THE ATLANTIC-WIDE RESEARCH PROGRAMME FOR BFT (ICCAT GBYP Phase 14)

SHORT-TERM CONTRACT FOR THE 2025 AERIAL SURVEY DATA ANALYSIS – TASK A

Design-based inference to estimate abundance and biomass of Bluefin Tuna in the Mediterranean Sea: analysis including the aerial visual survey for 2025.

FINAL REPORT

December 2025

CREEM, University of St Andrews

L. Burt, C. G. M. Paxton, M. Chudzińska

Please cite this report as: Burt *et al*. (2025). Design- based inference to estimate abundance, and biomass of bluefin tuna in the Mediterranean Sea: analysis including the aerial visual survey for 2025. Report number CREEM-2025-02. Provided to ICCAT, December 2025 (Unpublished).

Document control

Please consider this document as uncontrolled copy when printed.

Version	Date	Reason for issue	Prepared by	Checked by
1	08 December 2025	First draft	LB	MC, CP
2	09 December 2025	Issue final draft to ICCAT	LB	ICCAT - GBYP
3	10 December 2025	Final	LB	

Co-funded by the European Union

CREEM Centre for Research into Ecological and Environmental Modelling

University of St Andrews

1 Contents

2 Summary

This report is in response to Task a, as specified in the call for tender ICCAT GBYP circular # G-00510/2025.

Aerial surveys are conducted annually in regions in the Mediterranean Sea to collect data to estimate abundance and biomass of Bluefin tuna. In 2025, region A, around the Balearic Islands, was surveyed. Line transect distance sampling methods were employed on the survey and 5,796 km of search effort were flown, and 7 schools of adult Bluefin tuna were detected on search effort along the survey transects.

A detection function obtained previously using detections from surveys in 2017 to 2022 was applied to the survey data from 2017 to 2025 data to obtain a strict update of annual indices of estimates of abundance of individuals and total biomass. Abundance for block A in 2025 was estimated to be 31,235 fish (CV=0.38) and biomass was estimated to be 4,404 tonnes (CV=0.43).

3 Introduction

Aerial surveys have been undertaken in Mediterranean Sea to detect Bluefin tuna (BFT) from 2010 to 2025 under the auspices of the International Commission of the Conservation of Atlantic Tunas (ICCAT) Atlantic-wide research programme for Bluefin Tuna (GBYP). The main objectives of this programme are to improve a) understanding of the key biological and ecological processes, b) current assessment methodology, c) management procedures and d) advice. This report is in response to Task a as specified in the call for tender ICCAT GBYP circular # G-00510/2025 and presents the analyses of all the 2025 GBYP Balearic Sea aerial survey data carrying out the same design-based approach already applied in previous surveys, to produce a strict update of the GBYP aerial survey index of relative spawning stock biomass and abundance time series.

Estimates are obtained using line transect distance sampling methods (Buckland *et al*. 2001) and the biomass (total weight) and abundance (numbers of individuals) are updated using a strict update. To provide a strict update, the detection function fitted in Paxton *et al*. (2023) (i.e. the same variables and values of the model parameters) were used to obtain estimates for 2025 abundance and biomass respectively.

4 Methods

4.1 Overview of the aerial surveys

In recent years, three regions, or blocks, have been surveyed denoted by A, C and E (Figure 1); block G (not shown) was last surveyed in 2019. In 2025, only block A was surveyed. Details on survey protocol and outcomes are provided by Pérez-Gil and Pérez-Gil (2025), and so here, only information relevant for this report is provided.

