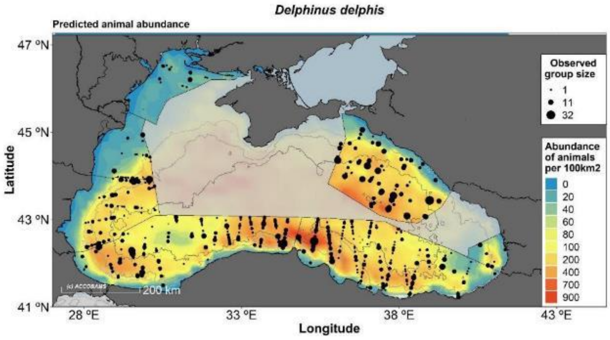
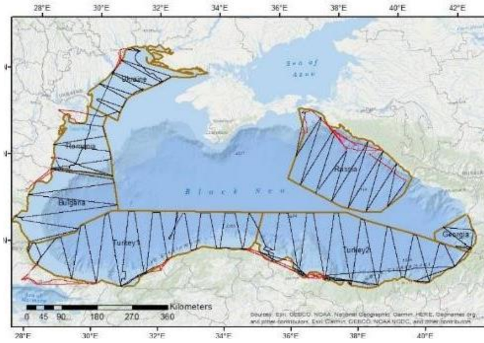
Estimates of abundance and distribution of cetaceans in the Black Sea from 2019 surveys



©CeNoBS



©CeNoBS

©CeNoBS

©Clean Seas

With financial
support of the
European Union

Authors:
Romulus-Marian Paiu, Simone Panigada, Ana Cañadas, Pavel Gol'din, Dimitar Popov, Léa David, Ayaka Amaha Ozturk, Dmitri Glazov

Contributors:
Svetlana Artemieva, Galina Balusheva, Laura Boicenco, Ayhan Dede, Erdem Danyer, Ertug Duzgunes, Zurab Gurielidze, Phil Hammond, Natia Kopaliani, Irina Makarenko, Galina Meshkova, Otilia Mihail, Mihaela Mirea-Candea, Evgeny Nazarenko, Bayram Öztürk, Angelica Paiu, Marina Panayotova, Gleb Pilipenko, Vincent Ridoux, Miroslava Robinson, Olga Shpak, Costin Timofte, Arda M. Tonay, Karina Vishnyakova

ASI/CeNoBS Aerial surveys Team leaders and Observers: Romulus-Marian Paiu, Dimitar Popov and Ayhan Dede, Pavel Gol'din, Galina Meshkova, Costin Timofte, Arda M. Tonay

ASI/EMBLAS-Plus Russian Black Sea Survey Team Leader and Observers: Dmitri Glazov and Svetlana Artemieva, Evgeny Nazarenko, Gleb Pilipenko, Olga Shpak

ASI/CeNoBS survey coordination and administrative support:
ASI Scientific Coordinator: Simone Panigada

CeNoBS Scientific Coordination working group: Ana Canadas, Lea David, Pavel Gol'din, Romulus-Marian Paiu, Simone Panigada, Dimitar Popov, Marine Roul

CeNoBS Lead Partner Mare Nostrum: Mihaela Candea-Mirea, Marian Paiu

ACCOBAMS Secretariat: Julie Belmont, Florence Descroix-Comanducci, Célia Le Ravallec, Susana Salvador

Special thanks to the National Authorities, to the CeNoBS Advisory board members, to the aerial companies Action Air Environment and AeroVolga and its pilots, and to the ACCOBAMS Scientific Committee for its ambition and continuous support to the development of the ASI project since the ACCOBAMS origin.

ASI/CeNoBS survey Technical Partners:

The ASI/CeNoBS Survey was funded by ACCOBAMS and the European Union.

Co-funded by
the European Union

ASI/EMBLAS-Plus Survey Technical partners:

IEE RAS

CLEAN SEAS
International Ecological Fund

The ASI/EMBLAS-Plus Russian Black Sea Survey was funded thanks to ACCOBAMS and the international Project «Improving Environmental Monitoring in the Black Sea — Selected Measures» (EMBLAS-Plus).

This project is funded by the European Union

EMBLAS-Plus
Environmental Monitoring in the Black Sea

UN DP
*Empowered lives.
Resilient nations.*

Citation:

ACCOBAMS, 2021. Estimates of abundance and distribution of cetaceans in the Black Sea from 2019 surveys. By Paiu, R.M., Panigada, S., Cañadas, A., Gol'din, P., Popov, D., David, L., Amaha Ozturk, A., Glazov, D. Ed. ACCOBAMS - ACCOBAMS Survey Initiative/CeNoBS Projects, Monaco, 54 pages.

Disclaimer:

The designations employed and the presentation of the information on this document do not imply the expression of any opinion whatsoever on the part of ACCOBAMS concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The views expressed in this report are those of the author(s) and do not necessarily reflect the views or policies of ACCOBAMS and European Union. The European Commission is not responsible for any use that may be made of the information it contains.

Table of Contents

FOREWORD

The aerial surveys conducted in the Black Sea in 2019 were carried out under the umbrella of the ACCOBAMS Survey Initiative, within the framework of the CeNoBS project "Support MSFD implementation in the Black Sea through establishing a regional monitoring system of cetaceans (D1) and noise monitoring (D11) for achieving GES" (https://www.cenobs.eu/) and through a collaboration with the EMBLAS-Plus project "Improving Environmental Monitoring in the Black Sea – Selected Measures" (http://emblasproject.org/).

CeNoBS is financially supported by the European Commission, under the DG ENV call for proposals "Marine Strategy Framework Directive - Second Cycle: Implementation of the new GES Decision and Programmes of Measures", and ACCOBAMS through the ACCOBAMS Survey Initiative.

CeNoBS project tackles MSFD Descriptor 1 – Biodiversity/cetaceans and Descriptor 11 – Energy including underwater noise in the Black Sea, improving the second cycle of MSFD implementation, by achieving greater consistency and coherence in determining, assessing and achieving good environmental status.

The main objectives of this project are:

- assessing D1 cetaceans related criteria and supporting the establishment of thresholds values,
- assessing and supporting the development of D11 monitoring in the Black Sea and
- enhancing coordination among the Black Sea region throughout the dissemination of the project activities, results and outcomes.

CeNoBS activities aim to fill the lack of background data on the distribution/abundance of cetacean populations and on bycatch pressure in the Black Sea and the lack of national expertise to implement effective noise monitoring.

The EMBLAS-Plus project is funded by the European Union and it is aimed at improving protection of the Black Sea environment through further technical assistance focused on marine data collection and local small-scale actions targeted at reduction of pollution by marine litter, public awareness raising and education.

Within the framework of the EMBLAS-Plus project, a collaboration was established between ACCOBAMS and Russian scientists from the A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, and the Federal State Budgetary Institution N.N. Zubov's State Oceanographic Institute to extend the coverage of the aerial survey to Black Sea Russian waters, from the Adler district of Sochi to the midline of the Kerch Strait (Krasnodar Krai).

This report provides the results of the analysis conducted with the cetacean related datasets collected during both CeNoBS and EMBLAS-Plus aerial surveys. It is based on CeNoBS Deliverable 2.2.2. "Detailed Report on cetacean populations distribution and abundance in the Black Sea, including proposal for threshold values".

I. INTRODUCTION

The Black Sea is one of the most vulnerable regional seas. Three species of odontocetes, Black Sea common bottlenose dolphin (*Tursiops truncatus ponticus* Barabash, 1940), Black Sea short-beaked common dolphin (*Delphinus delphis ponticus* Barabash, 1935), and Black Sea harbour porpoise (*Phocoena phocoena relicta* Abel, 1905) inhabit the basins of the Black and Azov Seas.

A comprehensive abundance estimate for the entire Black Sea has never been conducted, and the largest-scale surveys mostly date back to 1987 and earlier. Since then, a study on bottlenose dolphins and short-beaked common dolphins in the waters of Ukraine and Russia (along the Crimean and Caucasian coasts to a depth of 200 m and in the Kerch Strait) was carried out in 2002-2003 (Birkun *et al.,* 2003). Based on the results of a vessel survey in September-October 2003 in coastal waters of Crimea and the Caucasus, the following estimates were obtained: 1 157 ± 602 individuals of harbor porpoises, 4 193 ± 1 090 individuals of bottlenose dolphins, and 5 376 ± 1 718 individuals of common dolphins (Birkun *et al*., 2004).

In addition, there were local surveys, mostly in coastal waters, conducted by NGO research groups[1], research institutes[2] and academia [3] (Baș *et al*., 2019; Birkun *et al*., 2004; 2006; 2014; Dede & Tonay, 2010, Gladilina & Gol'din, 2016; Gladilina *et al*., 2017, Kopaliani *et al*., 2015; Mihalev, 2005; Paiu *et al*., 2019; Panayotova & Todorova, 2015; Popov *et al*., 2017).

The only large-scale abundance estimation of cetaceans in the riparian country's waters was conducted in 2013 along the North Western Black Sea (Birkun *et. al*., 2014) covering Ukrainian, Romanian and Bulgarian waters, for all the three species. Estimates were indicating an abundance of 29 465 (95%CI 19568 – 44368) individuals of harbour porpoise, 60 400 (95%CI 41 316 – 88 298) of common dolphins and 26 462 (95%CI 19586 – 35751) of bottlenose dolphins.

In 2019, in cooperation and with support from ACCOBAMS in the framework of the ACCOBAMS Survey Initiative, two international teams worked hand by hand within two riparian projects "Support MSFD implementation in the Black Sea through establishing a regional monitoring system of cetaceans (D1) and noise monitoring (D11) for achieving Good Environmental Status" (CeNoBS) and "Improving Environmental Monitoring in the Black Sea – Selected Measures" (EMBLAS-Plus) to assess the status of the Black Sea cetaceans.

Within the CeNoBS framework, this activity was part of the CeNoBS Work Package 2, focusing on the 'Assessment of cetacean populations distribution and abundance at the regional scale', which has been coordinated by ACCOBAMS and Mare Nostrum with the participation of other project Partners (Green Balkans (Bulgaria), Turkish Marine Research Foundation - TUDAV (Turkey), Ukrainian Scientific Center of Ecology of the Sea – UkrSCES (Ukraine), National Institute for Marine Research and Development – NIMRD (Romania)).

---

[1] e.g. Mare Nostrum NGO - Romania, Green Balkans NGO - Bulgaria, Turkish Marine Research Foundation - TUDAV – Turkey, BREMA - Ukraine

[2] e.g. UKRSCES, TNU - Ukraine; IO-BAS – Bulgaria, P.P. Shirshov Institute of Oceanology RAN, A.N. Severtsov Institute of Ecology and Evolution - Russia

[3] Ilia State University – Georgia, Russian Academy of Sciences – Russia, Istanbul University – Turkey

Due to the constraints imposed for the moment in the area, the CeNoBS project proposes the biggest coverage ever included in a cetacean Black Sea survey, allowing to cover half of the sea. A complementary survey was conducted in Russian waters through the EMBLAS-Plus project, in collaboration with N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, and the Federal State Budgetary Institution N.N. Zubov's State Oceanographic Institute, using the same methodology and protocols to allow statistical comparison of the results and to facilitate merging the data for the analysis.

The main aim of these surveys was to assess cetacean's density and abundance in the Black Sea, by applying the most robust and up-to-date methodology. Shared and systematic protocols have been used, to facilitate data comparison and to create a baseline data to allow future analysis in time and space, to assess eventual trends. A robust analytical modelling framework was applied to the dataset, facilitating training activities for scientists in the region and encouraging a participatory approach.

This report provides the results of the analysis conducted with the cetacean related datasets collected during both CeNoBS and EMBLAS-Plus aerial surveys. Under the CeNoBS project, these results are used to initiate the definition of the MSFD thresholds values for cetaceans related indicators and criteria, in particular D1C2 (cetaceans populations abundance) and D1C4 (cetacean distributional range), in line with the new GES Decision (Commission Decision (EU) 2017/848).

II. METHODS

II.1 AERIAL SURVEY

Cetacean populations' distribution and abundance were assessed through a regional aerial survey aimed at collecting visual observations of cetaceans following specific and shared/standardized protocols. The aerial survey methodology offers the possibility of a large coverage in a short period of time and is the most precise and robust approach for estimating the abundance of some cetacean species. The Black Sea is known for its rough sea conditions and the capacity of going from 0 (calm sea) to 5 (rough sea) sea state in a matter of minutes. Therefore, using planes has allowed the necessary flexibility for easily adapting to weather constraints.

The line transect distance sampling method was used for the survey. In this method data are collected by observers on board of aircrafts following specific transects designed to ensure an equal coverage probability and representation of the study area (Buckland, 2001, 2004; Buckland *et al.*, 2015). This standardized approach is used in several other regional contexts (SCANS initiative – Small Cetaceans in the European Atlantic waters and North Sea – and more recently during the Mediterranean surveys conducted by ACCOBAMS in 2018 within the framework of the ACCOBAMS Survey Initiative project), and it is globally recognized as the best approach to assess distribution, density and abundance of cetacean species at large scale. In particular, several EU-countries implement this methodology as part of their cetaceans MSFD monitoring programmes.

The data collection protocols and the survey design were prepared by a Scientific Coordinator in close collaboration and consultation with scientists from the CeNoBS project Partners[4] and partnering Scientific organisations from Russia[5]. The aerial survey has covered the waters of Romania, Bulgaria, Turkey, Ukraine, Georgia and Russia (territorial waters and exclusive economic zones) following pre-defined transect lines within different blocks. The survey design was adjusted according to Flight Information Regions (FIRs) constraints, as this was limiting the possibility of flying in specific areas.

While targeting cetaceans was the highest priority during the aerial survey, other relevant observations were made in relation with D1 (biodiversity) and human activities (marine traffic, fisheries). In relation with the GES Descriptors, the aerial survey did also collect information on D10 Marine Litter. The aerial survey was conducted using three small planes, 2 Cessna 337 and one La-8, equipped with 2 engines, high wings and bubble windows, to allow the vertical view by the observers. Flights were conducted during daytime, with good weather conditions (<4 Beaufort).

Three teams, one per plane, were involved in data collection. Each team was composed of one Team Leader and of two to four observers. In addition to the data recording work, the Team Leader fulfilled the specific task to coordinate the flight planning with the pilot and organizing the logistics of the team. The research teams were mixed, involving observers with experience in aerial surveys and new observers trained specifically for the survey. This was conducted as part of the capacity building component of the project, in view of future cycles of implementation of MSFD. The CeNoBS teams also had mixed representation in terms of participating countries, involving scientists from Romania, Bulgaria, Turkey and Ukraine. The EMBLAS-Plus team was comprised of Russian scientists only.

---

[4] Mare Nostrum, Green Balkans, TUDAV, UkrSCES, NIMRD

[5] Cleans Seas International Ecological Fund, A.N. Severtsov Institute of Ecology and Evolution / Russian Academy of Sciences, and the Federal State Budgetary Institution N.N. Zubov's State Oceanographic Institute

All teams have worked under the supervision of the Scientific Coordinator who was in charge of the different phases before the field work, as well as a regular monitoring of the implementation of the aerial surveys, to ensure appropriate use of the methodology, providing guidance and advice to the Team Leaders in their flight planning, and to validate the collected data. The Scientific coordinator was also in charge of training the teams on the distance sampling methodology and data collection protocols.

During the surveys, target altitude was 183m (600 feet) as customarily dealt in other surveys such as SCANS, SAMM, OBSERVE or REMMOA, and ASI, with target speed of 100 knots. The data recorder used SAMMOA software[6], dedicated to data acquisition on marine megafauna from visual observation during aerial survey, developed by Pelagis Observatory-La Rochelle University-CNRS with technical support of a data processing office Code Lutin. SAMMOA is connected to a GPS and has a simultaneously audio recording system. SAMMOA allows to establish a flight plan before take-off, with planned tracklines and observer's position onboard. SAMMOA also allows the data validation with the same interface and the checking, thanks to the voice recordings associated to each visual observation.

EcoOcéan Institut took part in the training of the teams for the use of SAMMOA software and significant amount of time was spent to ensure good coding of the different kind of sightings and homogeneity in coding for all observers. Plenary sessions were run to train, discuss and fix the different parameters to collect within SAMMOA, with the right codes. This process enhances the coherence and standard way to collect data and reduce a lot of mistakes, heterogeneity between observers or missing data. The attendees went through the auto-validation process together during the training, so the data received had a high quality. The communication through the WhatsApp group with Team Leaders during the validation process helped in real time to solve problems with the software and data storage, and verification of the data collected.

The survey was conducted flying along the planned surveys primarily in passive mode, unless it was necessary to obtain reliable estimates of school size or confirm species by circling over the sighted animals. The survey was then resumed at the exact point it was left and all the secondary sightings (i.e., the additional sightings made after leaving the predetermined trackline) although recorded have not been used to obtain the abundance and density estimates. The environmental conditions, reported by the observers, were recorded at the beginning of each transect and/or whenever a change occurred. The variables collected are the sea state (Beaufort scale), glare, cloud cover, turbidity of the sea and overall general sighting conditions. Sightings data, also reported by the observers, included species, group size and composition, direction of swimming and group behavior. Other accessory information such as the presence of human activities was also recorded. Observations were made through so-called bubble-windows allowing direct view on the track-line below the plane and recorded on a laptop with dedicated software (Fig. 1). The plane position, speed and altitude were continuously recorded through a GPS and angle were measured with a clinometer.

---

[6] SAMMOA 1.1.2. Système d'Acquisition des données sur la Mégafaune Marine par Observations Aériennes, Software developed by UMS 3462 Pelagis LRUniv-CNRS and Code Lutin (2012-2019).

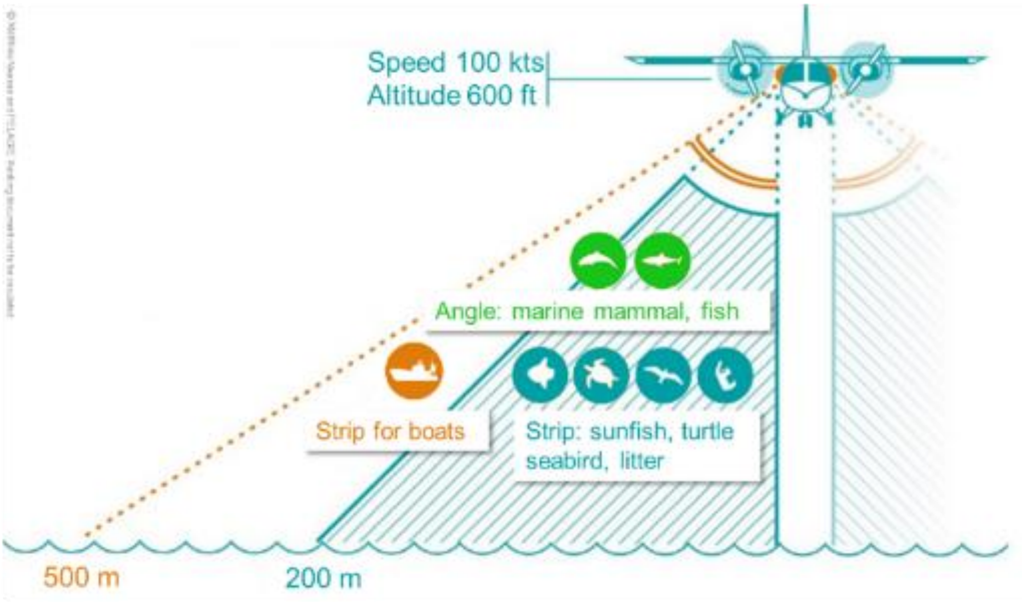


Fig. 1 – A schematic for data collection of sightings during aerial survey.

At the end of the survey EcoOcéan Institut proceeded with the pre-treatment of the data collected during the survey (data verifying, data cleaning, and data extracting) in view of the analysis, in direct link with Team Leaders and task coordinators. The data were sent to the specialist in charge of the analysis based on her recommendation for the format.

