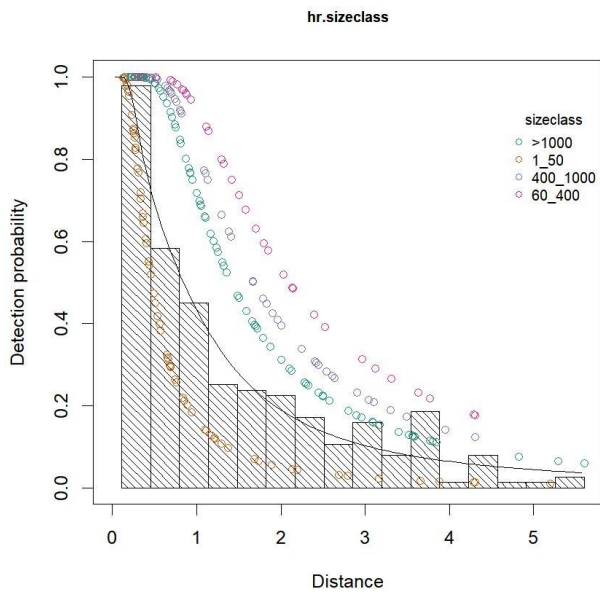


Period 2015-2019 all size classes

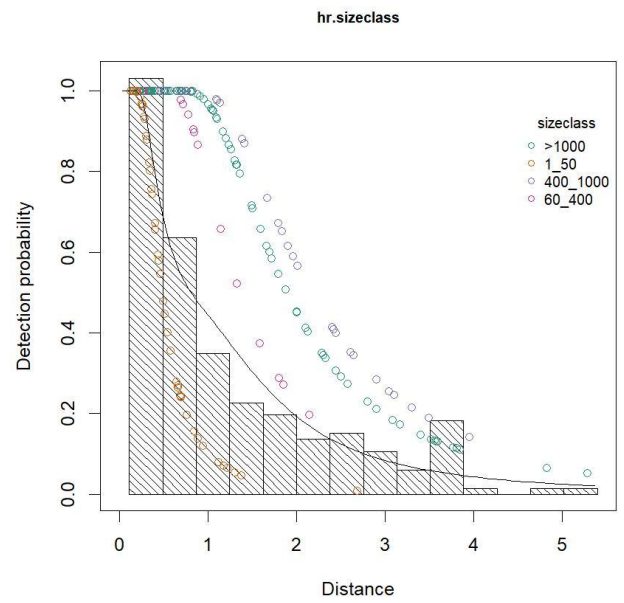


Period 2015-2019 adults only

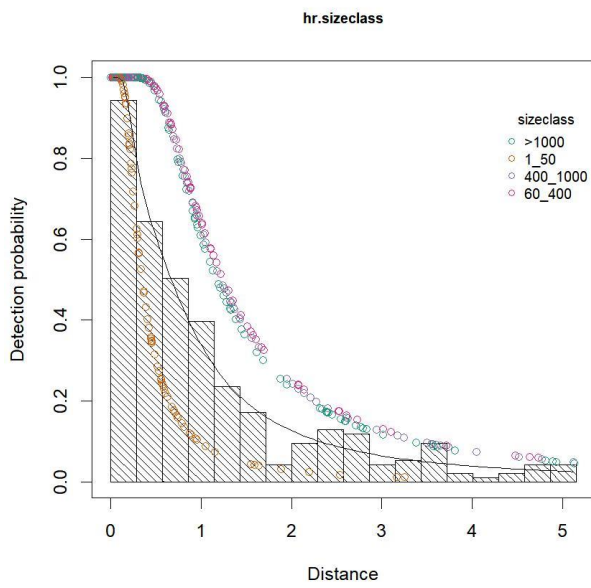
Size classes



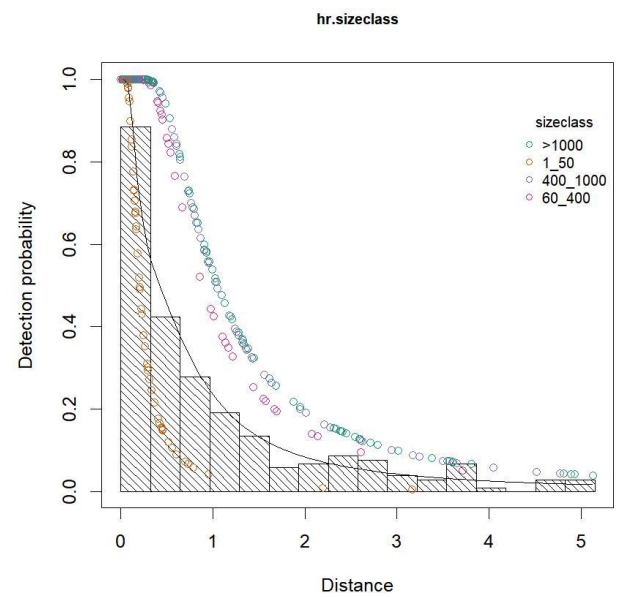
Period 2010-2013 all size classes



Period 2010-2013 adults only



Period 2015-2019 all size classes