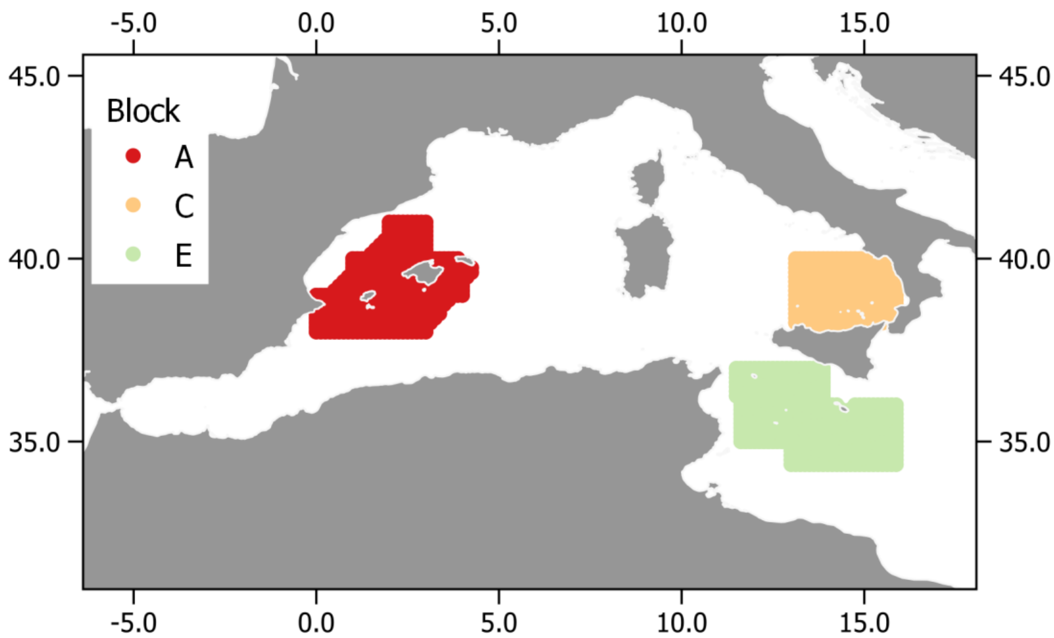

Figure 1. Depiction of the three survey blocks in the Mediterranean Sea.

Table 1 summarises the timing, company and airplane type used for the survey.

Table 1. Summary of the survey in 2025.

Block	Dates	Company	Airplane
A	09 June – 26 June	Airmed	Partenavia

4.2 Statistical methods

Although a strict update is required and hence the detection function has already been obtained, the analysis methods are included for context. Line transect distance sampling methods (Buckland *et al*. 2001) were used to estimate density and abundance and these methods are described below.

4.2.1 Data processing

Data from the 2025 survey and for previous surveys were provided by ICCAT and were processed to obtain the structure and information required for distance sampling analysis. All data from 2017 onwards were processed (as part of another project) to ensure it was done in a systematic and consistent way.

4.2.2 Estimating density and abundance

In distance sampling (DS) methodology, the perpendicular distances to detections of BFT are used to model how detectability decreased with increasing distance and hence estimate a probability of detection ($\hat{p}$). Using standard methodology (Buckland *et al*. 2001), the estimated density ($\widehat{D}$) and abundance ($\widehat{N}$) of fish in a survey block was obtained from

$$\widehat{D} = \frac{n}{2wL}.\frac{1}{\hat{p}}.E[s]$$

$$\widehat{N} = A.\widehat{D}$$

where for each block, A is the size of the block, n is the number of detected schools, w is the truncation distance associated with the detection function, L is the total length of transects covered on search effort and $E[s]$ is the expected school size.

Biomass of fish is also of interest and to obtain this, school size was replaced in the equation above by expected biomass (which was recorded for each detected school).

4.2.3 Calculating perpendicular distance

The perpendicular distance from the detected school to the transect was calculated using the trigonometric relationship:

$$y_i = h_i * \tan((90 - \theta_i)$$

where y_i is the perpendicular distance between the transect and the i^{th} school, θ_i is the declination angle measured when the plane was a beam and h_i is the height of the airplane above sea level when abeam of the detected school (Figure 2).