II.2 SURVEY DESIGN

A total of 6 blocks were originally created (Fig. 2.). The rationale for the blocks boundaries was the best compromise achieved between oceanographic zones, bathymetric characteristics, and political/jurisdictional constraints. The first two are likely to have a marked effect on cetacean distributions. The design of the blocks was constantly updated as the survey was approaching, to take into consideration last minute issues related to permit issues and other logistical considerations, such as Flight Information Region (FIR) boundaries regulations, as this had influence on flight authorizations.

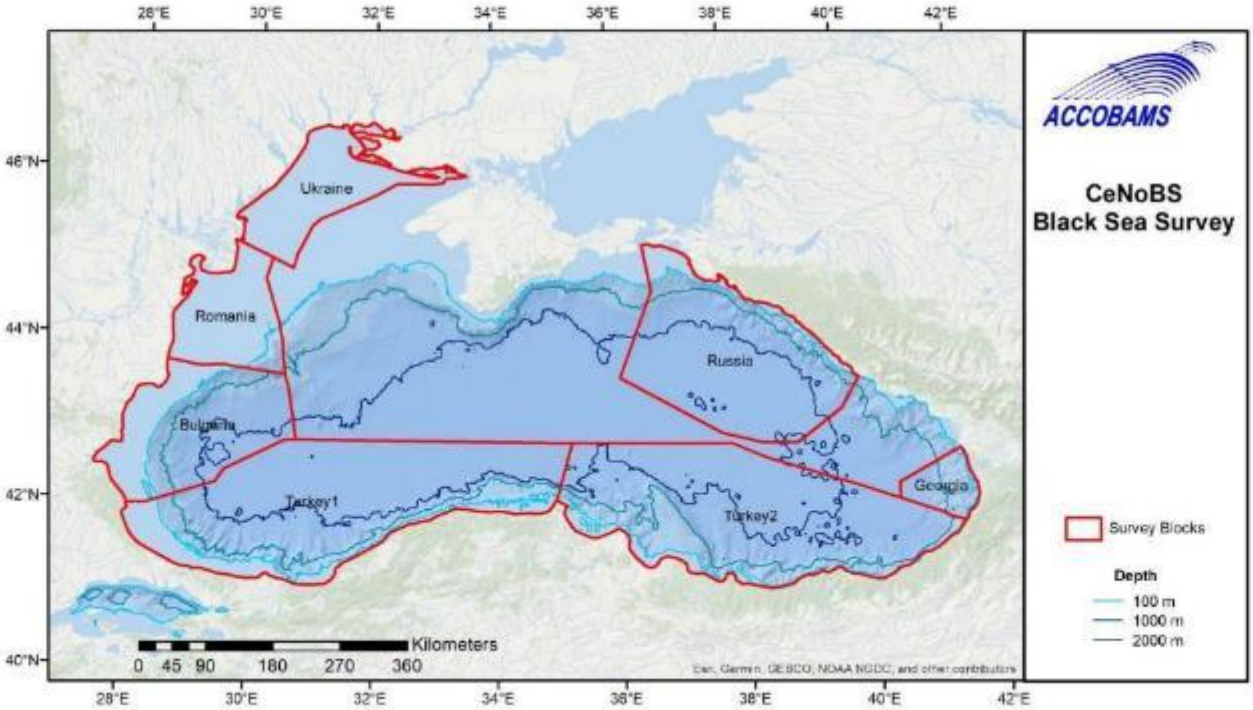


Fig. 2 – The original six blocks for the six countries of CeNoBS and the EMBLAS-Plus block, added in a second phase.

For all blocks equal spaced zigzag (ESZ) design was selected. The direction of the tracks was set to be as perpendicular as possible to depth contours and the coast, according to best practice for distance sampling, as in this way tracks would generally be perpendicular to the gradient of cetacean density.

The design aimed to achieve a minimum of 3% coverage of the areas, in order to be consistent with the Mediterranean survey, conducted in summer 2018. Five hundred iterations of each design were run in order to obtain the map of coverage probability (to assess whether it was homogeneous or not, by calculating the probability of tracks passing over every single point of the area), and the mean percentage coverage, mean total on effort trackline length and mean total trackline length.

The survey design was performed using the dedicated software Distance 7.3 that allows to choose the effort for each block, the orientation of the different tracks and calculate the best route to guarantee that each area has the same possibility of being covered by the planes (Thomas *et al.*, 2010). This is called Equal Coverage Probability and ensuring that the collected data are robust and statistically valid (see Buckland *et al.*, 2001, for further information and details on the methodology). The selected tracks allowed a final coverage of 5% for all the areas. Figure 3. shows the tracks actually covered during the survey by the two teams.

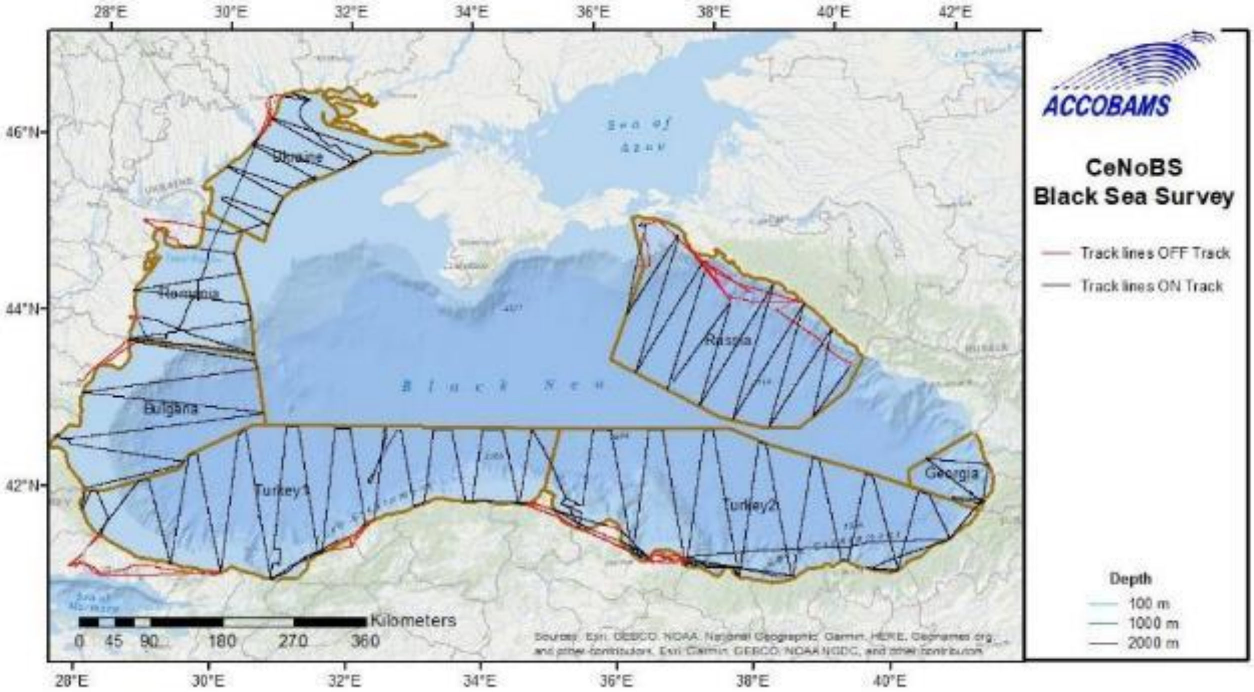


Fig. 3 – The tracks covered by the two planes (black=on effort; red=off effort).

II.3 DATA ANALYSIS

The collected data was analyzed to estimate abundance, density and assess distribution of the different species. Data analysis was performed with the support of skilled experts, using both model-based and design-based frameworks.

II.3.1 Design-based analysis

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* (effective strip half-width: probability * truncation (strip) width). 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 *eswL* 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.

A detection function was obtained for the three species, as enough sample size has been collected to estimate it for bottlenose dolphins, common dolphins and harbour porpoises.

The design-based analysis was performed in R, with an ad-hoc script prepared for this dataset. Segments of tracks and sightings with sea state 4 (Douglas scale) or above were excluded from the analysis.

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 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 are shown in Table 1.

Table.1 - Covariates tested in the models and their ranges or factor levels

Covariate	Type	Levels
Sighting related		
School size	Numerical	
Observer	Categorical	Observers names
Effort related		
Seastate (Douglas scale)	factor & numerical	0 (calm) 1 (very light) 2 (light breeze) 2.5 (isolated whitecaps) 3 (gentle breeze) 4 (moderate breeze)
Seastate2	factor	0-1 2-3 4-5
Swell	factor & numerical	0 1 m 2 m
Turbidity	factor & numerical	0 (clear) 1 (moderately clear) 2 (moderately turbid)
Sky glint	factor & numerical	0 (no glint) 1 (glint)
Glare severity	factor & numerical	0 (null) 1 (slight) 2 (moderate) 3 (strong)
Glare under	factor & numerical	0 (clear) 1 (glare)
Clouds	numerical	0 to 8 from clear to totally Cloudy
Clouds2	factor	0-2 3-5

		6-8
Subjective	factor	Subjective conditions in both sides (being E=excellent, G=good, M=moderate, P=poor) EE / EG / EM / GG / GM / GP / MM / MP / PP
Subjective2	factor	Subjective condensed into three classes EEG(EE / EG / GG) EMMG (EM / GM / MM) GPPM (GP / MP / PP)
Time day	factor	am (6-12am) noon (12-2pm) pm (2-8pm)
Aircraft	factor	Names of all aircrafts
Team	factor	Names of all teams
Effortstate	factor	Y (on track) N (off track)

Left truncation

By default, left truncation is set at 0 distance (i.e. no left truncation). But particularly for aerial surveys, it is common practice to left truncate perpendicular distance data if the histograms of frequency of perpendicular distances show that the area close to the line transect (distance=0) has clearly less observations than a bit further away. This happens always when there are no bubble windows (the observers cannot see right under the plane), and sometimes even when there are bubble windows (e.g. the windows are narrow and observers find very uncomfortable to look directly under the plane, observers tend to look further away and do not concentrate on the transect line, etc.).

After exploration of the data, it was clear that left truncation was necessary. The problem was more acute for bottlenose dolphins and harbour porpoises. The distribution of perpendicular distances was explored at fine detail, and the following left truncations were chosen: 30 m for bottlenose dolphins, 60 m for harbour porpoises and 40 m for common dolphins.

Right truncation

It is common practice to right truncate perpendicular distance data to eliminate sightings at large distances that have little or no influence on estimation of f(0) but adversely affect overall fit of the model. After visual inspection of the data (histograms of perpendicular distances) different right truncation distances were tested. A compromise between the comparison of the diagnostics of each of the different truncation distances and the percentage of data lost in each one was used to decide on the final right truncation. The diagnostics used were the qq-plots and the Cramer von Misses diagnostics (both of which show how well the fitted function fits the observed data).

The final right truncation distances were: 325 m for common dolphins, 570 m for harbour porpoises and 320 m for bottlenose dolphins.
Considering both left and right truncation, the number of observations discarded for analysis were 130 (16.1%) for common dolphins, 174 (19.5%) for harbour porpoises and 18 (7.44%) for bottlenose dolphins.

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 (CvM) statistics (that focus on the squared differences between cdf and edf). The smallest value of the CvM (and higher p-value) means better fit. The smaller AIC was also preferred as it means a better compromise between fit of the model and its complexity (number of parameters). The AIC was the main diagnostics used. If there were several competing models (similar AIC within 2 points), then we looked at the CvM to asses which of them produced a better fit.

II.3.2 Model-based analysis

Spatial and environmental covariates

Density surface models were produced by modelling species abundance as a function of environmental covariates. A spatial grid was created covering the survey area to provide values of environmental covariates for the effort segments and to predict abundance spatially. The resolution of the grid cells was chosen as the finest consistent resolution that captures all available environmental covariates (10x10 km). Environmental data was thus assigned to the centre of each grid cell.

Environmental variables were derived from a large number of data sources. They included variables such as water depth (m), distance to the several depth contours (as proxies for coastal, continental shelf, oceanic habitats, etc.), distance to canyons and seabed slope. As indices of marine hydrology and/or biological activity/primary productivity, we included sea surface temperature, levels of chlorophyll-a and others. For a complete list of variables used, see Table2.

Table. 2. - Covariates tested in the spatial models.

Covariate	Description	Units
Fixed		
Lat	Latitude	dec. deg
Lon	Longitude	dec. deg
Aspect	Orientation of the sea floor (0-359º)	deg
Depthmean	Mean depth within the grid cell	m
Dist0	Distance to coast	km
Dist50	Distance to the 50m depth contour	km
Dist100	Distance to the 100m depth contour	km
Dist200	Distance to the 200m depth contour	km
Dist500	Distance to the 500m depth contour	km
Dist1000	Distance to the 1000m depth contour	km
Dist2000	Distance to the 2000m depth contour	km

DistCan	Distance to canyons	km
DistEsc	Distance to escarpments	km
DistCanEs	Distance to canyons/escarpments	km
DistShelf	Distance to the continental shelf	km
DistSlope	Distance to the slope	km
DistAbyss	Distance to the abyss (beyond the slope)	km
Slope	Slope of the sea floor	deg
Dynamic		
chl_mean	Mean chlorophyll concentration for June-September	mg/l
chl_mean_season	Mean chlorophyll concentration for the month the segment was surveyed	mg/l
mld_mean	Mean mixed layer depth for June-September	m
mld_mean_season	Mean mixed layer depth for the month the segment was surveyed	m
sbt_mean	Mean sea bottom temperature for June-September	deg.C
sbt_mean_season	Mean sea bottom temperature for the month the segment was surveyed	deg.C
ssc_mean	Mean current intensity for June-September (upper 5 m)	m/sec
ssc_mean_season	Mean current intensity for the month the segment was surveyed (upper 5 m)	m/sec
ssh_mean	Mean sea surface height anomaly for June-September	m
ssh_mean_season	Mean sea surface height anomaly for the month the segment was surveyed	m
sss_mean	Mean sea surface salinity for June-September (upper 5 m)	psu
sss_mean_season	Mean sea surface salinity for the month the segment was surveyed (upper 5 m)	psu
sst_mean	Mean sea surface temperature for June-September (upper 5 m)	deg.C
sst_mean_season	Mean sea surface temperature for the month the segment was surveyed (upper 5 m)	deg.C
chl_sd	Standard deviation of chlorophyll concentration for June-September	mg/l
chl_sd_season	Standard deviation of chlorophyll concentration for the month the segment was surveyed	mg/l
mld_sd	Standard deviation of mixed layer depth for June-September	m
mld_sd_season	Standard deviation of mixed layer depth for the month the segment was surveyed	m
sbt_sd	Standard deviation of sea bottom temperature for June-September	deg.C
sbt_sd_season	Standard deviation of sea bottom temperature for the month the segment was surveyed	deg.C
ssc_sd	Standard deviation of current intensity for June-September (upper 5 m)	m/sec
ssc_sd_season	Standard deviation of current intensity for the month the segment was surveyed (upper 5 m)	m/sec
ssh_sd	Standard deviation of sea surface height anomaly for June-September	m
ssh_sd_season	Standard deviation of sea surface height anomaly for the month the segment was surveyed	m
sss_sd	Standard deviation of sea surface salinity for June-September (upper 5 m)	psu
sss_sd_season	Standard deviation of sea surface salinity for the month the segment was surveyed (upper 5 m)	psu
sst_sd	Standard deviation of sea surface temperature for June-September (upper 5 m)	deg.C
sst_sd_season	Standard deviation of sea surface temperature for the month the segment was surveyed (upper 5 m)	deg.C

The dynamic covariates SST and CHL-a were obtained from SeaWiFS and MODIS-Aqua sensors and the SST of MODIS-Terra and MODIS-Aqua. Depth was extracted from ETOPO (a 1 arc-minute global relief model of Earth's surface that integrates land topography and ocean bathymetry, https://ngdc.noaa.gov/mgg/global/global.html). Its derivatives were obtained using ArcGis 10.5.

Segments of effort

All on-effort transects (i.e. where searching conditions were acceptable) were divided into segments (mean= 10.1 km) with homogeneous effort types, and under the assumption that little variability in physical and environmental features occurred, as they were clipped to fit each in a grid cell. Therefore, each segment was associated with the values of the covariates of the specific cell in which it fell. The clipping of the segments was done in ArcGis 10.5 using the Tool "Identity" to clip the effort lines with the grid cells, resulting in a final mean segment length of 10.2 km. As for the design-based method, segments of tracks and sightings with sea state 4 were excluded from the analysis, as were sightings beyond the truncation distances for each species.

Stratification

All estimates were produced for each individual block as well as for the whole of the study area (sum of the blocks).

A complication of the analysis was that the Russian block was surveyed about 2 months later (in September) than the rest of the blocks. When analysing the data altogether using dynamic covariates that may change between the two survey periods, a bias or a misleading result could be obtained because of the confounding effect of potential real differences in distribution between Russia (at the easternmost part of the Black Sea) and the rest of the blocks (westernmost and southern parts), and differences due to changes in the environmental conditions within the two months lag between both surveys. Therefore, there are two fundamental problems: (a) the distribution of animals could be different in the two periods and (b) the relationship between density and environmental covariates could be different in the two periods. To explore this possibility, separate analyses were done for Russia and the rest of the blocks, and another analysis pooling together all blocks including Russia.

Models structure

The count of groups in each segment was used as the response variable. The abundance of groups was modelled using a Generalized Additive Model (GAM) with a logarithmic link function, and a Tweedie error distribution, very close to a Poisson distribution but allowing for some over-dispersion. The general structure of the model is:

$$n_i = \exp\left[\ln(a_i) + \theta_0 + \sum_k f_k(z_{ik})\right]$$

where n_i is the number of groups in the i^{th} segment, the offset a_i is the effective search area for the i^{th} segment (calculated as the length of the segment multiplied by twice the effective strip half-width – *esw*), Θ is the intercept, f_k are smoothed functions of the explanatory covariates, and z_{ik} is the value of the k^{th} explanatory covariate in the i^{th} segment. The *esw* was obtained for each species/species group from their detection function, according to the covariates included in it.

In the case of modelled group sizes, the observed group size of each sighting was taken as a response variable, no offset was used, and the distribution family was negative binomial.

Model fitting and selection

As a first step, an exploration of correlations was performed among covariates. As a result, “families” of covariates were created such as only one element of each family could be tested in each model. Figures 4 and 5 show the collinearity plots resulting for fixed and dynamic covariates. All correlations equal or above 0.7 were considered as collinear and therefore not used together in the same model.