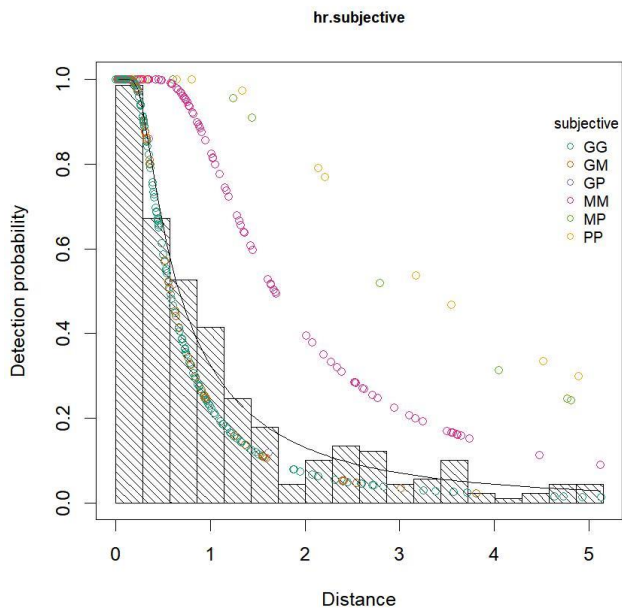


Period 2015-2019 adults only

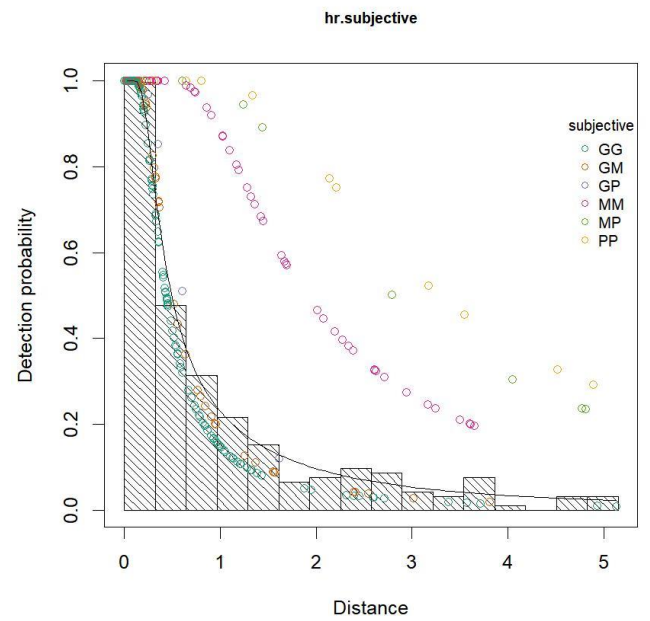
Subjective

Period 2010-2013 all size classes

Period 2010-2013 adults only

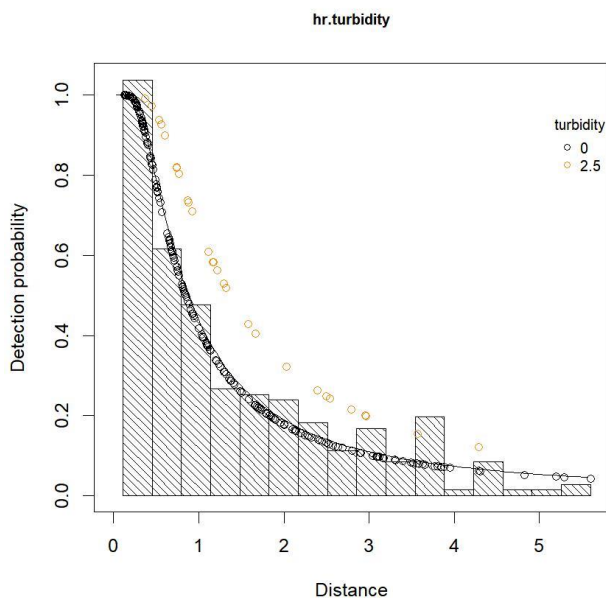


Period 2015-2019 all size classes

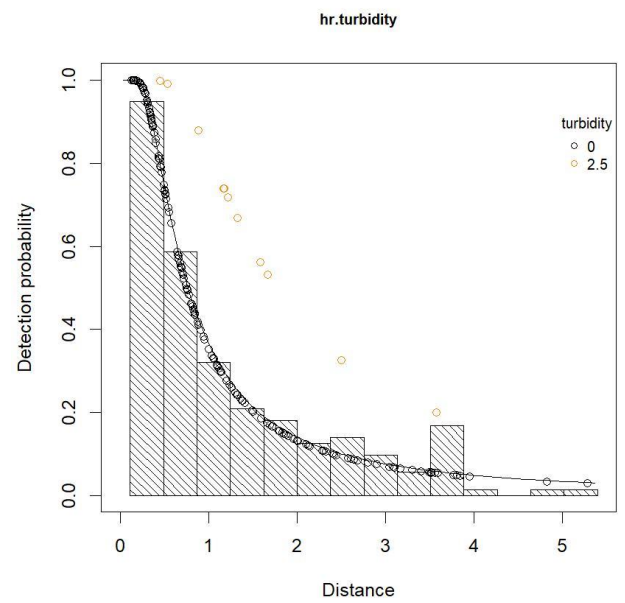


Period 2015-2019 adults only