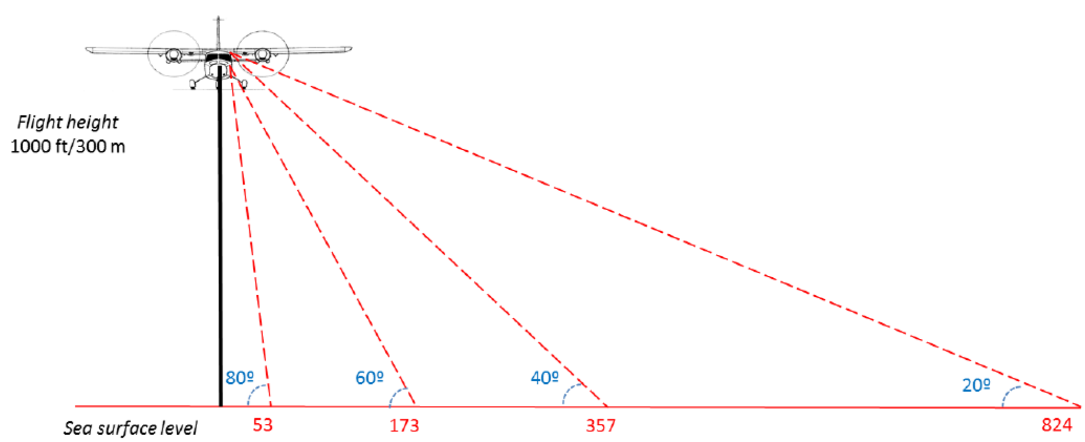

Figure 2. Example of the key declination angles and perpendicular distances at an altitude of h = 1000 ft = 300 m (Figure 5 from ICCAT survey protocol. Source: https://www.iccat.int/.)

4.2.4 Detection function

Two critical assumptions of DS methods are that all schools on the transect (i.e., at zero perpendicular distance) are detected with certainty and that distance measurements are exact (i.e., measured without error). Given these assumptions, the distribution of perpendicular distances is used to model how the probability of detection decreases with increasing distance from the transect. If detection on the transect is not certain (i.e. $g(0)<1$), the estimates will underestimate the true abundance and will represent estimates of relative numbers of animals.

In a conventional distance sampling approach, perpendicular distance is the only explanatory variable used to obtain $\hat{p}$ but the model can easily be extended to include additional explanatory variables which affect detectability, such as school size (Marques *et al*. 2007).

In Paxton *et al*. (2023), the variables selected in the detection function were *company* and *log(size)* to estimate tuna abundance and *company* and *log(biomass)* to estimate tuna biomass. These detections functions were fitted to data from 2017 to 2022 in blocks A, C, E and G (Figure 3). These models (i.e., using the same model parameter values) were applied to obtain estimates for 2025. This means that detections from recent years (2023, 2024 and 2025) are not included in the detection functions. To avoid changing the parameters, we have applied the same levels of company used by Paxton *et al*. (2023) to apply the detection function to the 2025 data; the levels were Action Air, Aerial Banners, Airmed, Air Perigord and Unimar.

Paxton *et al*. (2023) truncated the perpendicular distances at 1500 m, to avoid a long tail in the detection function and be consistent with previous analyses. The choice of this truncation distance was based on visual inspection of fitted detection function. No left truncation was applied; left truncation is a common practice for aerial surveys, due to difficulties in searching directly underneath the plane, especially when the plane does not have a bubble window, however, the planes used in the aerial surveys under consideration were fitted with bubble windows.

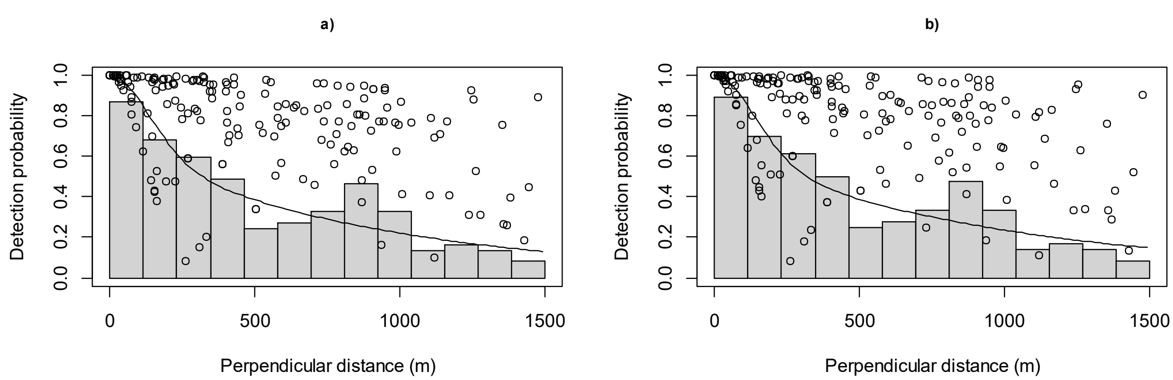

Figure 3. Detection functions (solid line) overlaid onto the scaled histogram of perpendicular distances: a) abundance and b) biomass. Dots indicate individual detections.

4.2.4.1 Estimating density and abundance and biomass

Detections and search effort were pooled within each block and year to obtain encounter rates, and hence obtain estimates of density and abundance, by year for each block. The lengths of the realised transects were calculated from the recorded positions (i.e. latitude and longitude), when observers were on search effort.