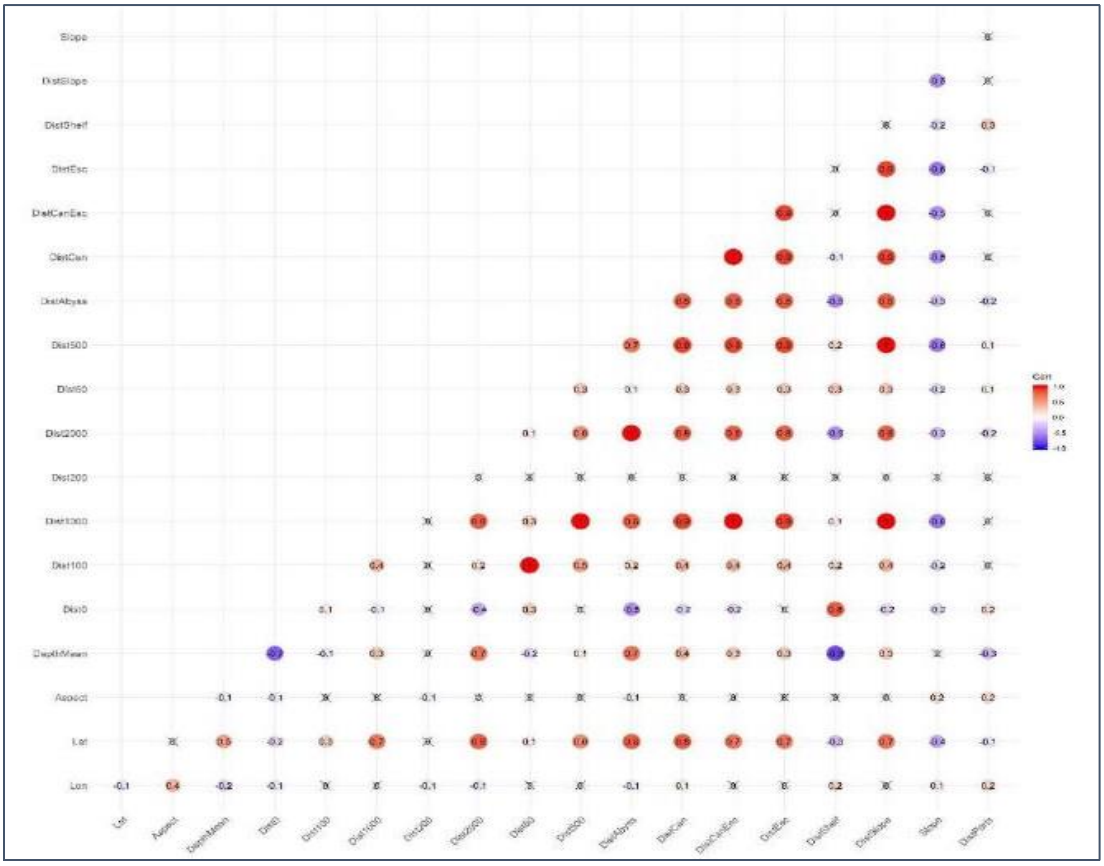


Fig. 4 - Collinearity plot for fixed covariates

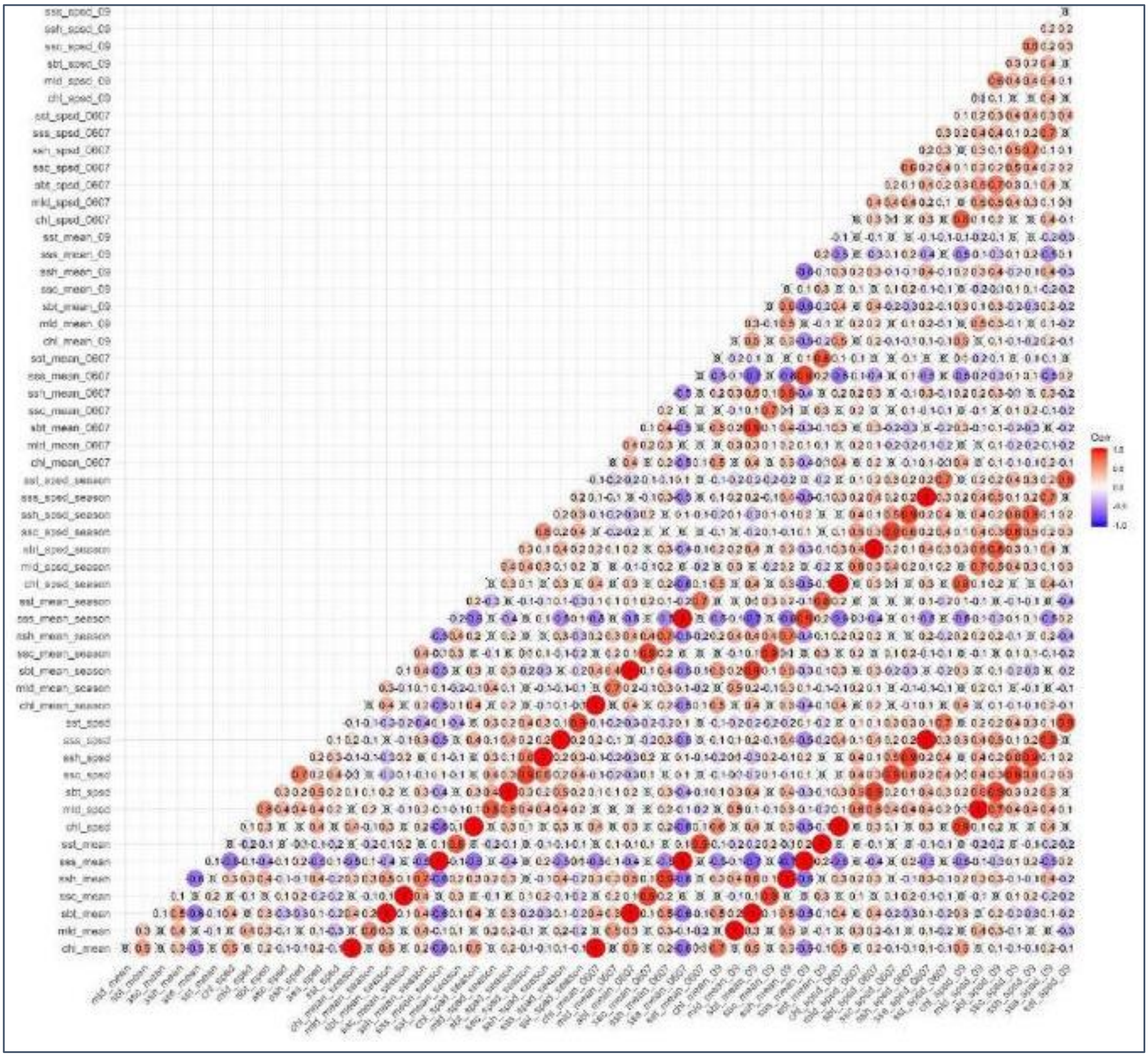


Fig. 5 - Collinearity plot for dynamic covariates

REML (Restricted maximum likelihood) was used to fit the models. Shrinkage smoothers were also used in all models, which reduces the effective degrees of freedom to zero if a covariate explains little variation in the data.

A full model (including all covariates) was run. Using REML and shrinkage smoothers, the non-useful covariates were discarded reducing it only to the covariates to be tested in the final models.

All the final models were run using all the potential combinations of the "useful" covariates selected by REML and the shrinkage smoothers from the full model, sequentially testing each covariate from each collinear family. All the resulting models were judged and ranked automatically by AIC avoiding time consuming and unreliable manual selection.

Abundance estimation

Abundance of groups in each grid cells is estimated by multiplying the predicted density of groups from the model (modelled count of groups with the effective search area as the offset) by the surface area of the grid cell. Abundance per species in each grid cell were obtained then multiplying the abundance of groups by the mean group size estimated for each substratum or the modelled group sizes if spatial variation was observed.

The total abundance estimates for the whole study area and for each block were obtained by summing up the abundance of all the grid cells comprised within the target study area.

Uncertainty

Variance of abundance was estimated by a parametric bootstrap procedure, also called "posterior simulation". This method generates bootstrap replicates based on resampling the parameters of the best fitting model, instead of resampling the data itself. The delta method was used to combine the CV from the bootstrap with the CV from the detection function and from the model. The 95% CIs will be obtained using the final CV and assuming the estimates were lognormally distributed.

All modelling was carried out using the statistical software R (R Core Team 2017) using the *mgcv* package (Wood, 2011) within an ad-hoc script created for this dataset.

III. RESULTS

Even though the plan of the CeNoBS survey was to cover all the riparian countries except Russian waters, thanks to the cooperation with the EMBLA-Plus project a 7th block was covering partially the Russian waters and was defined as EMBLAS-Plus. The aerial survey of the 6 blocks under CeNoBS project were conducted between June 17th and July 4th, 2019. Two planes were employed during the survey, one starting from Romania, in the North-West portion of the Black Sea and a second one surveying Turkish and Georgian waters, from east to west. The Russian block was covered with a third plane, between September 22nd and September 24th, 2019.

Given the relatively short period of time between the two surveys, and the expert's knowledge that Black Sea cetaceans do not extensively migrate in this time-frame, it is considered adequate to pull the data together. Nevertheless, they were analyzed together, as well as separated, as mentioned above, taking in consideration of actual differences.

III.1. SIGHTINGS

A total of 1,984 cetacean sightings were recorded during the aerial surveys, with 4,688 individuals from 3 different species (Table 3). A total of 15,246 kilometers was surveyed by the three planes in the different blocks, with 9,354 km on effort and 5,892 km off effort. A summary is presented in Table 4. The aerial survey in the waters of the Russian Federation in September 2019 included 2,030 km of effort, 15 transects. A total of 240 sightings of cetacean groups were recorded, including 94 sightings of common dolphins, 122 sightings of bottlenose dolphins and 6 sightings of harbour porpoises.

Table. 3 – The total number of sightings (left) and individuals (right) observed during the aerial surveys.

Species	**Number of sightings**		**Number of individuals**	
	CeNoBS	EMBLAS-Plus	CeNoBS	EMBLAS-Plus
Bottlenose dolphin	117	122	335	381
Common dolphin	715	94	1762	543
Delphinid	28	18	50	80
Harbour porpoise	884	6	1522	15
Total	**1744**	**240**	**3669**	**1019**

Table. 4 – The total number of kilometres covered per block on-effort and off-effort.

Block	**Km on effort**	**Km off effort**	**Total Km**
Bulgaria	1115.53	159.59	1275.12
Georgia	210.36	119.12	329.48
Romania	816.32	548.44	1364.76
Turkey1	2211.47	2095.2	4306.67
Turkey2	2203.03	1405.1	3608.13
Ukraine	767.39	735.7	1503.09
Russia	2030.3	829.4	2859.7
Total	**9,354.40**	**5,892.55**	**15,246.95**

The following figures present the geographical distribution of the different species of cetaceans observed, together with human pressures as they were sighted and recorded by the three teams (Figs. 6-18).

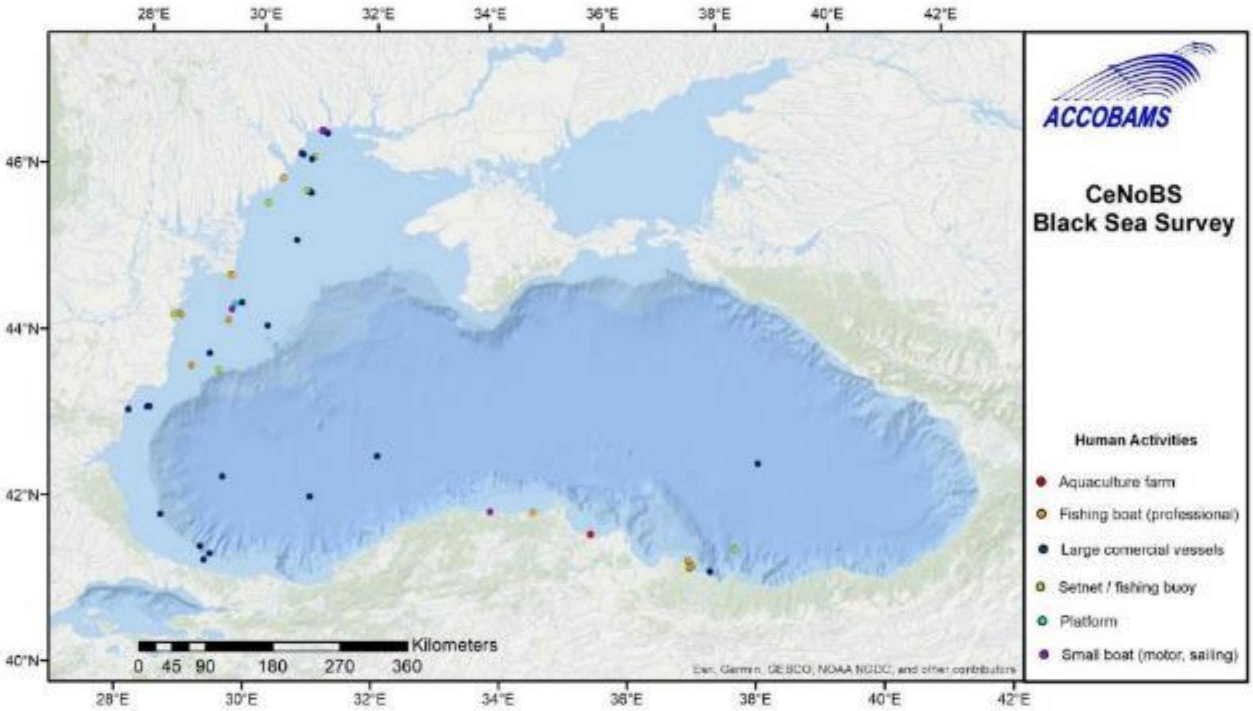


Fig. 6 – Human activities in terms of naval traffic and aquaculture farms.

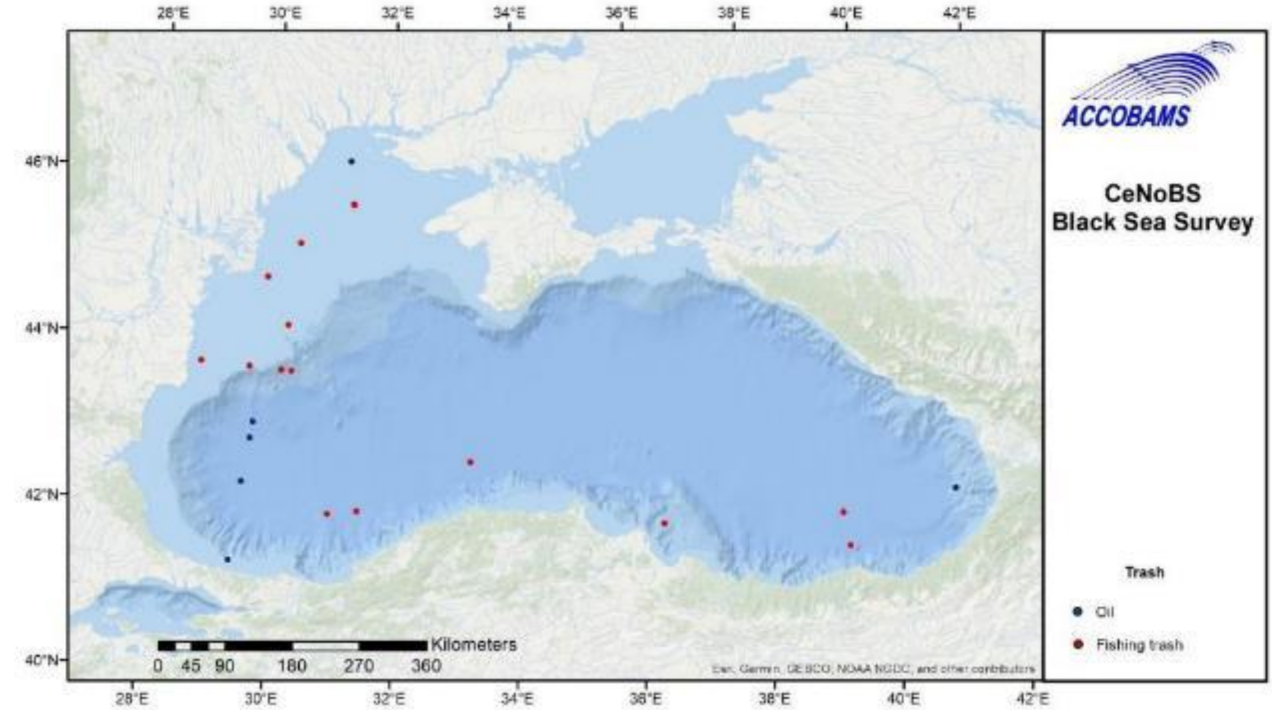


Fig. 7 – Oil pollution and fishing trash recorded by the teams.

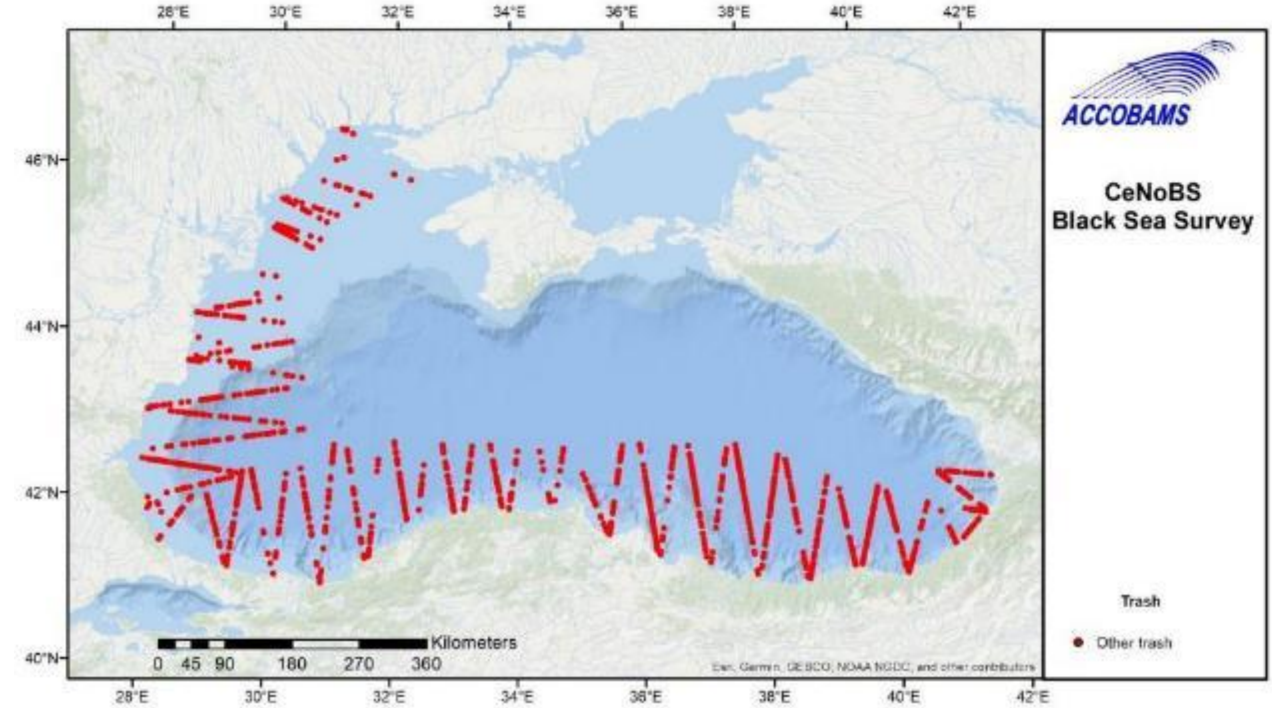


Fig. 8 – Marine debris, including plastic debris, recorded during the surveys.

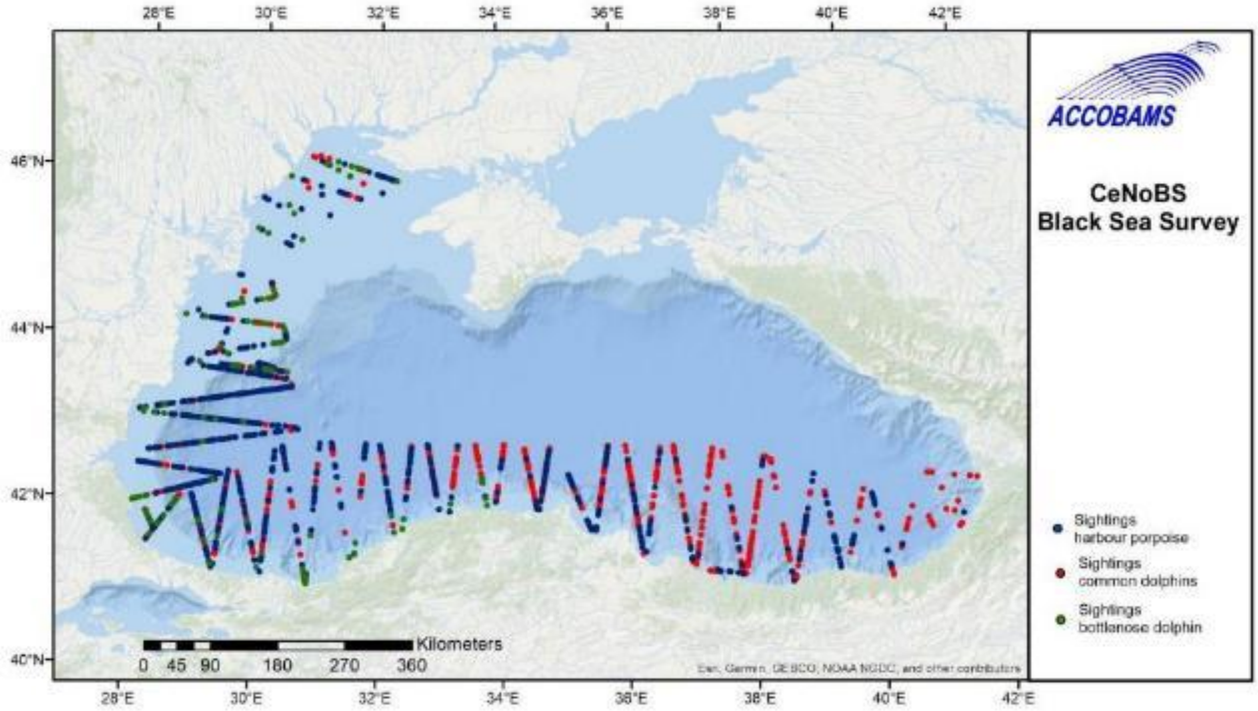


Fig. 9 – Cetaceans sightings recorded during the surveys within the CeNoBS blocks.