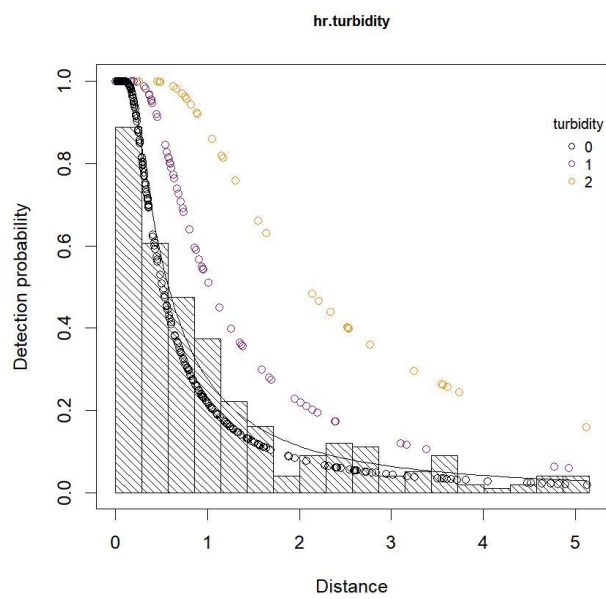
Turbidity



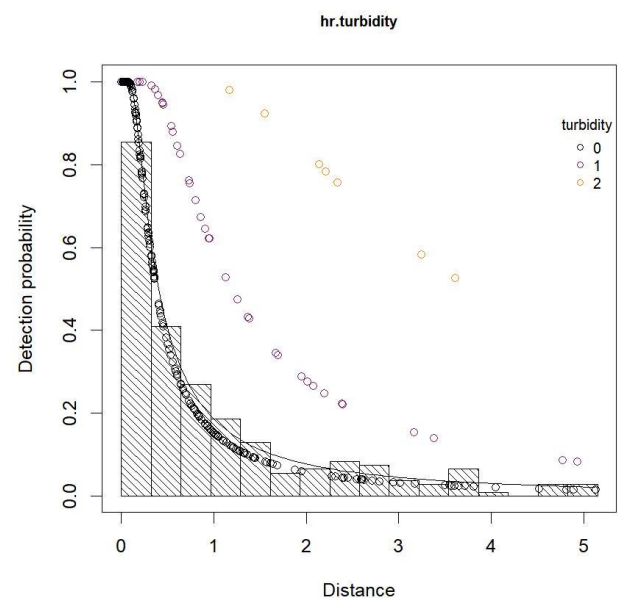
Period 2010-2013 all size classes



Period 2010-2013 adults only

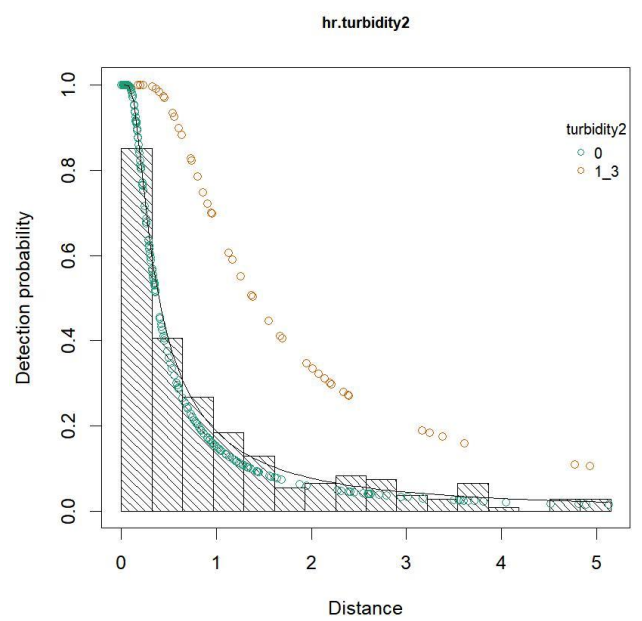
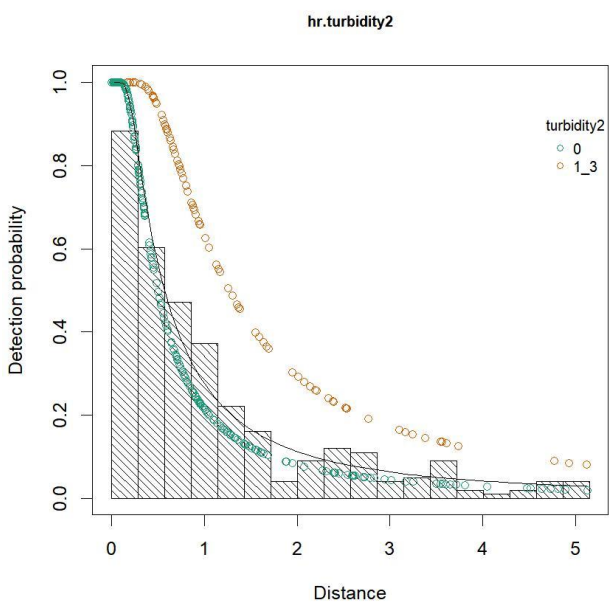
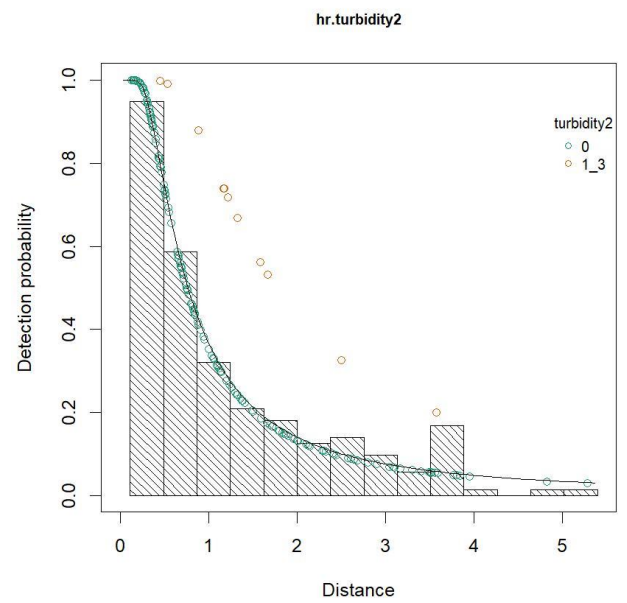
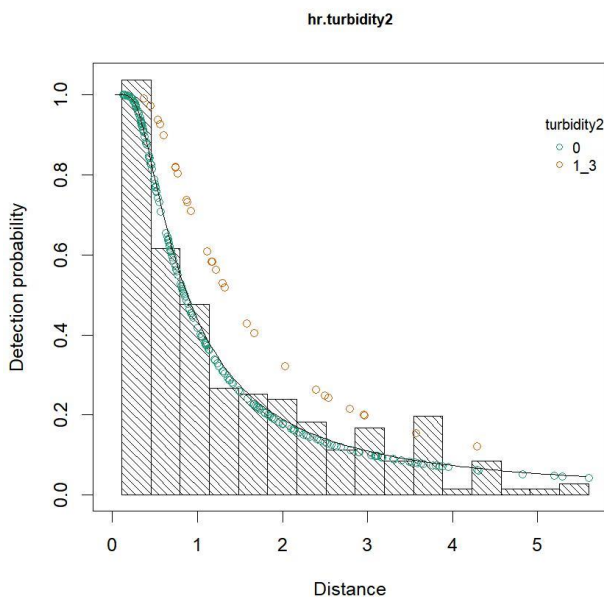