This same approach was used to estimate biomass; in this case, the size of observed schools was replaced by the estimated biomass.

Sightings of BFT schools were included if detected when the observers (both professional and scientific observers) were on search effort along the transect lines. Secondary sightings (schools seen, for example, when the plane left the transect to confirm school sizes for a previous sighting) were not included.

School sizes and biomass values recorded by the professional observers were used in preference to those of the scientific observer unless these values were missing, in which case estimates from the scientific observers were used, if available (ICCAT pers. comm).

Schools that were recorded as 100% small (i.e. individual fish < 25kg) were excluded. The remaining schools are referred to as adult schools. Sightings where perpendicular distances, school sizes or biomass values were missing were also excluded from the analysis.

The analysis was performed in R version 4.4.0 (R Core Team 2024) using the packages Distance (Miller *et al*. 2019) and mrds (Laake *et al*. 2020).

5 Results

5.1 Summary of search effort and BFT sightings for 2025 data

Table 2 summarises the search effort and number of detected BFT schools for the 2025 survey. Figure 4 shows the locations of the search effort and detected schools.

Table 2. Summary of survey data for 2025. Number of transects, total length of search effort along transects, size of the area covered by the survey, number of BFT schools detected during search effort along the transect lines and represent adult schools detected within 1,500m of the transects, encounter rate of schools (ER) and associated coefficient of variation (CV).

Block	Number of transects	Total length (km)	Covered area (km^2)	Number of schools	ER (schools/km)	CV
A	28	5795.7	17,388	7	0.0012	0.34

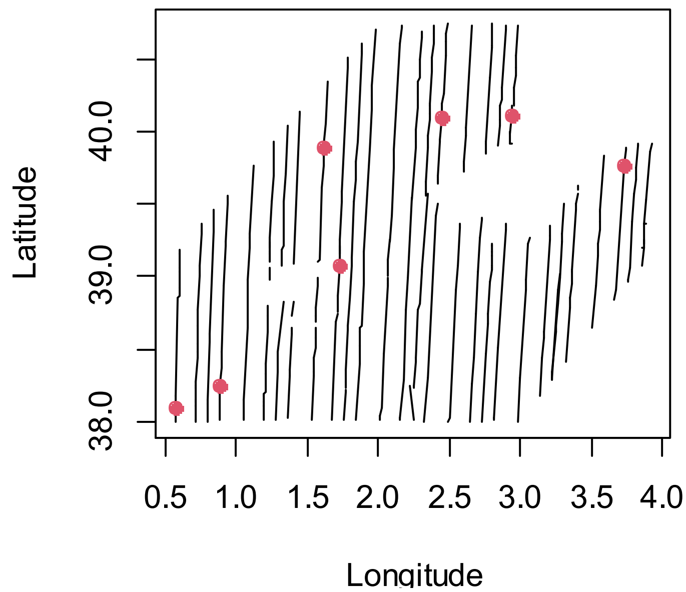

Figure 4. Location of the 2025 survey transects (lines) and detected schools (red dots) in block A. The detections represent on-effort detections of adult schools along the transects.

5.2 Estimates of abundance and biomass

The results for 2025 assuming an identical function to that fitted in Paxton *et al*. (2023) are given in Table 3.

Table 3. Estimated number of individuals (*N*, in thousands) and biomass (B, in tonnes) in block A in 2025 with lower (LCL) and upper (UCL) limits of a 95% confidence interval and associated coefficient of variation (CV).

Label	*N*	CV	LCI	UCI	B	CV	LCI	UCI
	Abundance				Biomass			
A-2025	31.2	0.38	14.8	65.8	4,404	0.43	1,903	10,191

Figure 5 adds the estimates for 2025 to previous estimates for block A; the patterns are similar for both indices. Note that there were some differences in estimates for early surveys due to the changes identified during the data processing. A summary of the survey data by block and year is given in Appendix A. Any changes identified were not included in the detection function so that the 2025 estimate is consistent with a strict update.

The expected size and biomass of each school in 2025 was higher than in 2024 contributing to higher estimates despite the same number of schools being detected (Appendix B).