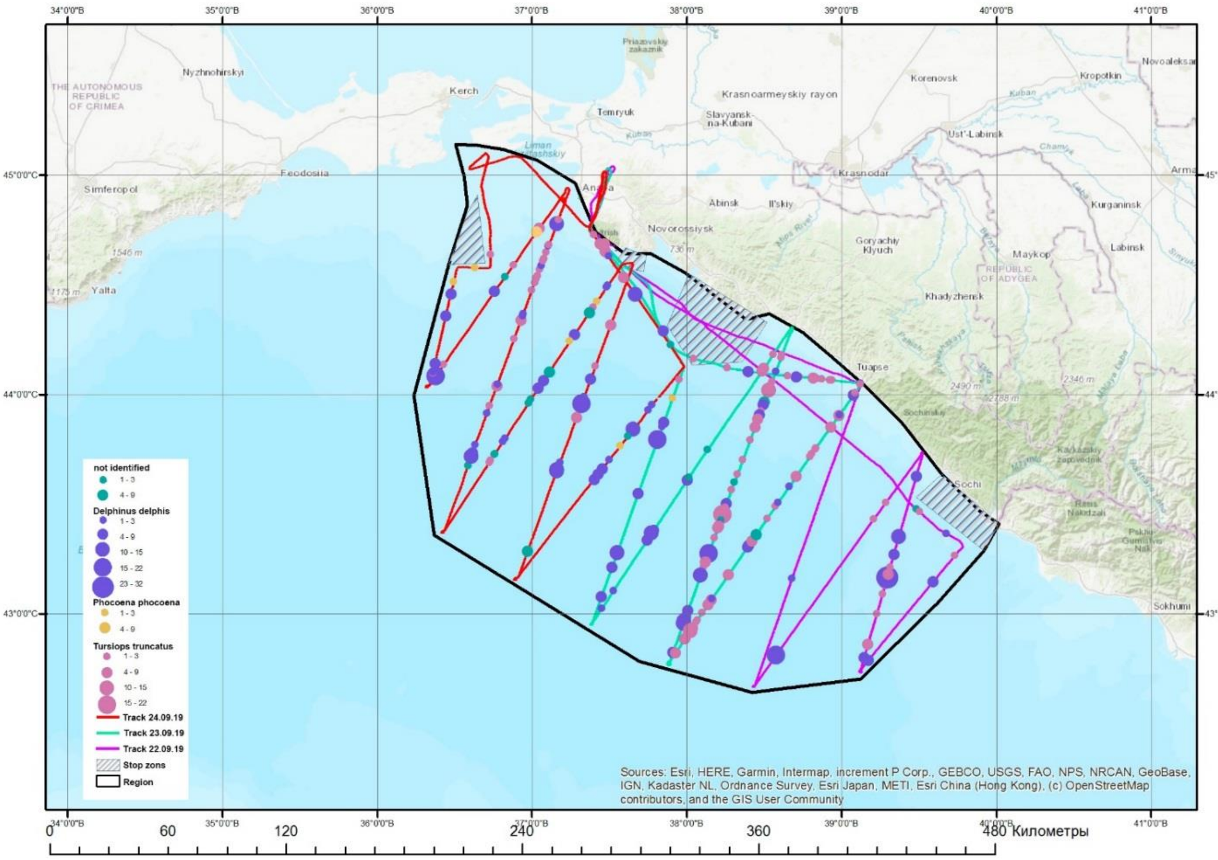


Fig. 10 – Cetaceans sightings recorded during the surveys within the EMBLAS-Plus block.

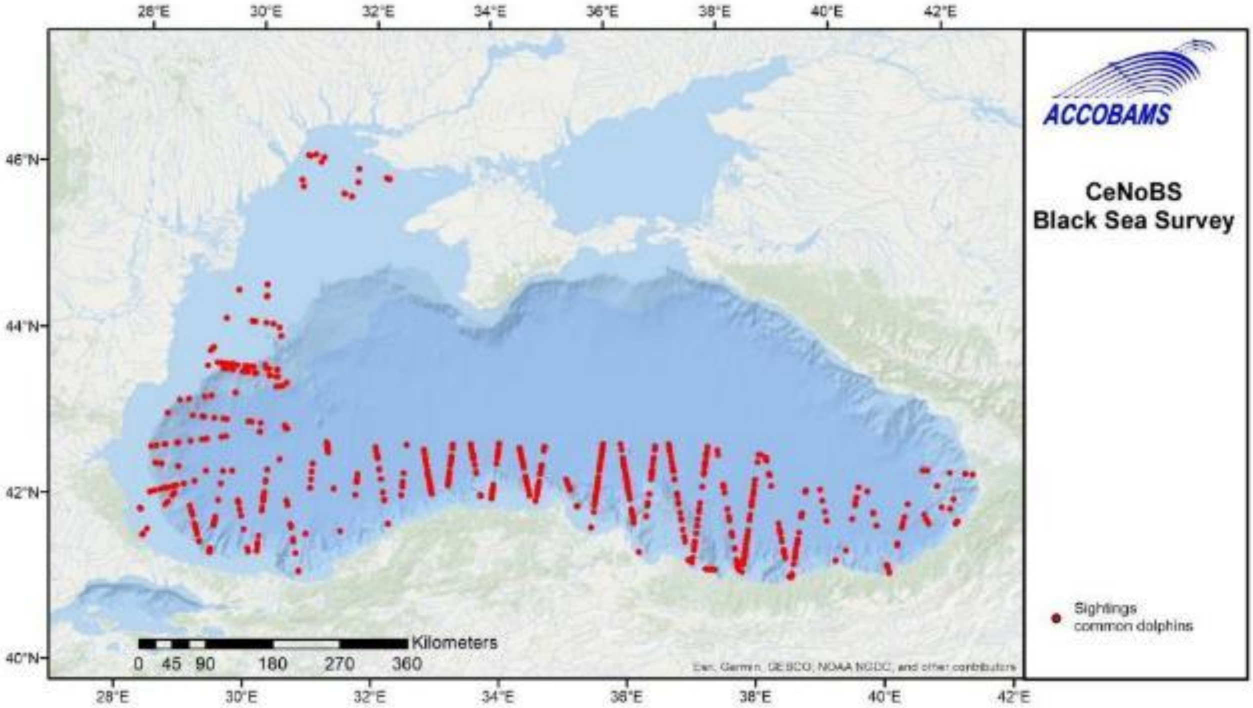


Fig. 11 – Black Sea common dolphins recorded during the surveys.

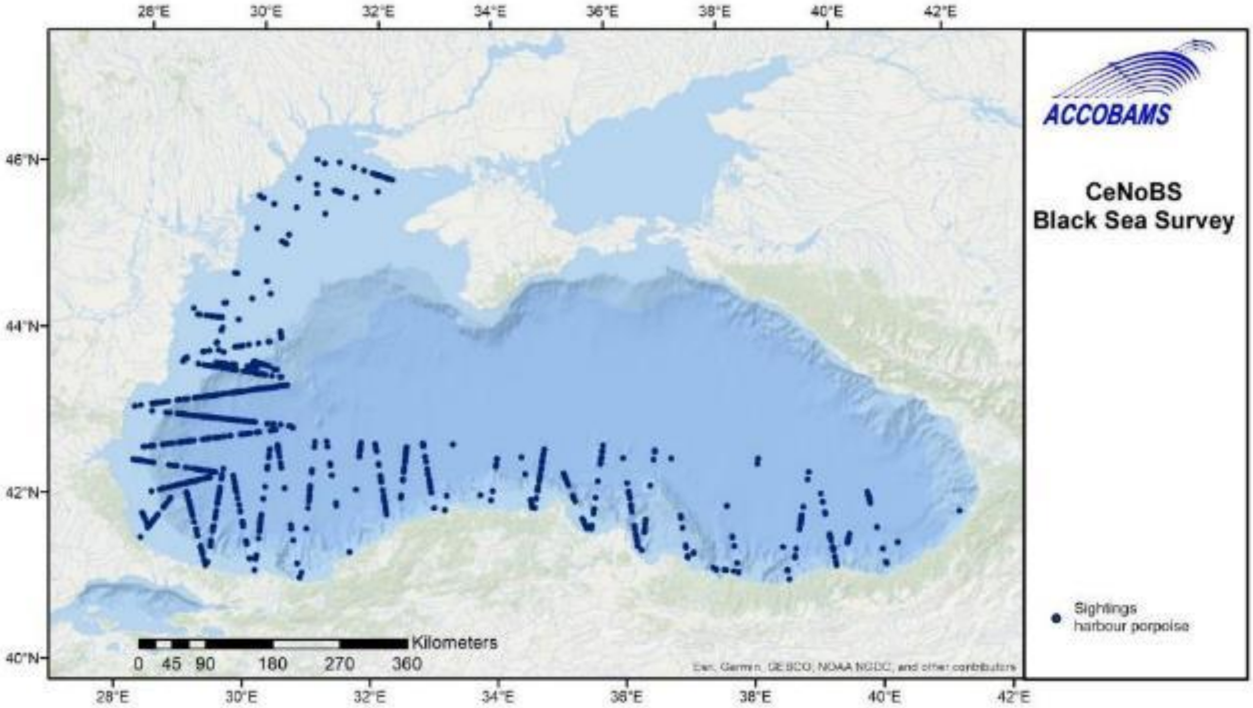


Fig. 12 – Black Sea harbour porpoises recorded during the surveys.

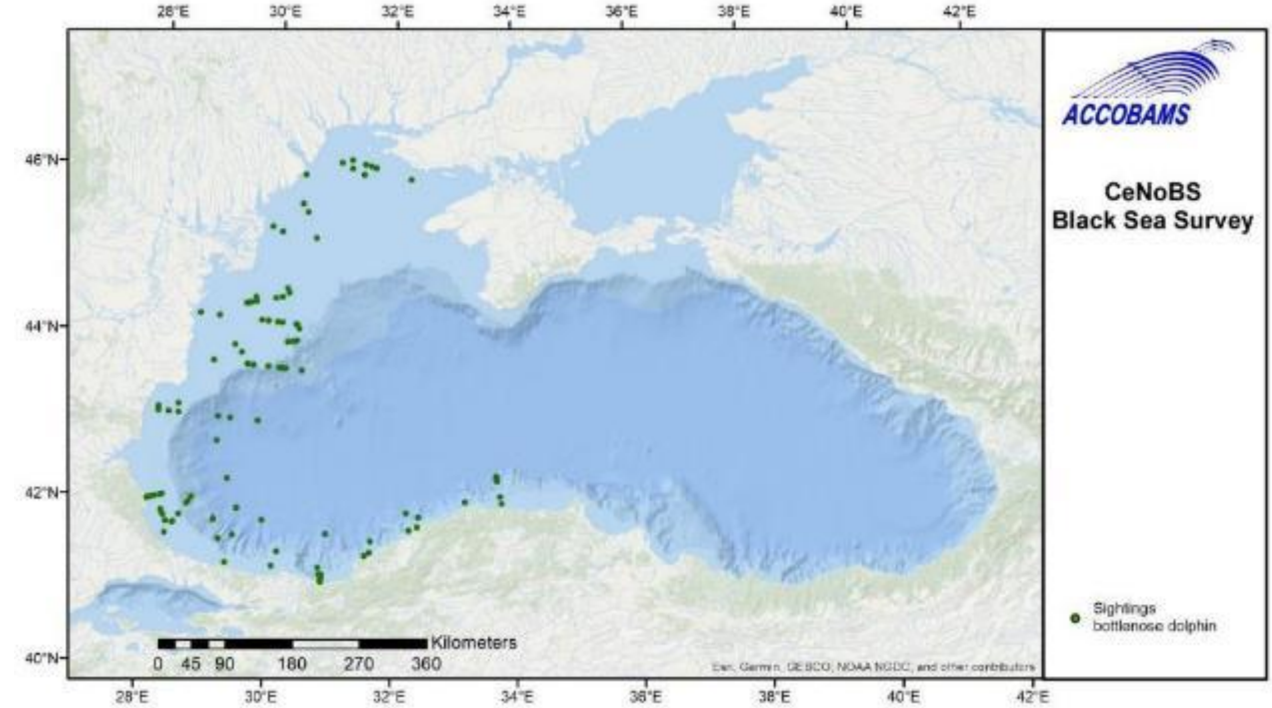


Fig. 13 – Black Sea bottlenose dolphins recorded during the surveys.

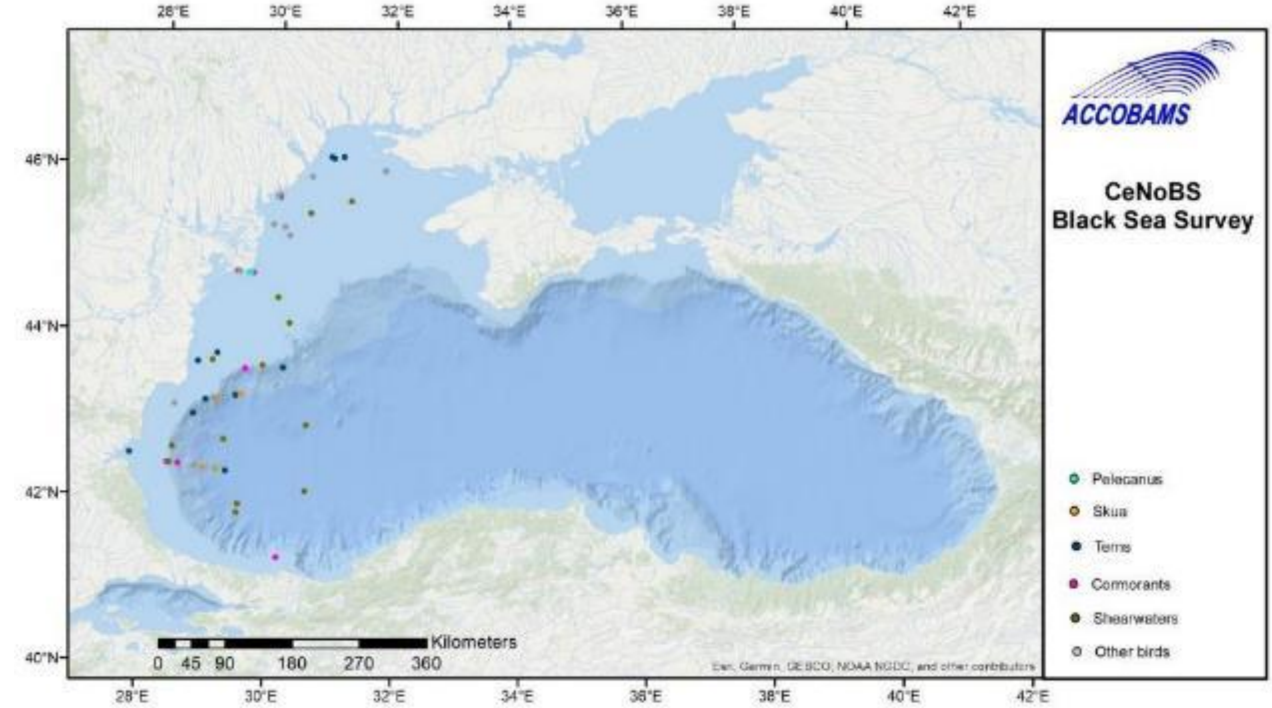


Fig. 14 – Marine birds recorded during the surveys.

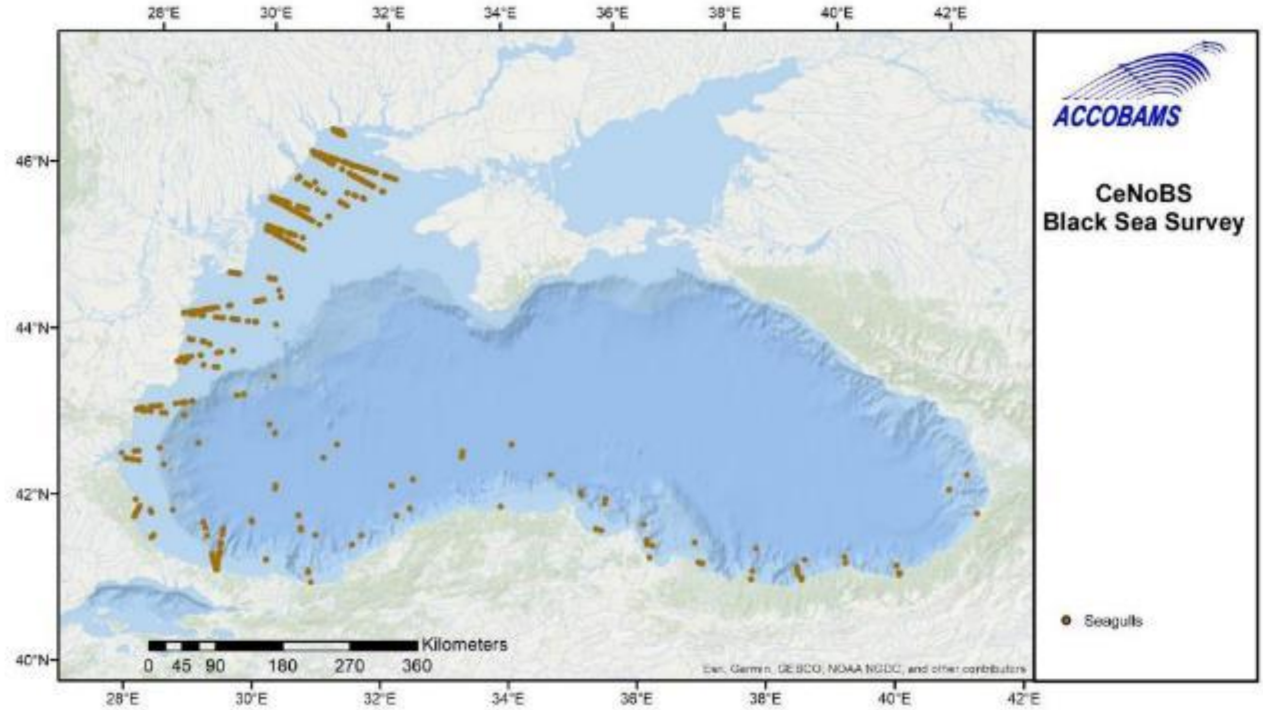


Fig. 15 – Seagull species recorded during the surveys.