Period 2015-2019 all size classes

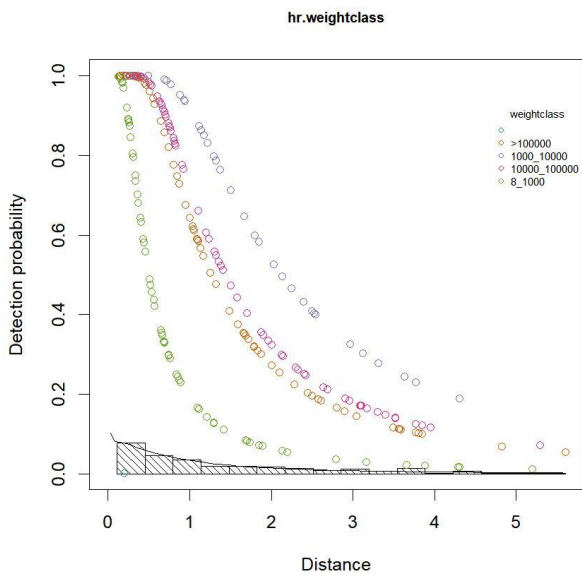


Period 2015-2019 adults only

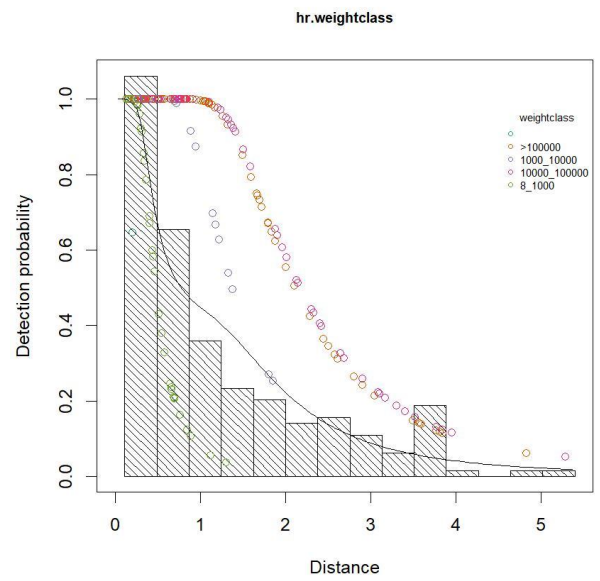
Turbidity2



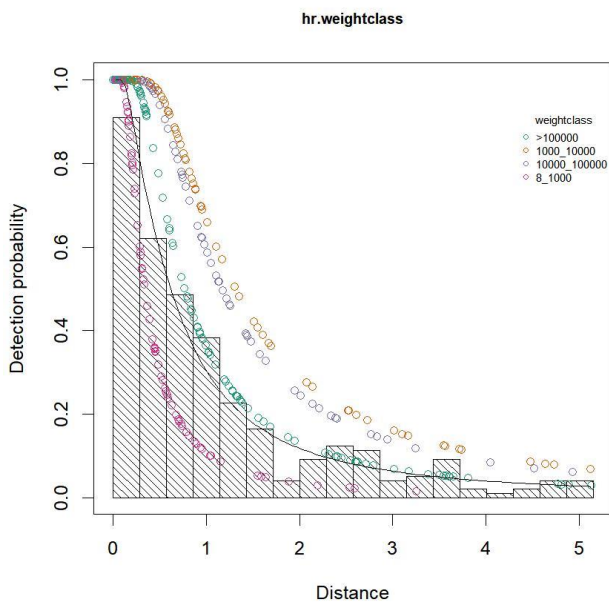
Weight classes



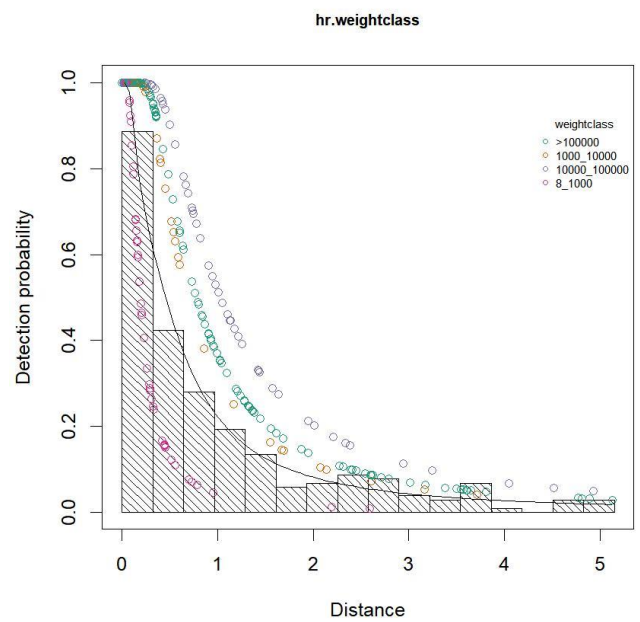
Period 2010-2013 all size classes



Period 2010-2013 adults only



Period 2015-2019 all size classes

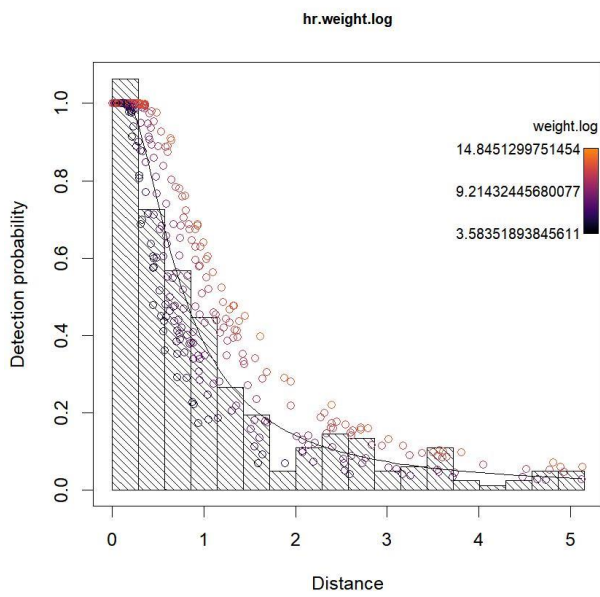


Period 2015-2019 adults only

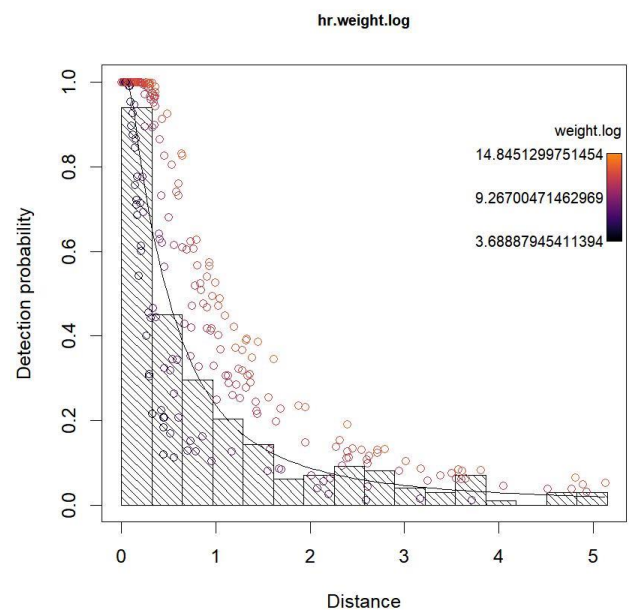
Log of weight

Period 2010-2013 all size classes

Period 2010-2013 adults only



Period 2015-2019 all size classes



Period 2015-2019 adults only

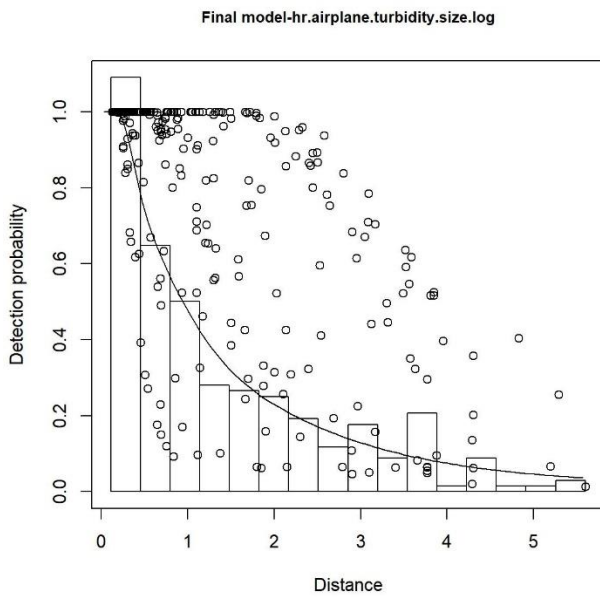
ANNEX 2

Selected detection functions

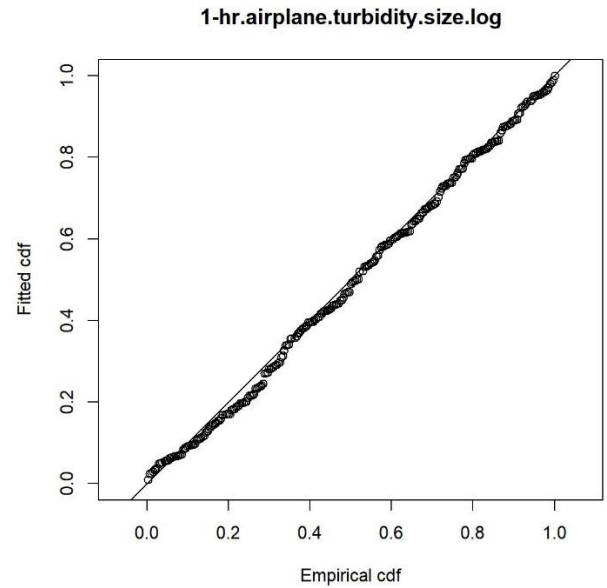
Only the detection functions for school size are shown here, as those for weight are identical to school size in the period 2015-2019, and with little variation in the period 2010-2013 (basically substituting size.log by weight.log). But they are available upon request.