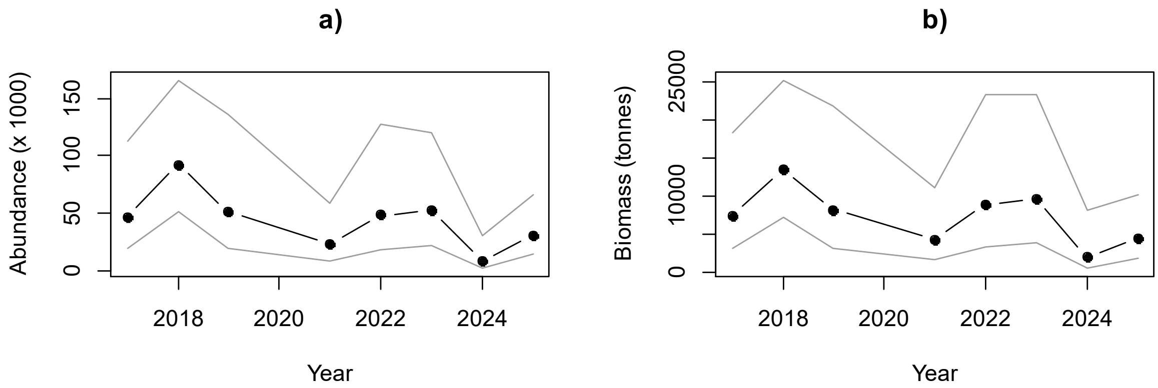

Figure 5. Estimates of a) abundance (in thousands) and b) biomass (in tonnes) of BFT for block A, using a detection function based on data from 2017 - 2022. Dots show estimated values, and grey lines show upper and lower limits of the 95% confidence interval.

6 Discussion

It should be emphasised that the estimates given here are based on detections of schools of fish (of one or more fish) observed at the surface, or close enough to the surface to be detected. It has been assumed that fish available to be detected on the transect (i.e. at zero distance) are certain to be detected. It is likely that some schools may be too deep to be detected, and available schools may be missed on the transect. Hence these estimates provide indices of relative abundance and biomass rather than absolute abundance/biomass; neither the availability of fish to be detected nor the detection of available fish on the transect have been considered in the calculations.

The detection function used here is based on a detection function using detections from 2017 to 2022 surveys and included the logarithm of school size or biomass and company. Three more years of survey data is now available, and additional sightings could be included in the detection function. It is likely that model parameters have changed and could be estimated more reliably, for example, the company Airmed, who conducted the survey in 2025 were last used in 2019 and their detection function may be different. To be consistent with previous analyses, five levels for company have been used but it may be that the levels could be reduced; “Unimar” and “Unimar/Aerial Banners” seem to provide a service in collaboration and so could be combined into one level. In addition, applying a strict update only works because the companies that undertake the surveys have not changed; if a new company is used in future, this detection function will not be applicable.

7 Acknowledgements

This work was carried out under the provision of the ICCAT. The contents of this document do not necessarily reflect the point of view of ICCAT, which has no responsibility over them, and in no ways anticipate the Commission's future policy in this area.

This work was conducted within the ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP) and partially funded by the European Union through the EU Grant Agreement No. 101169569 - GBYP Phase 14.

8 References

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling. Estimating abundance of biological populations. Oxford University Press, Oxford.

Laake, J., D. Borchers, L. Thomas, D. Miller, and J. Bishop. 2022. mrds: mark–recapture distance sampling. R package version 2.2.8. https://cran.r-project.org/package=mrds.

Marques, T. A., L. Thomas, S. G. Fancy, and S. T. Buckland. 2007. Improving estimates of bird density using multiple-covariate distance sampling. The Auk 124:1229-1243.

Miller, D. L., E. Rexstad, L. Thomas, L. Marshall, and J. L. Laake. 2019. Distance Sampling in R. Journal of Statistical Software 89:1 - 28.

Paxton, C. G. M., C. S. Oedekoven, M. Chudzinska, M. Pilar Tugores Ferrá, and D. Alvarez-Berastegui. 2023. Design- and model-based inference to estimate density, abundance and distribution of BFT in the Mediterranean Sea. Report number CREEM-2023-04.

Pérez-Gil M and Pérez-Gil E (2025) Prospección aérea para el seguimiento de las concentraciones de reproductores de atún rojo en el mar Mediterráneo Mar Balear (área A)

R Core Team. 2024. R: A Language and Environment for Statisical Computing. R Foundation for Statistical Computing.