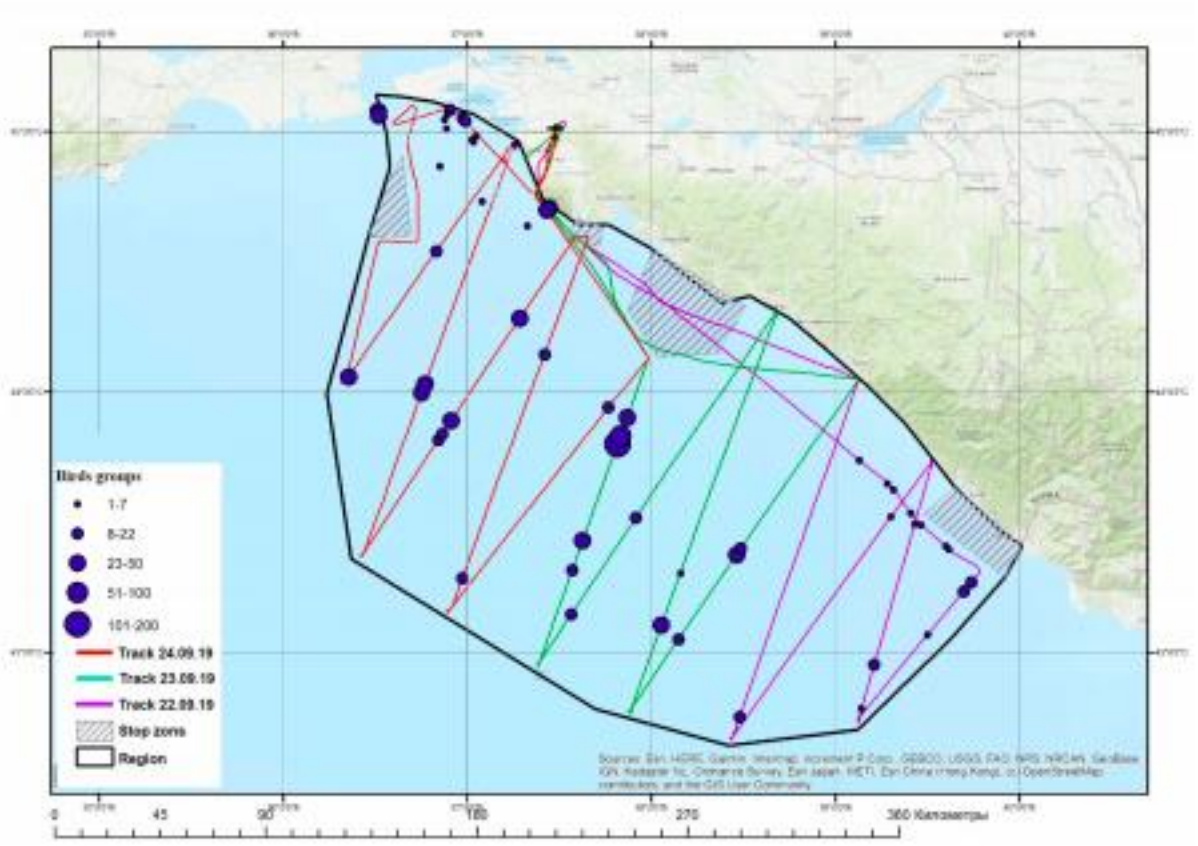


Fig. 16 – Marine birds recorded during the surveys within the EMBLAS-Plus block.

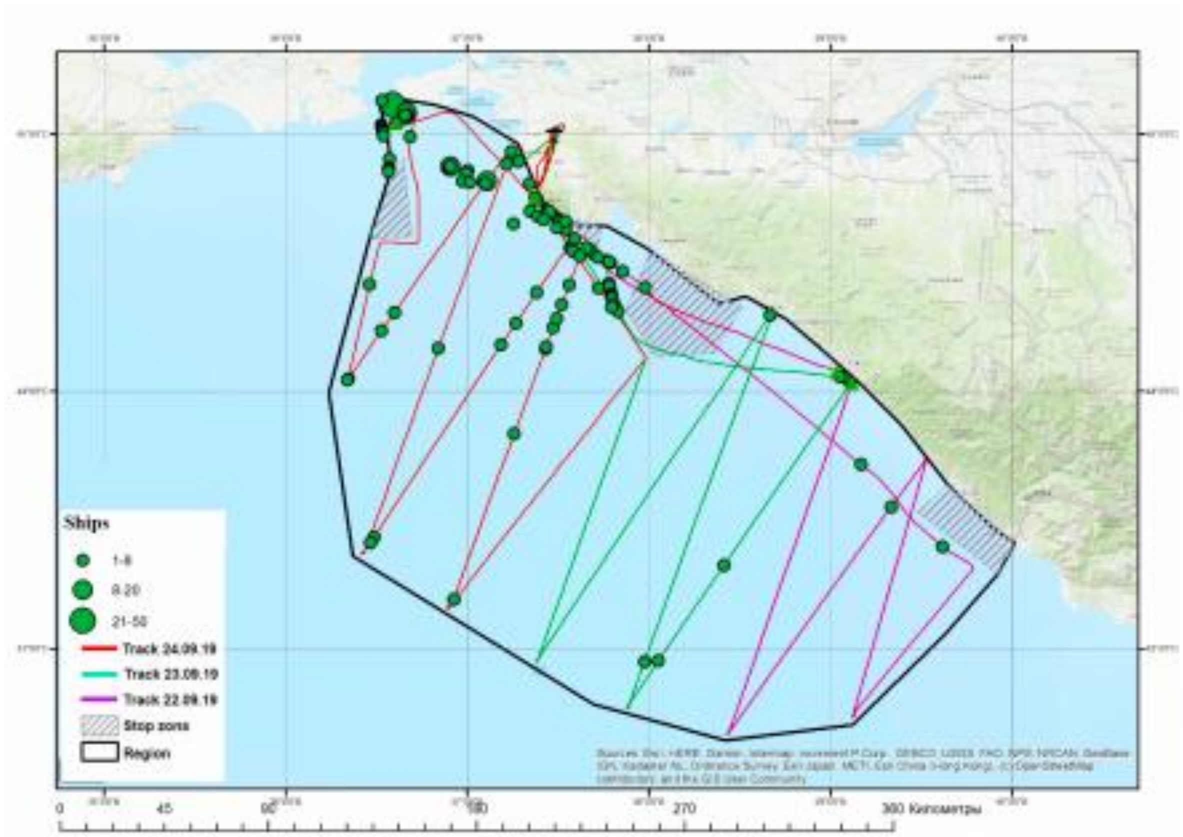


Fig. 17 – Human activities in terms of naval traffic recorded within the EMBLAS-Plus Block.

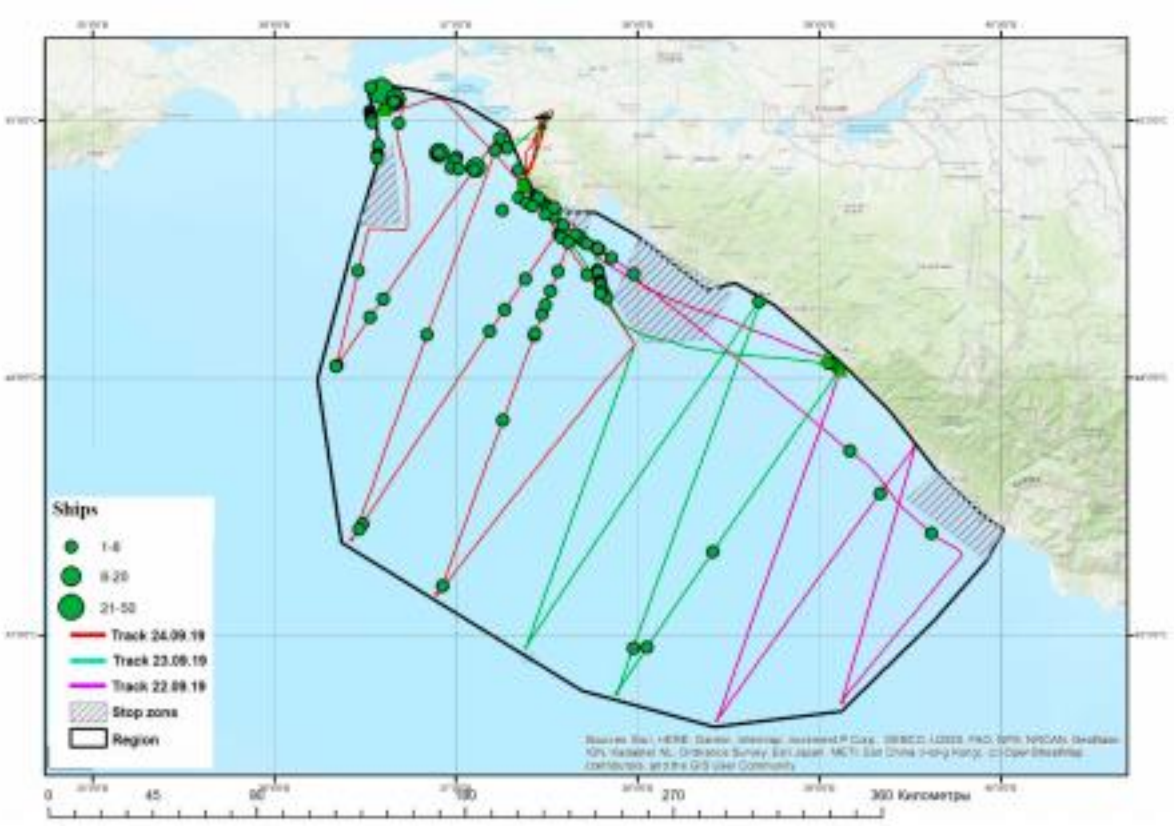


Fig. 18 – Marine birds recorded during the surveys within the EMBLAS-Plus block.

III.2. ABUNDANCE AND DENSITY ESTIMATION

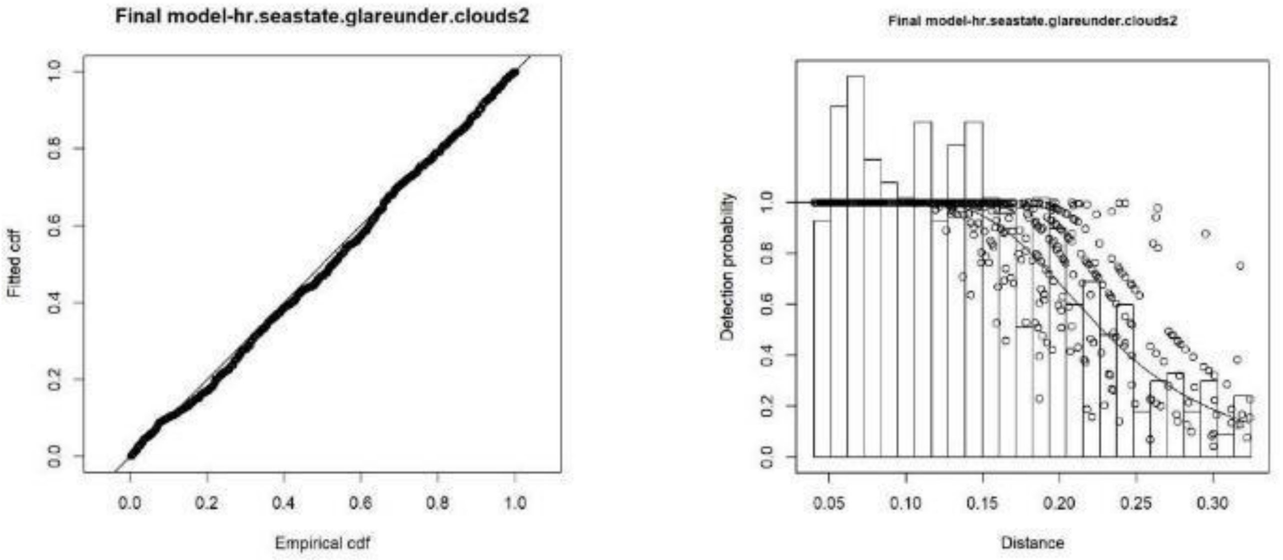
III.2.1. Design-based analysis

The final detection functions chosen for each species and their diagnostics are presented in Table 5 and Figures 19 to 21 The individual effect of each covariate in the selected model is presented in Figures 22 to 24.

The abundance estimates obtained with the design-based analysis for the three species of cetaceans can be found in Tables 6 to 8. In these tables, “mean group size” is the mean of the observed group sizes, while “expected group size” is the result of dividing the estimated abundance of individuals by the estimated abundance of groups.

Table 5. - Parameters and results of the detection functions. Codes: Truncation: L= left truncation (km), R= right truncation (km); n = number groups in detection function; key functions: HN = half-normal, HR =hazard-rate; p=probability of detection; CV p = coefficient of variation of the probability of detection; esw = effective half-strip width (km); CvM p = p-value of the Cramer von Misses goodness of fit.

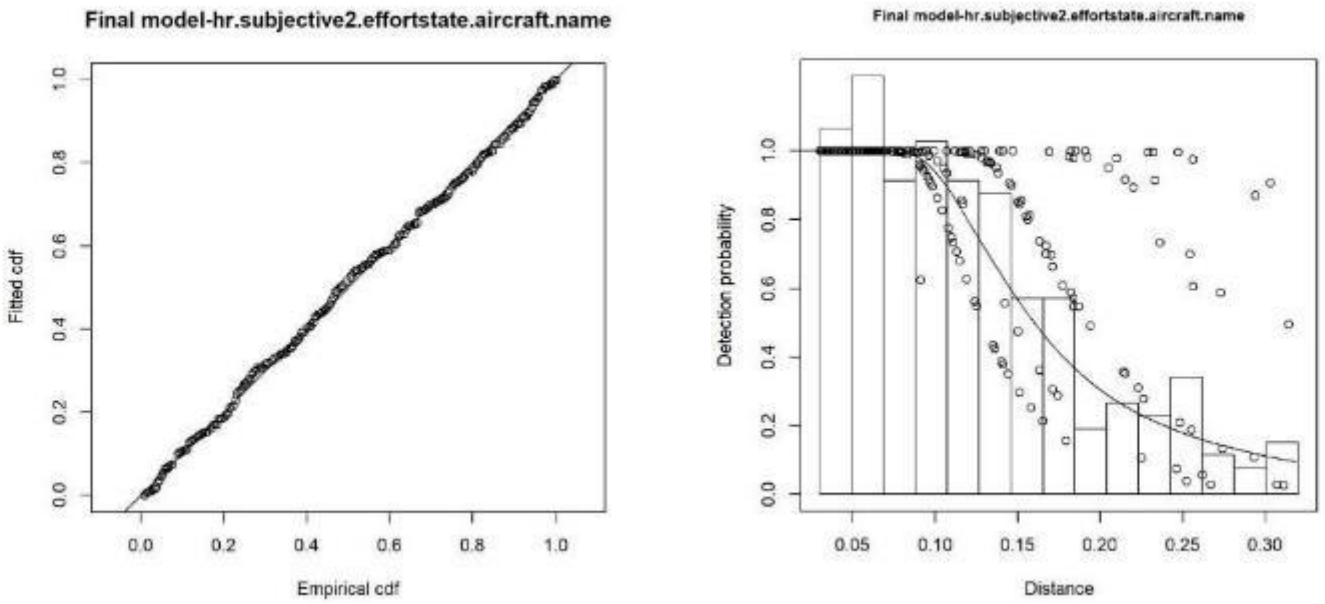
	Truncation								
Species	**L**	**R**	**n**	**Key function**	**Covariates**	**p**	**CV p**	**esw**	**CvM p**
Common dolphins	0.04	0.325	676	HR	seastate – glareunder – clouds2	0.683	0.029	0.195	0.330
Bottlenose dolphins	0.03	0.320	224	HR	subjective2 – effortstate - aircraft	0.515	0.063	0.149	0.978
Harbour porpoises	0.06	0.570	717	HR	seastate – turbidity – clouds2	0.318	0.029	0.162	0.949



Q-q plot

Detection function

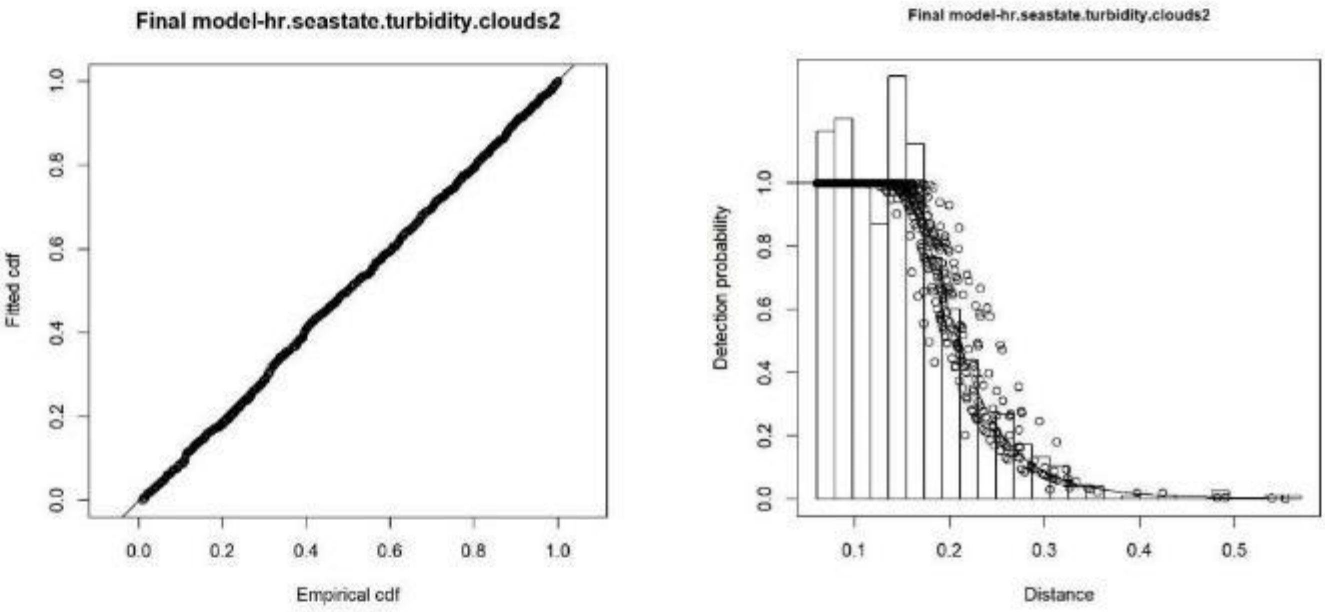
Fig. 19 - Q-q plot (left) and detection function (right) for common dolphins. The detection function is scaled to 1.0 at the left-truncated perpendicular distance, and the histograms represent the frequency of the observed sightings at different perpendicular distances. Dots represent individual sightings and the effect of the covariates considered.



Q-q plot

Detection function

Fig. 20 - Q-q plot (left) and detection function (right) for bottlenose dolphins. The detection function is scaled to 1.0 at the left-truncated perpendicular distance, and the histograms represent the frequency of the observed sightings at different perpendicular distances. Dots represent individual sightings and the effect of the covariates considered.



Q-q plot

Detection function

Fig. 21 - Q-q plot (left) and detection function (right) for harbour porpoise. The detection function is scaled to 1.0 at the left-truncated perpendicular distance, and the histograms represent the frequency of the observed sightings at different perpendicular distances. Dots represent individual sightings and the effect of the covariates considered.