Period 2010-2013

Period 2010-2013 – Areas 2010-2018 – All sizes

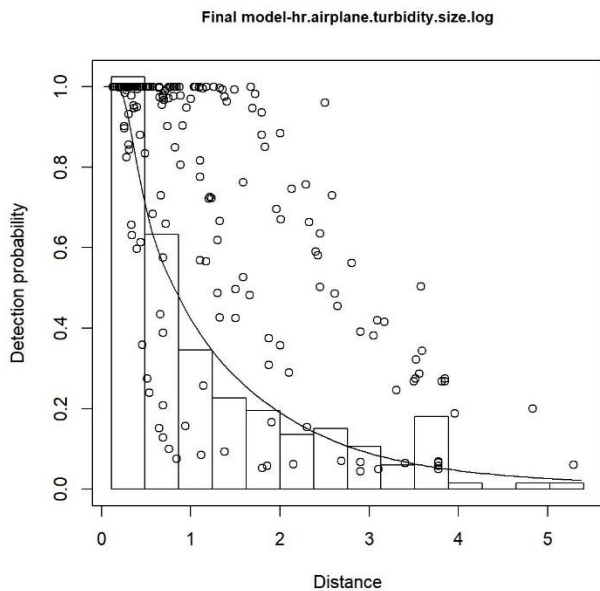


Best detection function

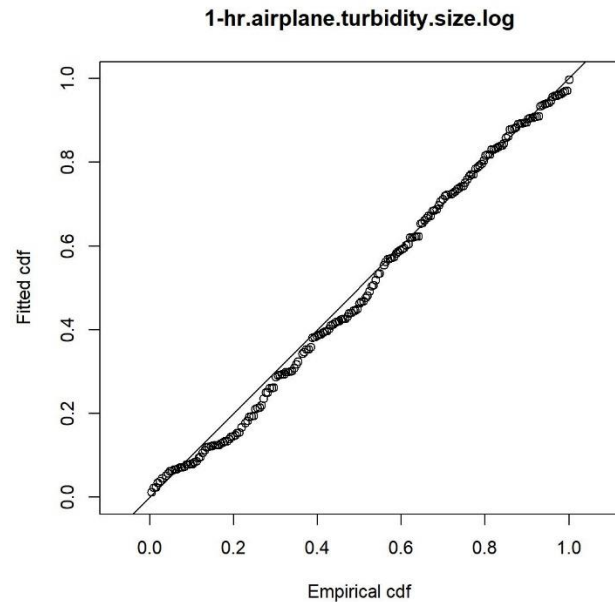


QQ-Plot

Period 2010-2013 – Areas 2010-2018 – Adults only

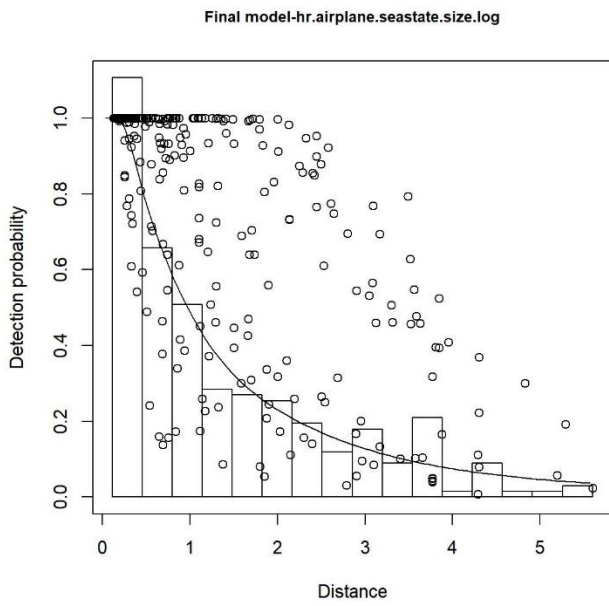


Best detection function

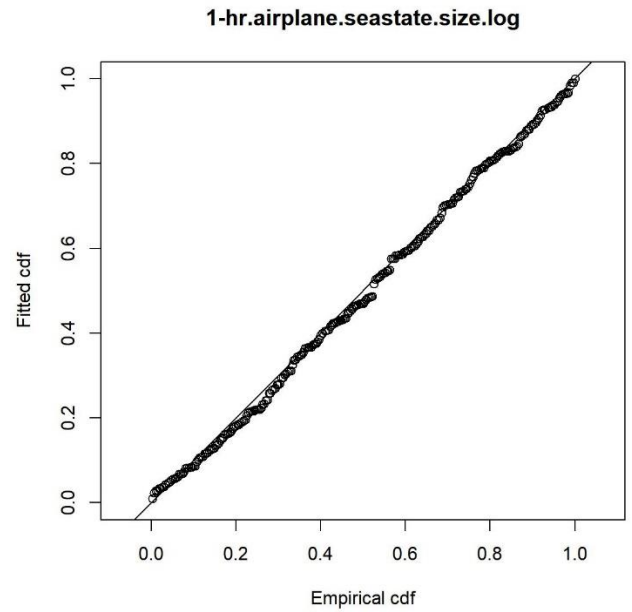


QQ-Plot

Period 2010-2013 – Areas 2019 – All sizes

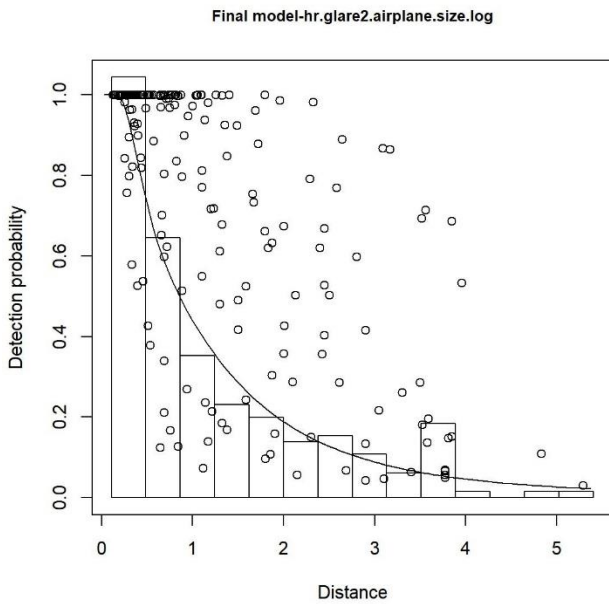


Best detection function

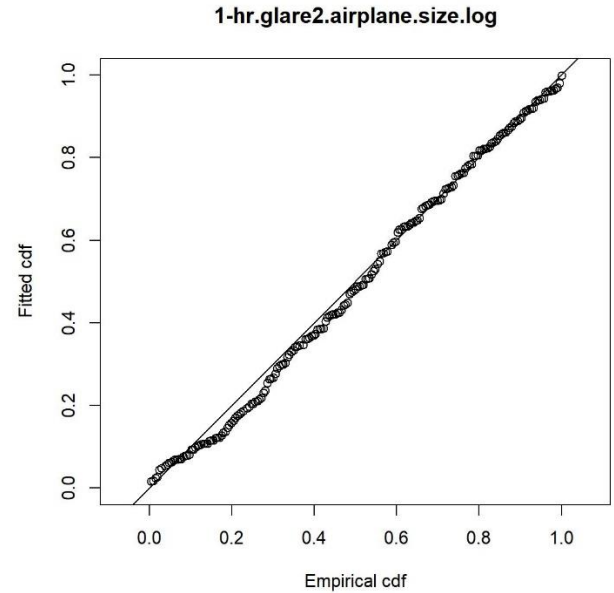