9 Appendix A: Summary of the survey blocks and realised survey data in each year

This appendix contains a summary of the survey blocks and survey data in each year. As part of another project (Task b as specified in the call for tender ICCAT GBYP circular # G-00510/2025), the data for the surveys listed in Table A2, were processed and formatted for distance sampling analysis in a systematic way. Thus, any decisions required regarding corrections could be applied consistently.

Table A1. Size of the survey blocks (km^2).

Block	Year	Area (km^2)
A	2017 - 2019	61,849
	2021 - 2025	61,837
C	2017 - 2025	53,868
E	2017 - 2025	93,614
G	2017 - 2025	38,788

Table A2. Company and aircraft used to undertake the surveys and data used in the analysis: *k* is the number of transects, *L* is the total length of search effort along transects, and *n* is the number of adult groups detected during search effort along the transects and within 1,500 m of the transects.

Year	Block	Company	Aircraft	k	L (km)	n
2017	A	Airmed	Partenavia	29	4996	18
	C	Unimar	Partenavia	25	4569	7
	E	Airmed	Partenavia	30	6478	5
	G	ActionAir	Cessna	57	4493	2
2018	A	Airmed	Partenavia	39	5996	25
	C	Unimar	Partenavia	25	4931	8
	E	Unimar	Partenavia	40	8822	7
	G	ActionAir	Cessna	56	4122	4
2019	A	Airmed	Partenavia	30	5466	12
	C	Unimar	Partenavia	23	4818	4
	E	ActionAir	Cessna	40	8567	5
	G	ActionAir	Cessna	55	4084	2
2021	A	ActionAir	Cessna	27	6317	8
	AO[1]	ActionAir	Cessna	12	2536	2
2022	A	Air Perigord	Cessna	30	5319	9
	C	Unimar/Aerial Banners	Partenavia	25	5144	11
	E	Unimar/Aerial Banners	Partenavia	30	6607	3
2023	A	Air Perigord	Cessna	30	5788	23[2]
	C	Unimar/Aerial Banners	Partenavia	25	4976	3
	E	Unimar/Aerial Banners	Partenavia	21	5165	8
2024	A	Air Perigord	Cessna	30	5679	7
	C	Unimar/Aerial Banners	Partenavia	25	4988	3
	E	Unimar/Aerial Banners	Partenavia	34	7234	8
2025	A	Airmed	Partenavia	28	5796	7

[1] Data from the survey block AO (an area surrounding block A) surveyed in 2021 were not included in this report but is included in this table for completeness.

[2] One detection missing a biomass estimate was excluded from the biomass analysis.

10 Appendix B: School sizes and biomass by year

This appendix illustrates the distributions of sizes (number of fish) and biomass (total weight) for adult schools of BFT detected in block A on search effort along the transects (data have not been truncated at 1500m) (Figure B1).

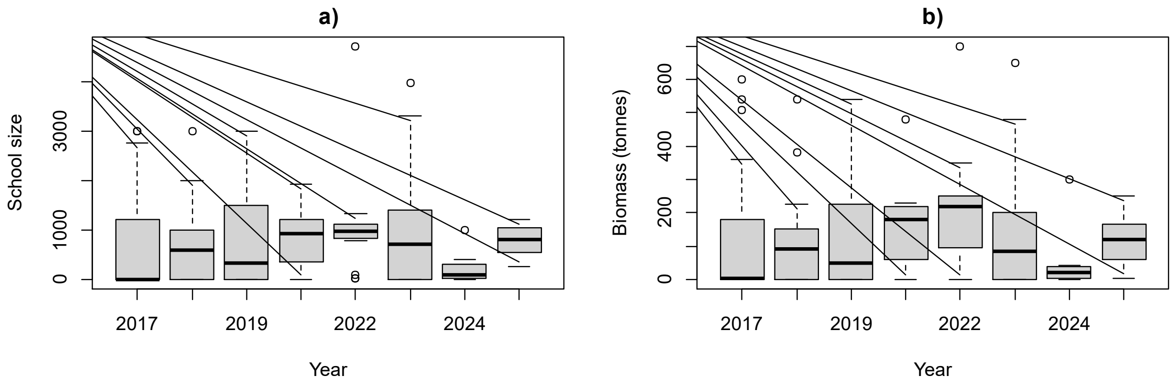

Figure B1. Distribution of a) school sizes and b) biomass for adult schools detected on search effort along transects in block A by year.