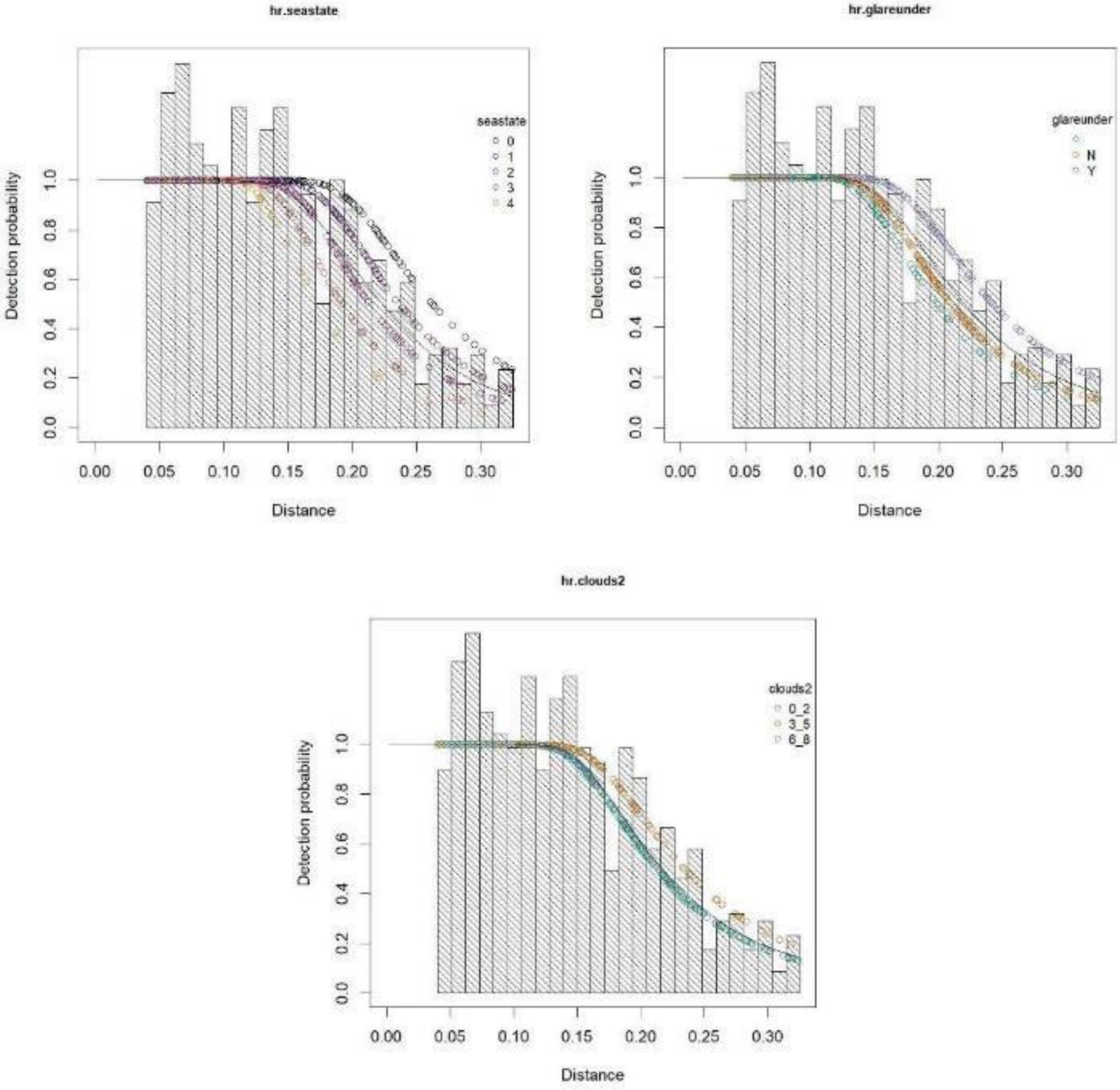


Fig. 22- Effect of the individual covariates from the final detection function for common dolphins. The detection function is scaled to 1.0 at the left-truncated perpendicular distance, and the histograms represent the frequency of the observed sightings at different perpendicular distances. Dots represent individual sightings and the effect of the covariates considered.

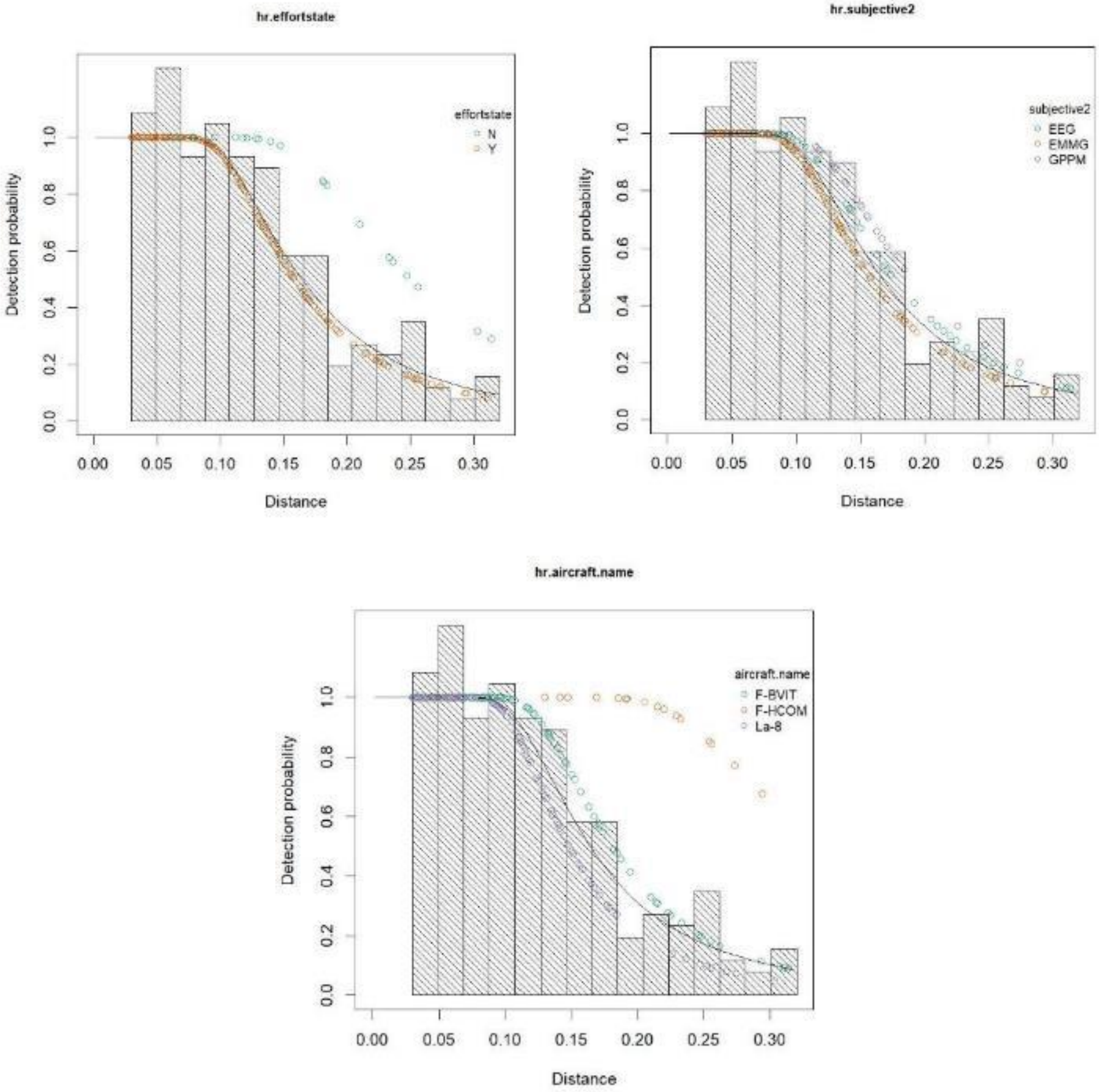


Fig. 23 - Effect of the individual covariates from the final detection function for bottlenose dolphins. The detection function is scaled to 1.0 at the left-truncated perpendicular distance, and the histograms represent the frequency of the observed sightings at different perpendicular distances. Dots represent individual sightings and the effect of the covariates considered.

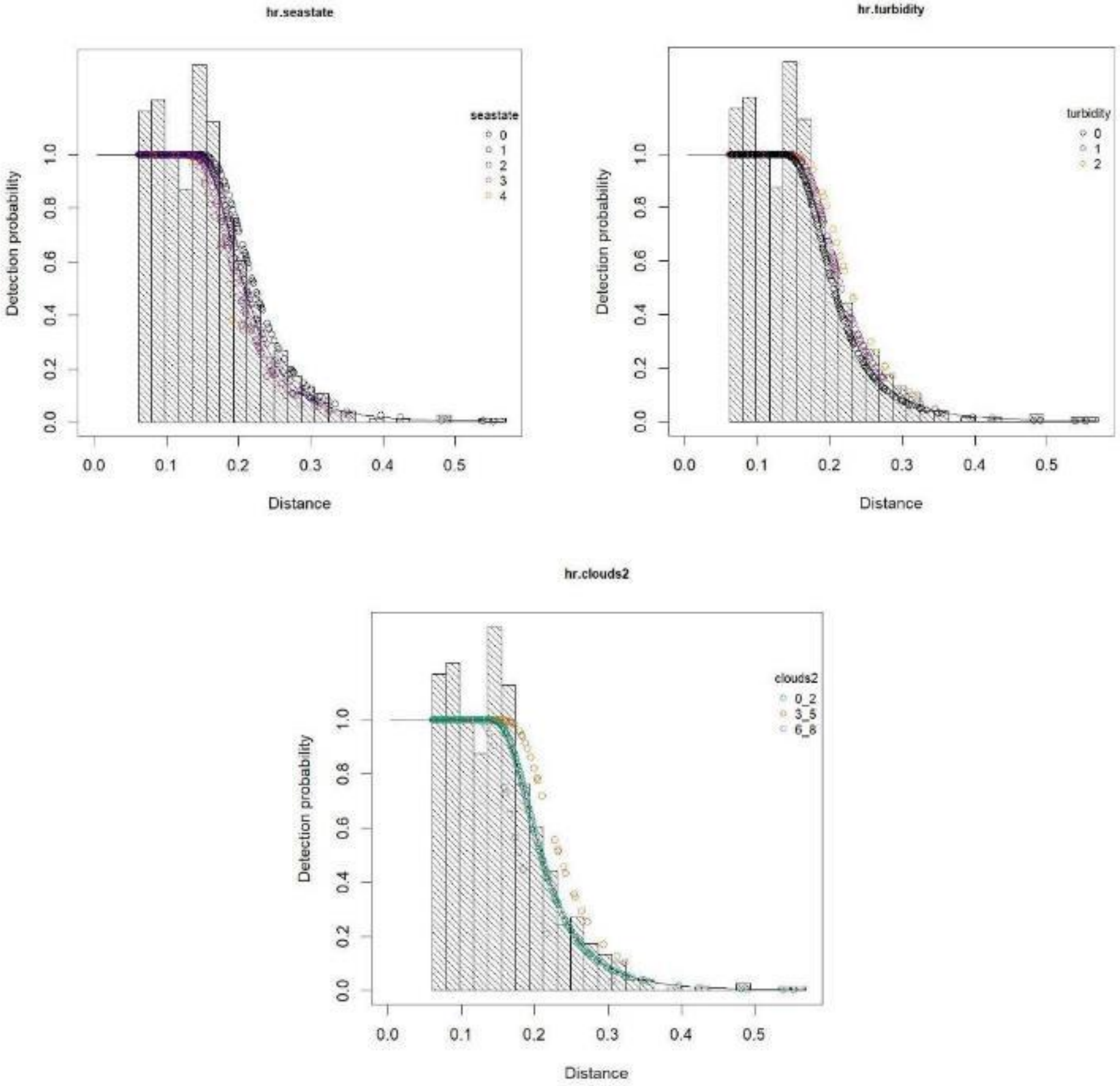


Fig. 24 - Effect of the individual covariates from the final detection function for harbour porpoise. The detection function is scaled to 1.0 at the left-truncated perpendicular distance, and the histograms represent the frequency of the observed sightings at different perpendicular distances. Dots represent individual sightings and the effect of the covariates considered.

Table 6 - Results of the design-based analysis for common dolphins.

Stratum	Area km^2	n groups	mean group size	exp. group size	CV exp. group size	Effort (km)	Enc. Rate groups (per km)	CV Enc. rate groups	Density (Anim./ km^2)	Abundance	CV	95% Confidence Interval	
Bulgaria	32683	72	2.43	2.49	0.1478	1187.6	0.0606	0.1445	0.4056	13258	0.2233	8568	20514
Georgia	6237	7	3.00	2.90	0.1908	329.5	0.0212	0.4260	0.2027	1264	0.4980	492	3250
Romania	18611	32	2.38	2.38	0.2796	1211.9	0.0264	0.2391	0.1413	2629	0.3564	1326	5213
Russia	48547	83	5.76	5.76	0.1018	2726.5	0.0304	0.1418	0.5215	25315	0.1962	17267	37113
Turkey1	71796	207	2.57	2.53	0.0806	3208.2	0.0645	0.1253	0.4193	30105	0.1445	22691	39941
Turkey2	69785	260	2.22	2.20	0.0767	3313.1	0.0785	0.1109	0.4222	29461	0.1451	22177	39139
Ukraine	21057	15	1.87	2.00	0.2709	1240.3	0.0121	0.3280	0.0571	1203	0.3975	564	2566
Total	**268716**	**676**	**2.79**	**2.83**	**0.0533**	**13233**	**0.0511**	**0.0654**	**0.3842**	**103234**	**0.0840**	**87580**	**121687**

Table 7 - Results of the design-based analysis for bottlenose dolphins.

Stratum	Area km^2	n groups	mean group size	exp. group size	CV exp. group size	Effort (km)	Enc. Rate groups (per km)	CV Enc. rate groups	Density (Anim./ km^2)	Abundance	CV	95% Confidence Interval	
Bulgaria	32683	16	3.31	3.14	0.1971	1187.6	0.0135	0.3723	0.1387	4532	0.3809	2188	9388
Georgia	6237	0				329.5	0.0000	0.0000	0.0000	0	0.0000	0	0
Romania	18611	38	2.34	2.36	0.2340	1211.9	0.0314	0.2349	0.2090	3890	0.3709	1912	7915
Russia	48547	115	3.13	3.26	0.1114	2726.5	0.0422	0.1643	0.5124	24877	0.2306	15894	38936
Turkey1	71796	40	3.05	3.29	0.1876	3208.2	0.0125	0.2002	0.1116	8009	0.3085	4426	14494
Turkey2	69785	0	0.00	0.00		3313.1	0.0000	0.0000	0.0000	0	0.0000	0	0
Ukraine	21057	15	3.60	3.54	0.2395	1240.3	0.0121	0.2800	0.1529	3219	0.3806	1556	6656
Total	**268716**	**224**	**3.03**	**3.17**	**0.0801**	**13233**	**0.0169**	**0.1086**	**0.1657**	**44527**	**0.1547**	**32915**	**60236**

Table 8 - Results of the design-based analysis for harbour porpoises.

Stratum	Area km^2	n groups	mean group size	exp. group size	CV exp. group size	Effort (km)	Enc. Rate groups (per km)	CV Enc. rate groups	Density (Anim./ km^2)	Abundance	CV	95% Confidence Interval	
Bulgaria	32683	309	1.71	1.70	0.0694	1187.6	0.2602	0.0980	1.3855	45284	0.1351	34707	59083
Georgia	6237	0				329.5	0.0000	0.0000	0.0000	0	0.0000	0	0
Romania	18611	53	3.13	3.22	0.5900	1211.9	0.0437	0.1852	0.4498	8372	0.6238	2690	26056
Russia	48547	5	2.80	2.79	0.4157	2726.5	0.0018	0.4446	0.0182	883	0.6153	289	2697
Turkey1	71796	203	1.68	1.69	0.0777	3208.2	0.0633	0.1102	0.3178	22814	0.1300	17686	29429
Turkey2	69785	113	1.39	1.38	0.0693	3313.1	0.0341	0.1499	0.1422	9926	0.1646	7196	13690
Ukraine	21057	34	2.03	2.02	0.1533	1240.3	0.0274	0.2529	0.1753	3692	0.3376	1927	7072
Total	**268716**	**717**	**1.78**	**1.74**	**0.0700**	**13233**	**0.0542**	**0.0740**	**0.3385**	**90970**	**0.0991**	**74902**	**110486**

III.2.2. Model-based analysis

The parameters and selected covariates for the density surface modelling for each species are presented in Table 9. For harbour porpoises there were not enough sightings in the Russian block to run an independent model.

Table 9. - Parameters and selected covariates. The meaning of the covariates can be consulted in Table 5; edf = estimated degrees of freedom; p = significance of the covariate.

		Groups				**Group size**			
Species	**Blocks**	**Covariates**	**edf**	**p**	**Deviance explained (%)**	**Covariates**	**edf**	**p**	**Deviance explained (%)**
Common dolphins	All except Russia	Lat,Lon	21.48	0.00000	39.82	Lat,Lon	15.63	0.00000	14.29
		Aspect	2.37	0.00188		DistCanEsc	0.85	0.00255	
		DistCanEsc	0.87	0.00496					
		ssc_spsd_season	0.98	0.00004					
		ssh_mean_season	6.12	0.00000					
	Russia	DistSlope	0.89	0.00924	3.46	DepthMean	0.78	0.03270	10.99
						sst_spsd_season	0.90	0.00560	
	All blocks	Lat,Lon	17.04	0.00000	33.72	Lon	5.57	0.00000	27.40
		Slope	3.41	0.00023		ssc_mean_season	0.96	0.00095	
		ssc_spsd	4.52	0.00000		ssc_spsd_season	5.96	0.00000	
		ssh_mean	5.46	0.00000		ssh_mean_season	5.35	0.00000	
						sst_spsd	0.89	0.00346	
Bottlenose dolphins	All except Russia	DistShelf	0.99	0.00004	13.10	Lat,Lon	13.46	0.07404	29.62
		Lon	0.87	0.01126					
		ssh_mean_season	0.91	0.00475					
	Russia	Lat,Lon	21.87	0.00000	45.89	DistSlope	1.98	0.00015	13.43
	All blocks	DistCanEsc	0.89	0.00559	22.59	Dist100	0.91	0.00400	13.60
		DistPorts	0.98	0.00022		DistSlope	4.77	0.00018	
		ssc_spsd_season	2.58	0.00001					
		sst_mean	5.15	0.00000					
Harbour porpoise	All blocks	Lat,Lon	21.30	0.00000	50.75	Lat,Lon	13.13	0.00000	26.79
		DepthMean	0.87	0.00831		Dist2000	7.57	0.00000	
		ssh_mean_season	3.13	0.00002		ssc_mean_season	8.21	0.00000	

Tables 10 to 12 show the results of abundance estimates for the model-based analysis for each species.

Table 10.- Results of the model-based analysis for common dolphins for the three sets of models

Dataset	**Stratum**	**Area km^2**	**mean group size**	**CV mean group size**	**Density (Anim./km^2)**	**Abundance**	**CV**	**95% Confidence Interval**	
All blocks	Bulgaria	32683	2.674	0.130	0.332	14231	0.1219	11506	18433
	Georgia	6237	2.750	0.255	0.139	1431	0.3823	735	2896
	Romania	18611	2.717	0.199	0.143	3661	0.1528	2772	4966
	Russia	48547	5.659	0.105	0.463	28657	0.1199	23732	37001
	Turkey1	71796	2.604	0.077	0.448	38896	0.0925	33392	47553
	Turkey2	69785	2.227	0.069	0.439	38033	0.0885	33548	45686
	Ukraine	21057	1.867	0.227	0.037	1242	0.2546	806	2086
	Total	**268716**	**2.787**	**0.047**	0.361	118328	0.0628	109398	136922
Without Russia	Bulgaria	32683	2.674	0.130	0.316	13542	0.1263	10898	17414
	Georgia	6237	2.750	0.255	0.162	1671	0.3703	882	3567
	Romania	18611	2.717	0.199	0.166	4243	0.1745	3105	6049
	Turkey1	71796	2.604	0.077	0.435	37776	0.0947	32898	46341
	Turkey2	69785	2.227	0.069	0.454	39332	0.0824	34918	47264
	Ukraine	21057	1.867	0.227	0.037	1255	0.3348	747	2634
	Total	**268716**	**2.375**	**0.047**	0.342	90895	0.0634	84616	105659
Russia	Russia	48547	5.759	0.105	0.537	33246	0.0936	28300	40073

Table 11. - Results of the model-based analysis for bottlenose dolphins for the three sets of models

Dataset	**Stratum**	**Area km^2**	**mean group size**	**CV mean group size**	**Density (Anim./km^2)**	**Abundance**	**CV**	**95% Confidence Interval**	
All blocks	Bulgaria	32683	3.172	0.195	0.240	10262	0.2736	6094	17537
	Georgia	6237			0.110	1134	0.4190	518	2475
	Romania	18611	2.342	0.206	0.243	6208	0.2561	3968	10325
	Russia	48547	3.130	0.086	0.279	17288	0.2643	10772	28852
	Turkey1	71796	2.957	0.134	0.198	17205	0.2849	9991	29852
	Turkey2	69785			0.229	19840	0.2862	11646	33949
	Ukraine	21057	3.600	0.250	0.131	4387	0.2890	2555	7697
	Total	**268716**	**3.027**	**0.065**	0.221	72369	0.2622	45174	119672
Without Russia	Bulgaria	32683	3.172	0.195	0.147	6310	0.2309	4220	10282
	Georgia	6237			0.003	26	1.2699	1	209
	Romania	18611	2.342	0.206	0.149	3801	0.2249	2651	5880
	Turkey1	71796	2.957	0.134	0.070	6094	0.2377	4173	9910
	Turkey2	69785			0.007	600	1.0936	74	4299
	Ukraine	21057	3.600	0.250	0.093	3101	0.2877	1881	5532
	Total	**268716**	**2.917**	**0.099**	0.068	18091	0.2449	14249	29922
Russia	Russia	48547	3.130	0.086	0.389	24078	0.1780	20954	39621

Table 12. - Results of the model-based analysis for harbour porpoise

Dataset	**Stratum**	**Area km^2**	**mean group size**	**CV mean group size**	**Density (Anim./km^2)**	**Abundance**	**CV**	**95% Confidence Interval**	
All blocks	Bulgaria	32683	1.702	0.055	1.143	48924	0.0899	42190	58986
	Georgia	6237			0.007	70	0.8996	15	347
	Romania	18611	2.391	0.450	0.426	10887	0.1384	8414	14489
	Russia	48547	1.667	0.400	0.006	380	0.5638	178	1298
	Turkey1	71796	1.657	0.065	0.363	31508	0.0983	27072	38719
	Turkey2	69785	1.389	0.072	0.130	11251	0.1384	8971	15152
	Ukraine	21057	2.029	0.146	0.098	3280	0.3163	2049	6324
	Total	**268716**	**1.768**	**0.085**	0.288	94219	0.0695	85430	109750

III.3. MODELLING RESULTS

Based on the collected data, modelling analysis were performed in order to predict the distribution and density of the species within the different surveyed blocks. The predictive maps are presented below species by species.