QQ-Plot

Period 2010-2013 – Areas 2019 – Adults only



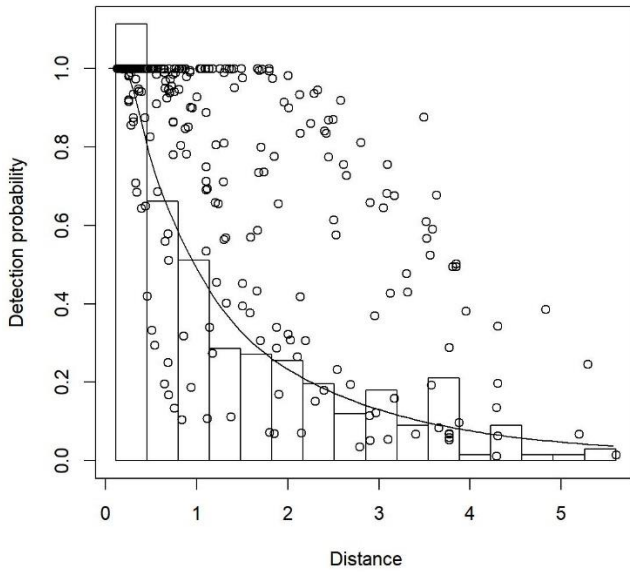
Best detection function



QQ-Plot

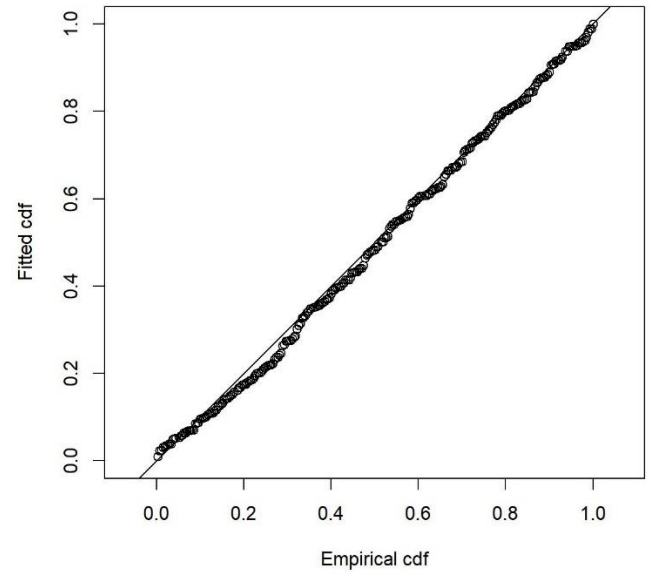
Period 2010-2013 – Areas 2018-2019 – All sizes

Final model-hr.airplane.turbidity.size.log



Best detection function

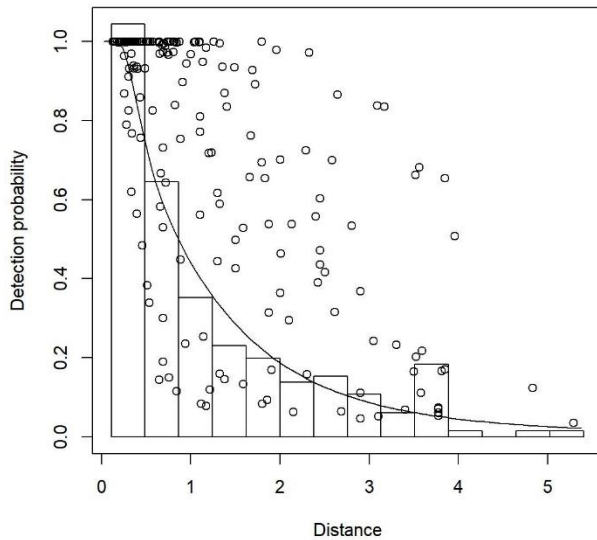
1-hr.airplane.turbidity.size.log



QQ-Plot

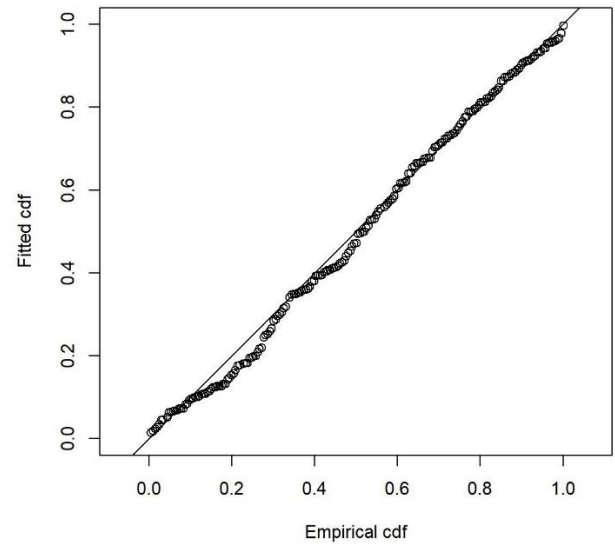
Period 2010-2013 – Areas 2018-2019 – Adults only