For common and bottlenose dolphins, different approaches in the data analysis have been applied and the following maps present them in this order:

1. Predictive maps including CeNoBS study area and Russian study area together,
2. Predictive maps including CeNoBS study area only,
3. Predictive maps including Russian study area only.

For harbour porpoise, only the predictive maps including CeNoBS study area and Russian study area together are presented, as the number of observations in the Russian area was too small to perform separate models.

III.3.1. Predictive maps for common dolphin

Black Sea common dolphins were the second most common species observed during the CeNoBS aerial surveys, with 715 sightings, totaling 1,762 individuals. This was the second most abundant species in the Russian survey, with 94 sightings.

The following maps present common dolphin predicted density and abundance in the surveyed area (Figs. 25-33).

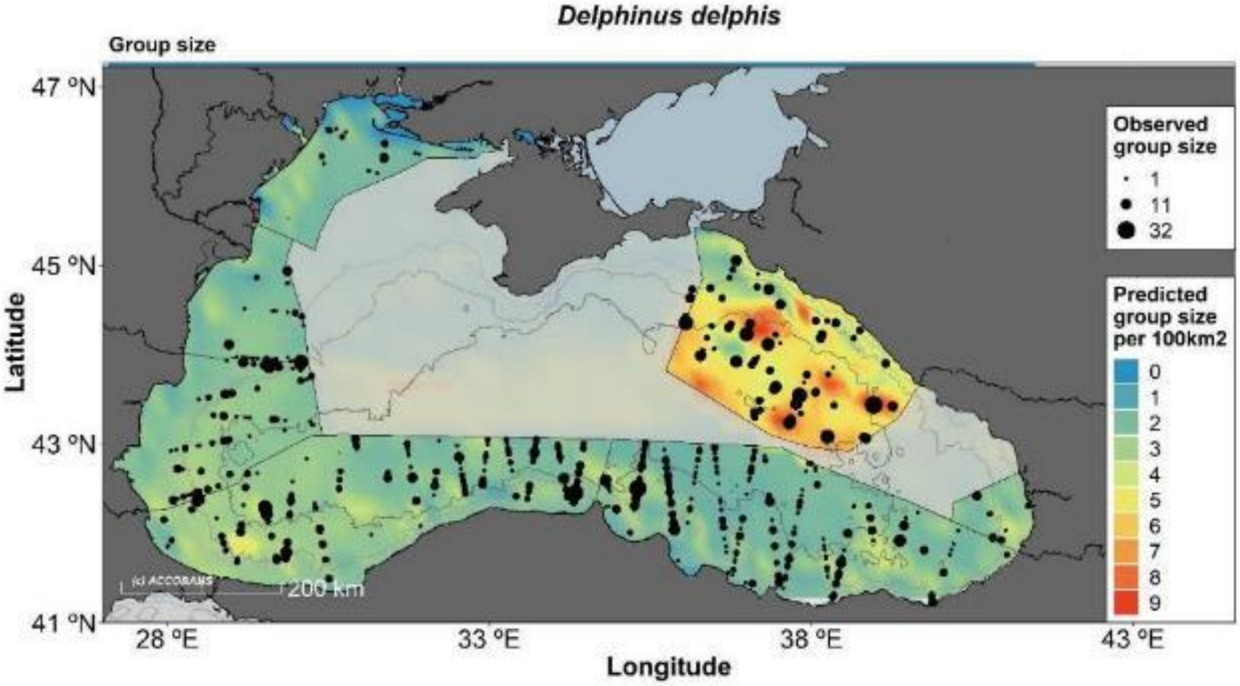


Fig.25 - Prediction of group sizes for common dolphins modelling all blocks.

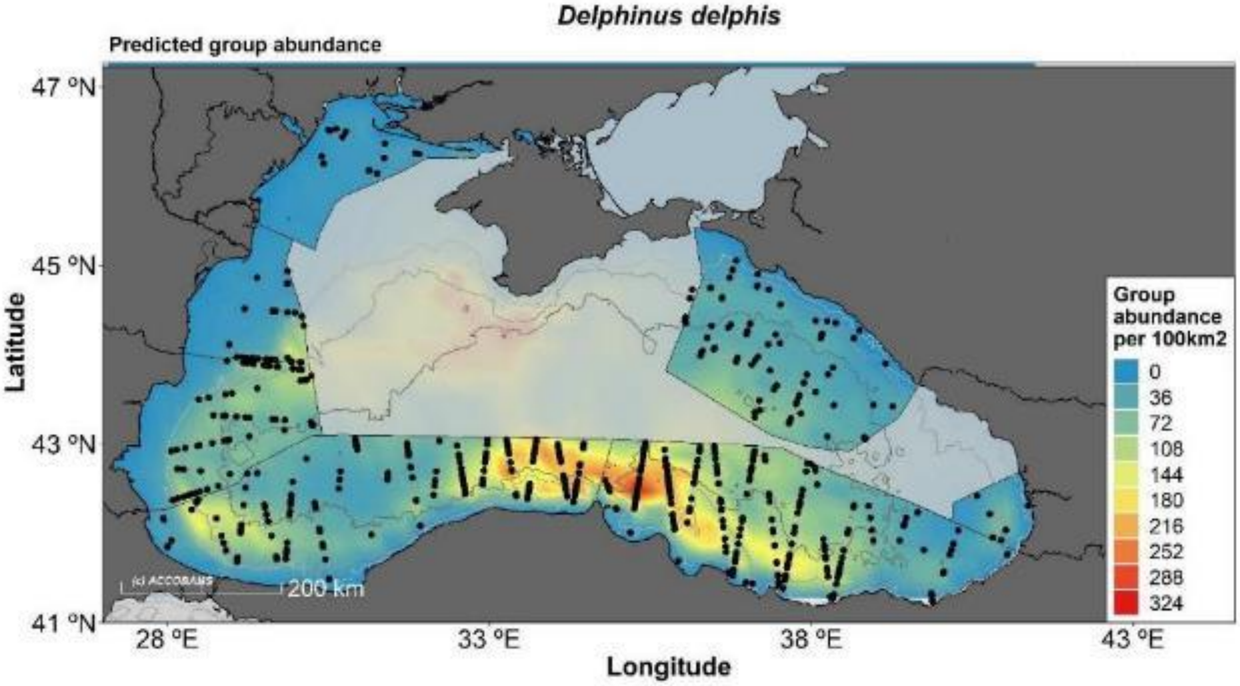


Fig. 26 - Prediction of abundance of groups for common dolphins modelling all blocks.

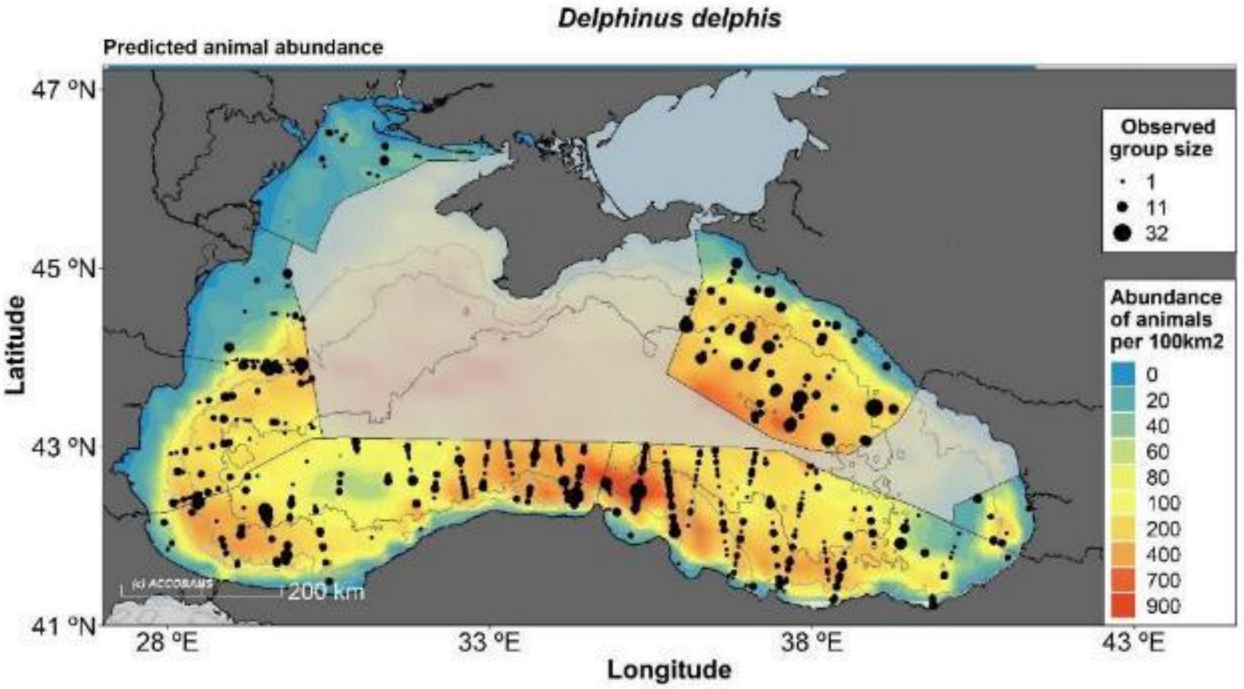


Fig. 27- Prediction of abundance of animals for common dolphins modelling all blocks.

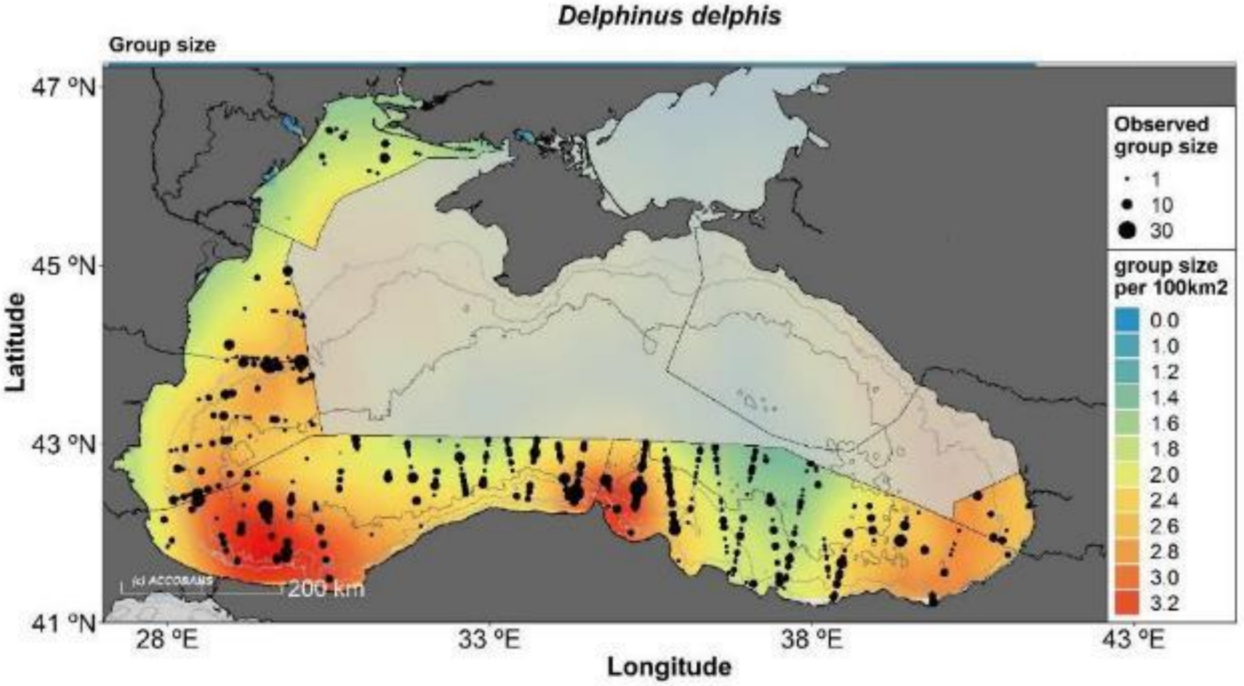


Fig. 28- Prediction of group sizes for common dolphins modelling only CeNoBS blocks.

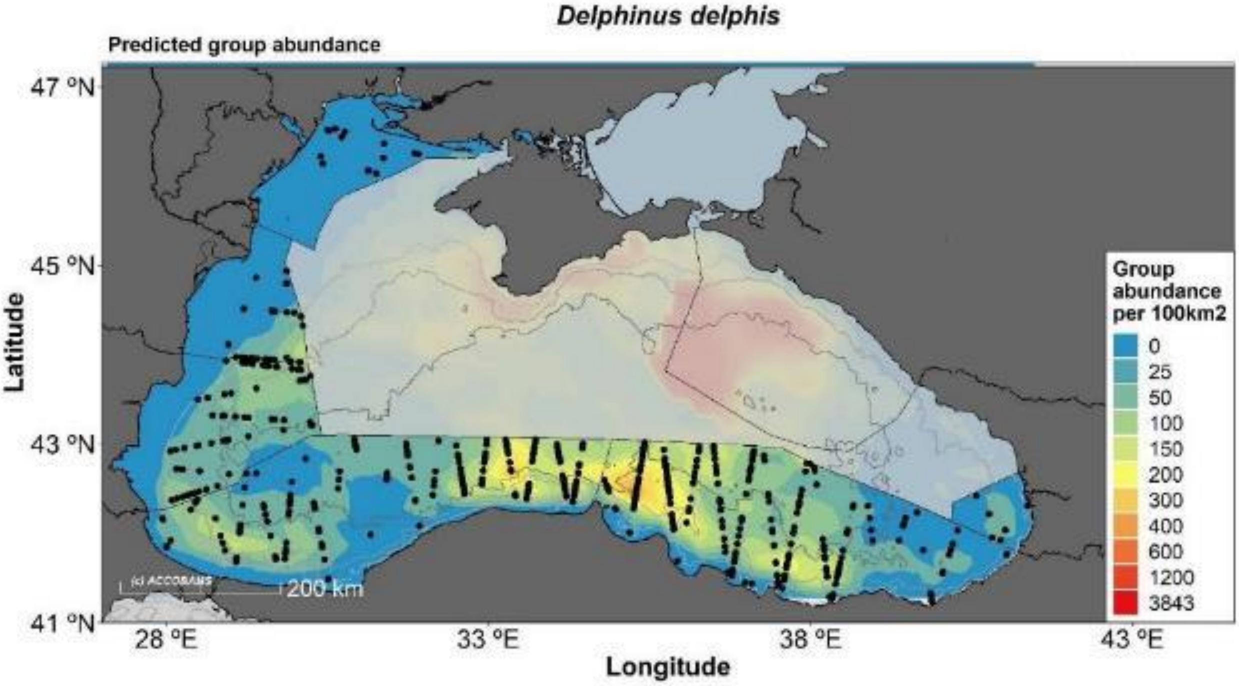


Fig. 29 - Prediction of abundance of groups for common dolphins modelling only CeNoBS blocks.

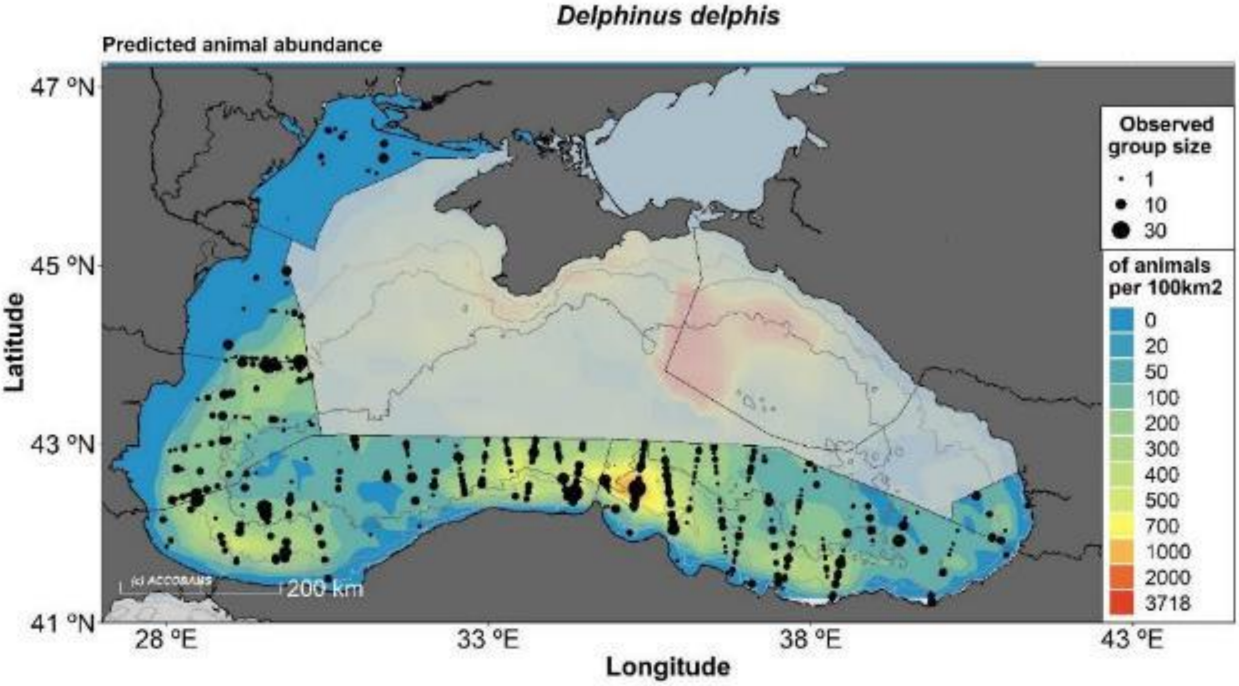


Fig. 30 - Prediction of abundance of animals for common dolphins modelling only CeNoBS blocks.