Final model-hr.glare2.airplane.size.log



Best detection function

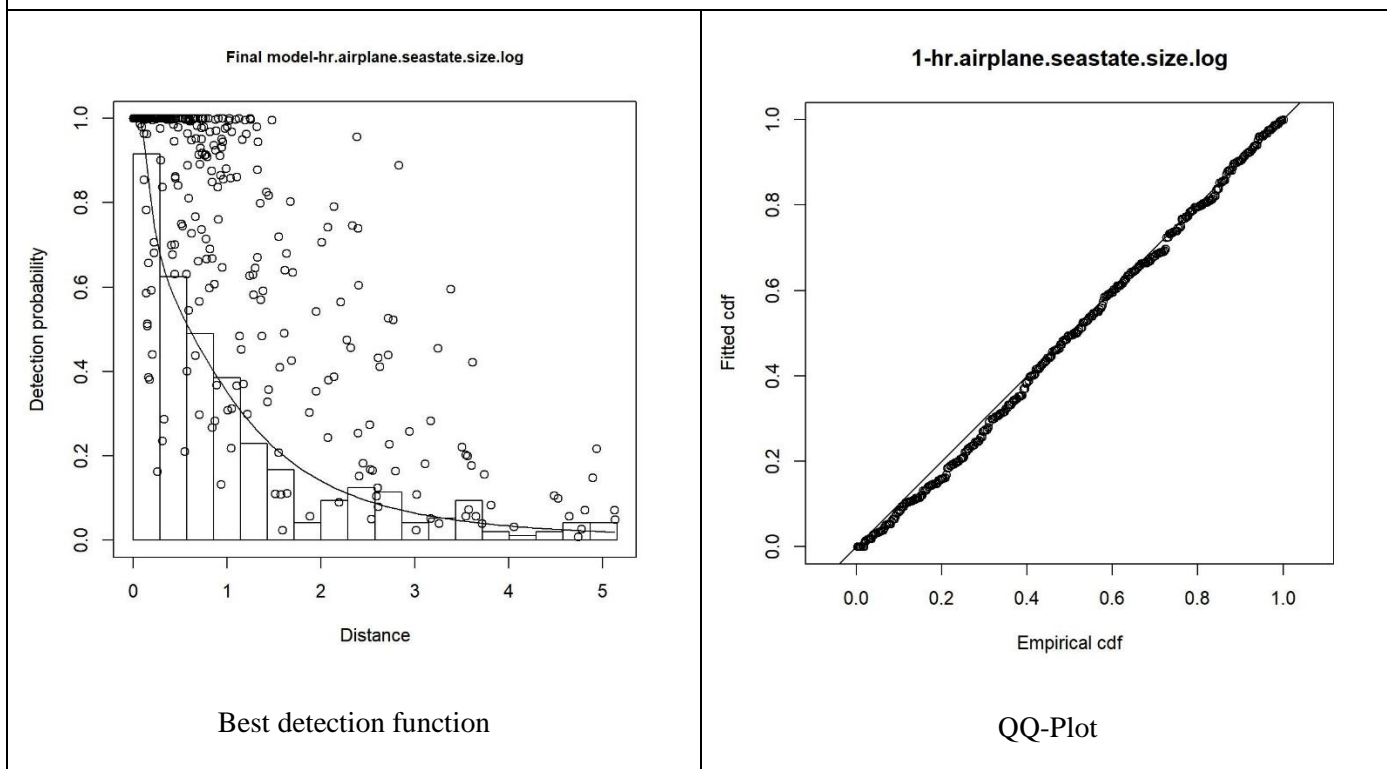
1-hr.glare2.airplane.size.log



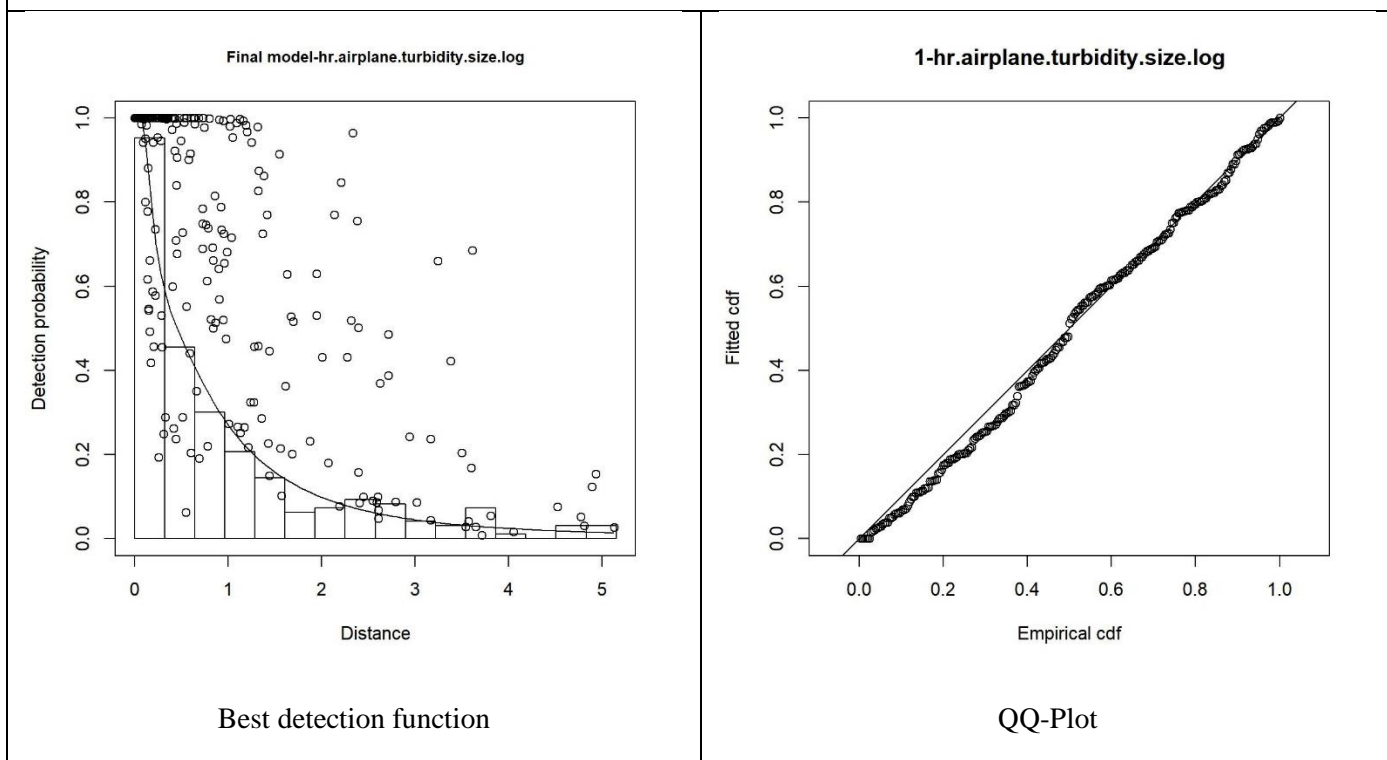
QQ-Plot

Period 2015-2019

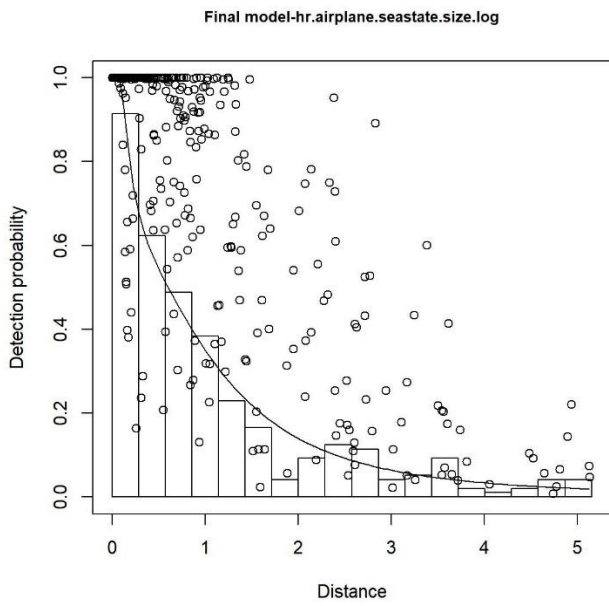
Period 2015-2019 – Areas 2010-2018 – All sizes – School size



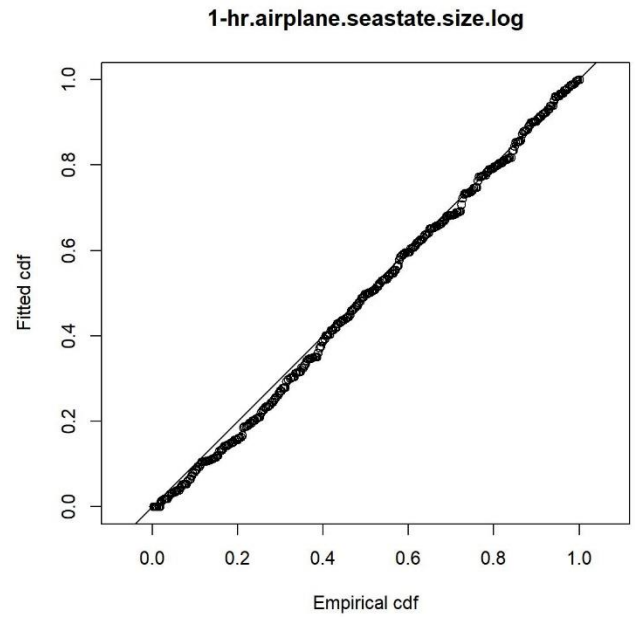
Period 2015-2019 – Areas 2010-2018 – Adults only – School size



Period 2015-2019 – Areas 2019 – All sizes – School size

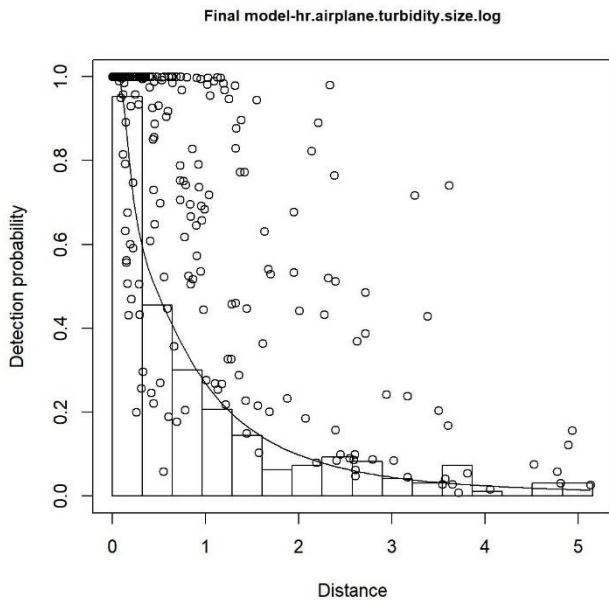


Best detection function

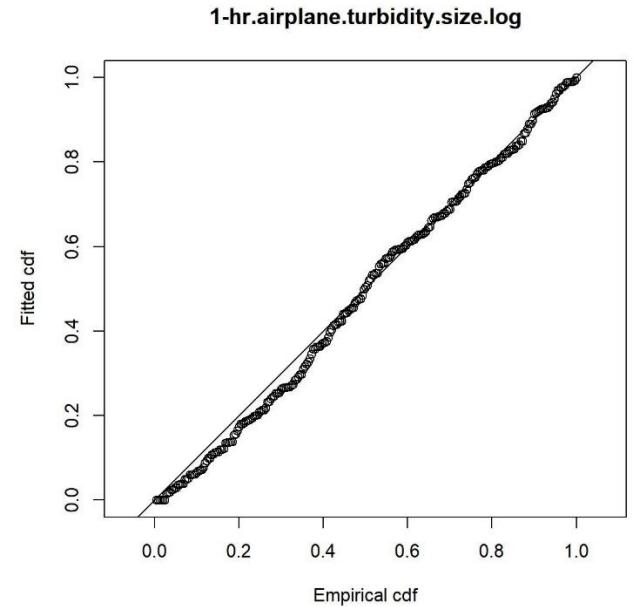


QQ-Plot

Period 2015-2019 – Areas 2019 – Adults only – School size

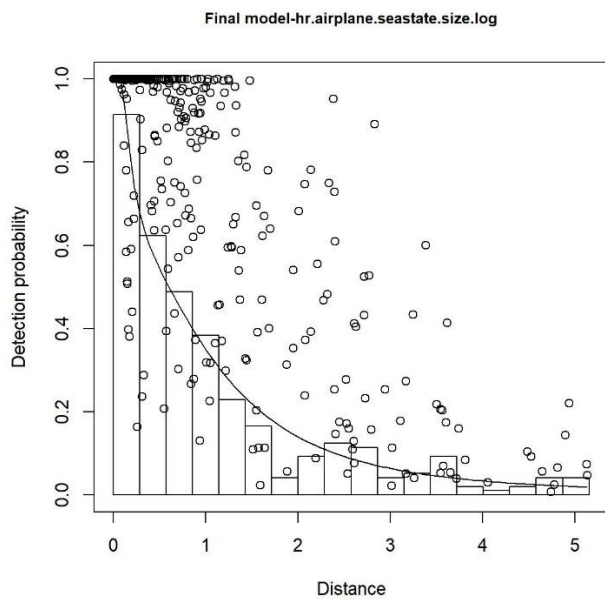


Best detection function

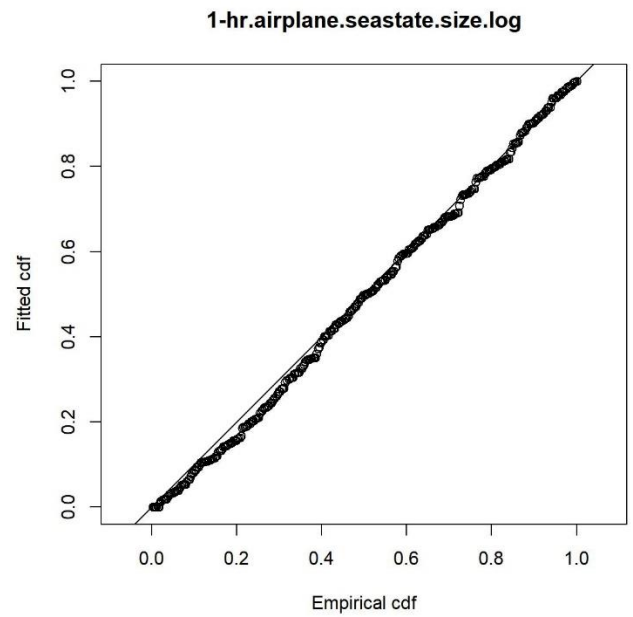


QQ-Plot

Period 2015-2019 – Areas 2018-2019 – All sizes – School size

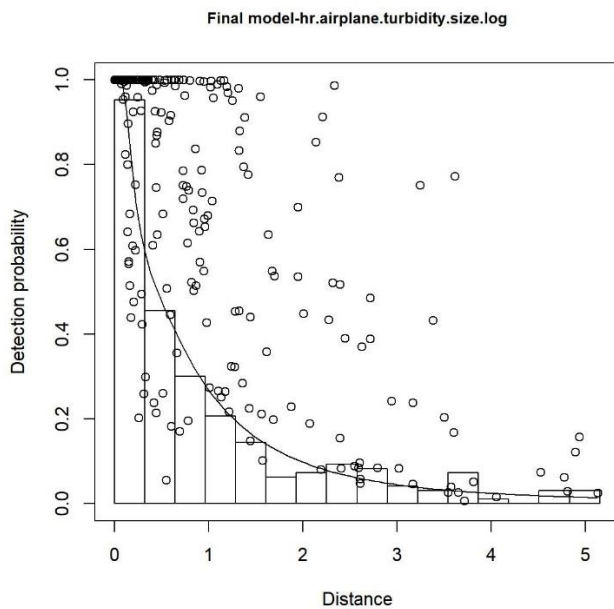


Best detection function

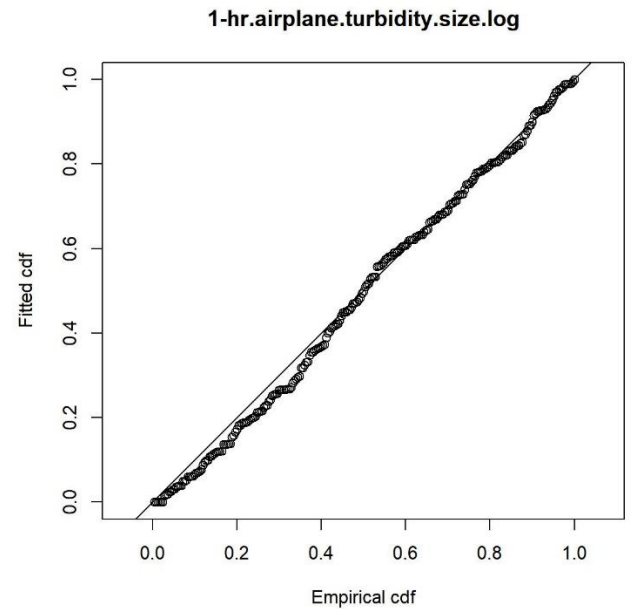


QQ-Plot

Period 2015-2019 – Areas 2018-2019 – Adults only – School size



Best detection function



QQ-Plot