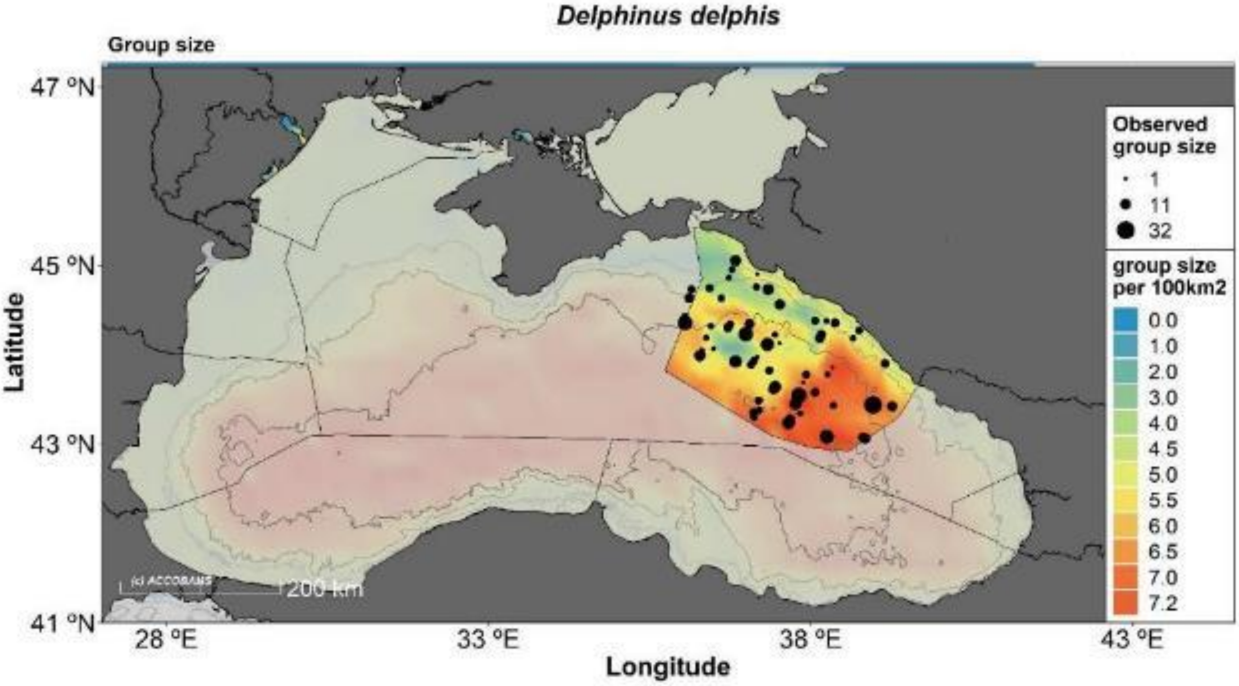


Fig. 31 - Prediction of group sizes for common dolphins modelling only EMBLAS-Plus block.

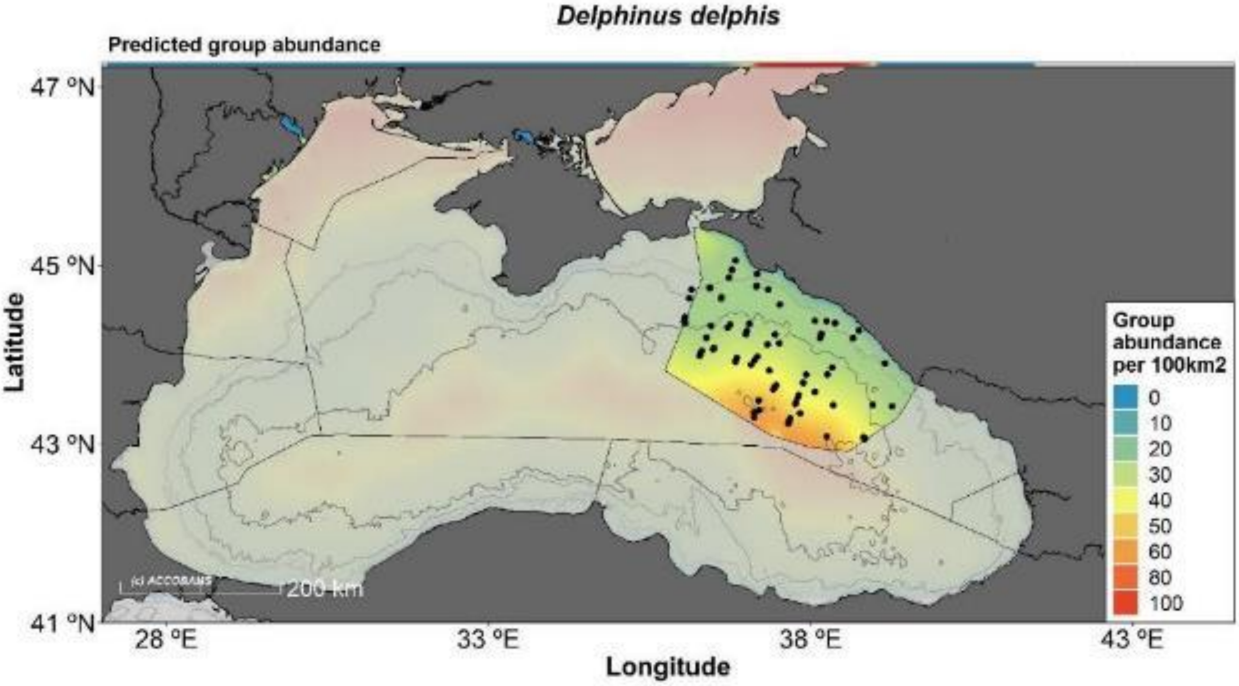


Fig. 32- Prediction of abundance of groups for common dolphins modelling only EMBLAS-Plus block.

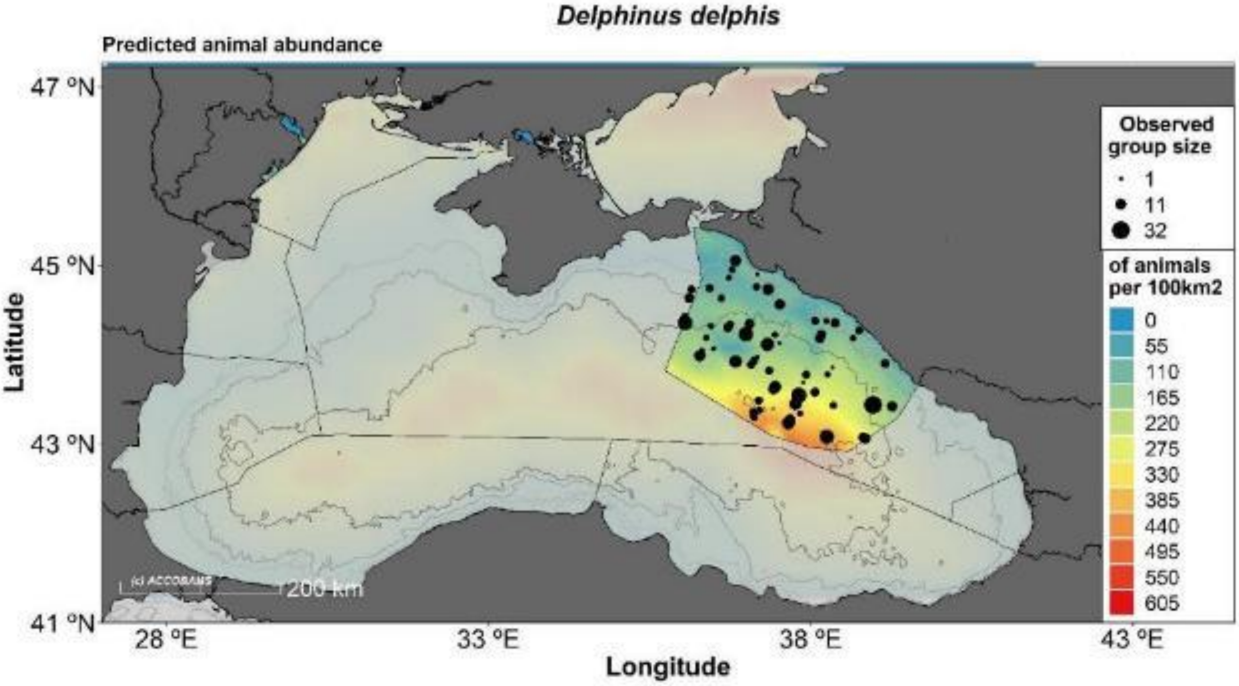


Fig. 33 - Prediction of abundance of animals for common dolphins modelling only EMBLAS-Plus block.

III.3.2. Predictive maps for bottlenose dolphin

Black Sea bottlenose dolphins were the least common species observed during the CeNoBS aerial surveys, with 117 sightings, totaling 335 individuals. On the contrary, they were the most abundant species in the Russian survey, with 122 sightings.

The following maps present bottlenose dolphin predicted density and abundance in the surveyed area (Figs. 34 - 42).

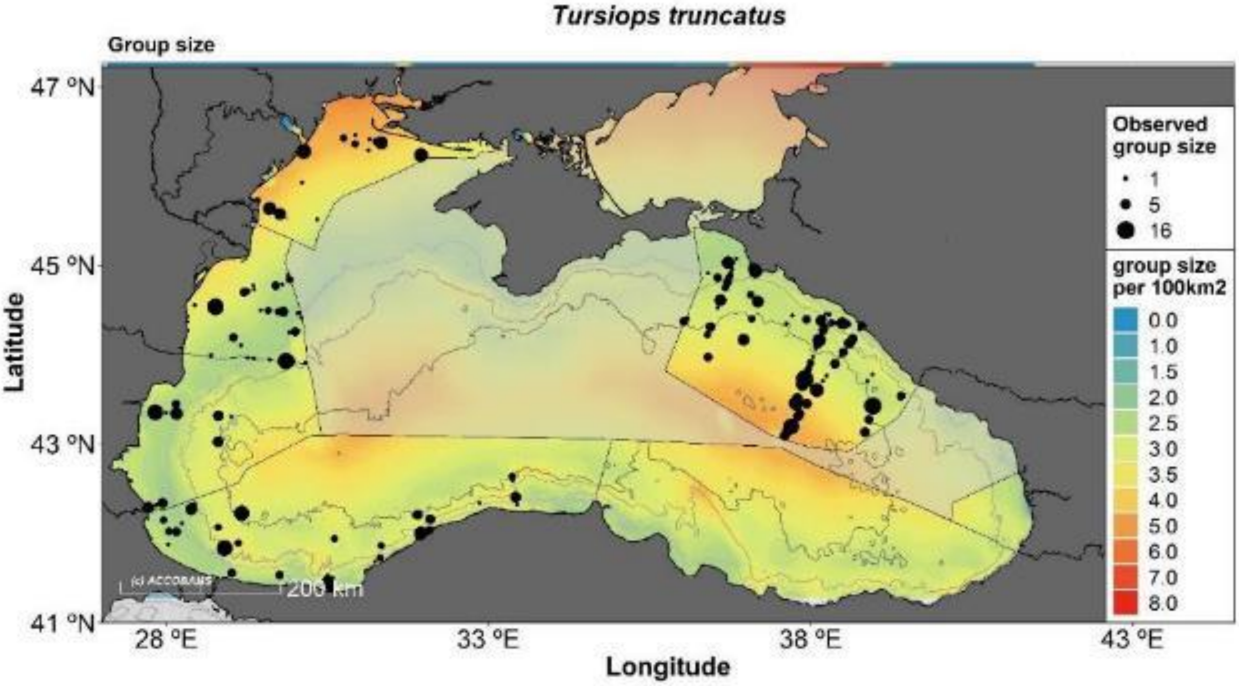


Fig. 34 - Prediction of group sizes for bottlenose dolphins modelling all blocks.

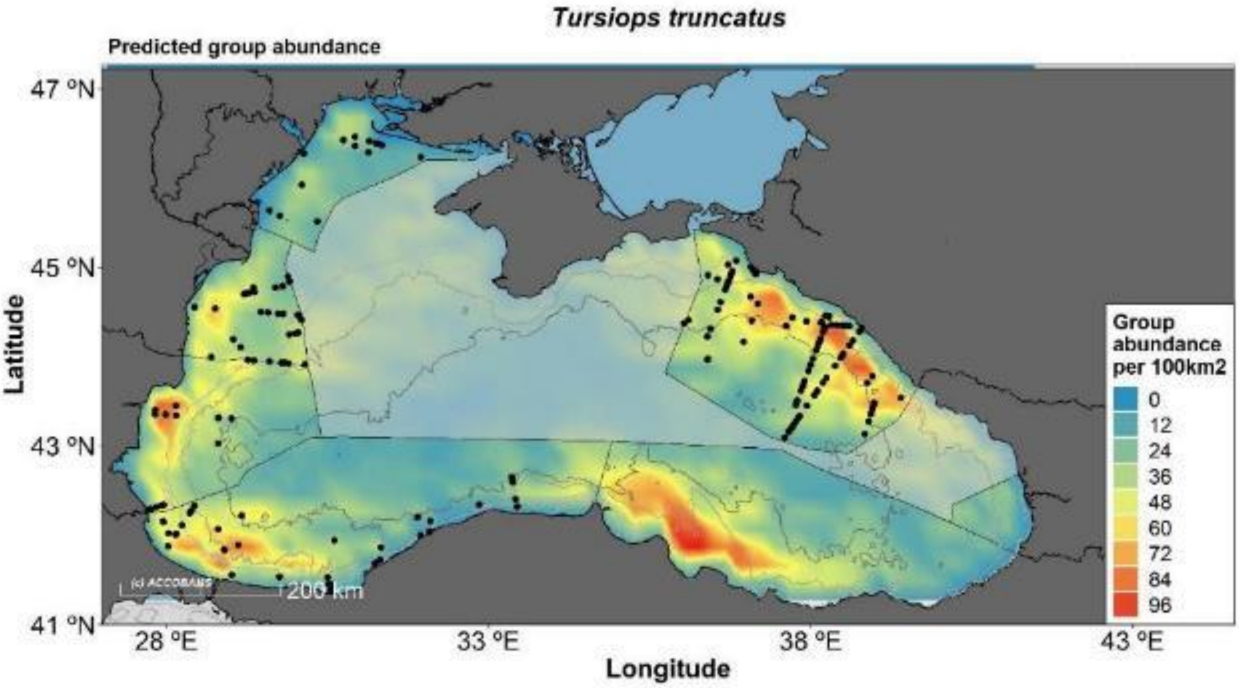


Fig. 35 - Prediction of abundance of groups for bottlenose dolphins modelling all blocks.

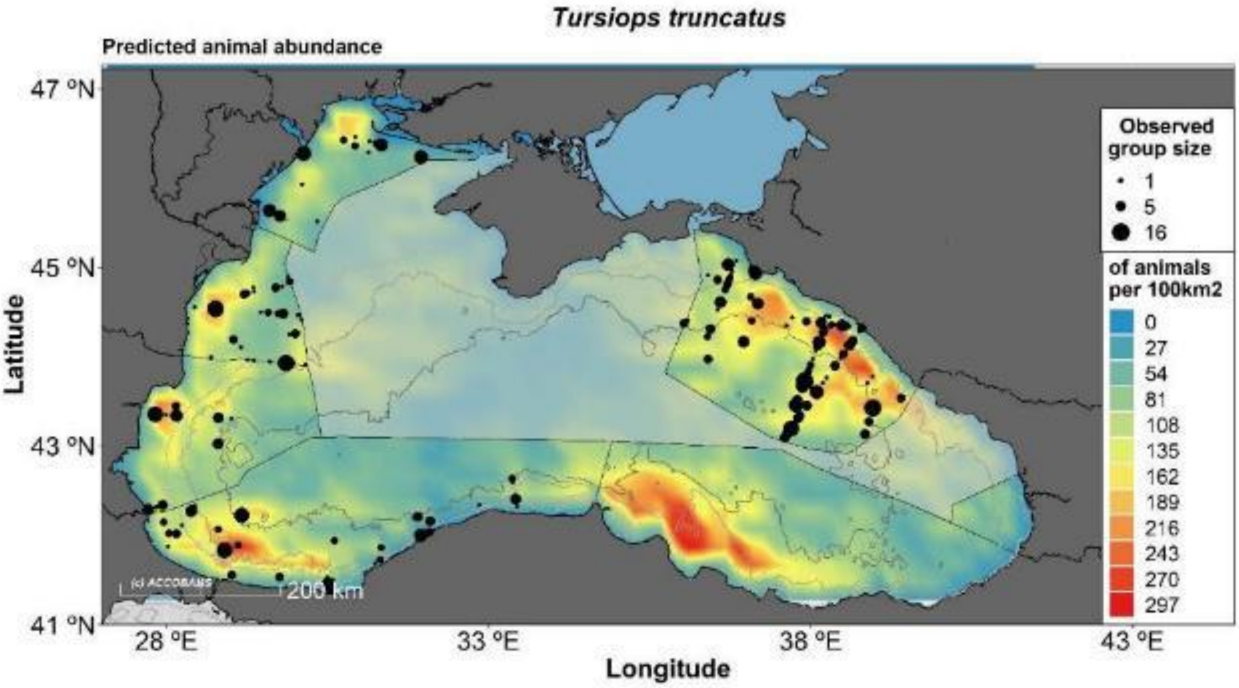


Fig. 36 - Prediction of abundance of animals for bottlenose dolphins modelling all blocks.

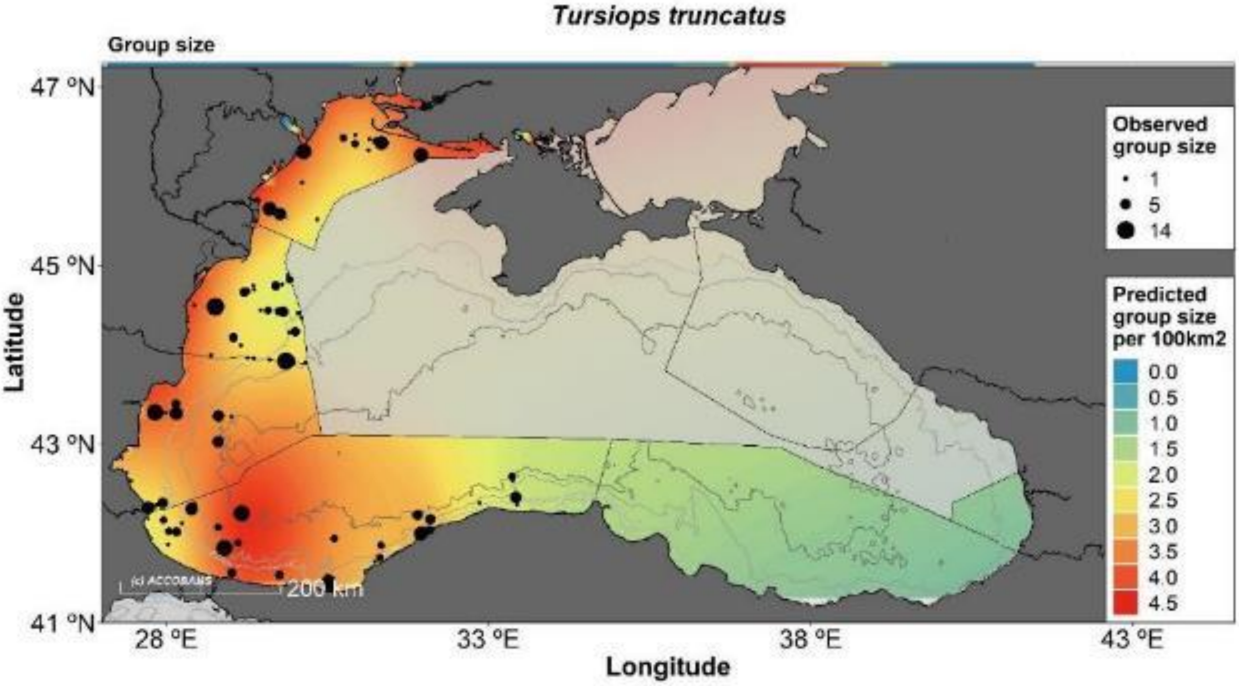


Fig. 37 - Prediction of group sizes for bottlenose dolphins modelling only CeNoBS blocks.

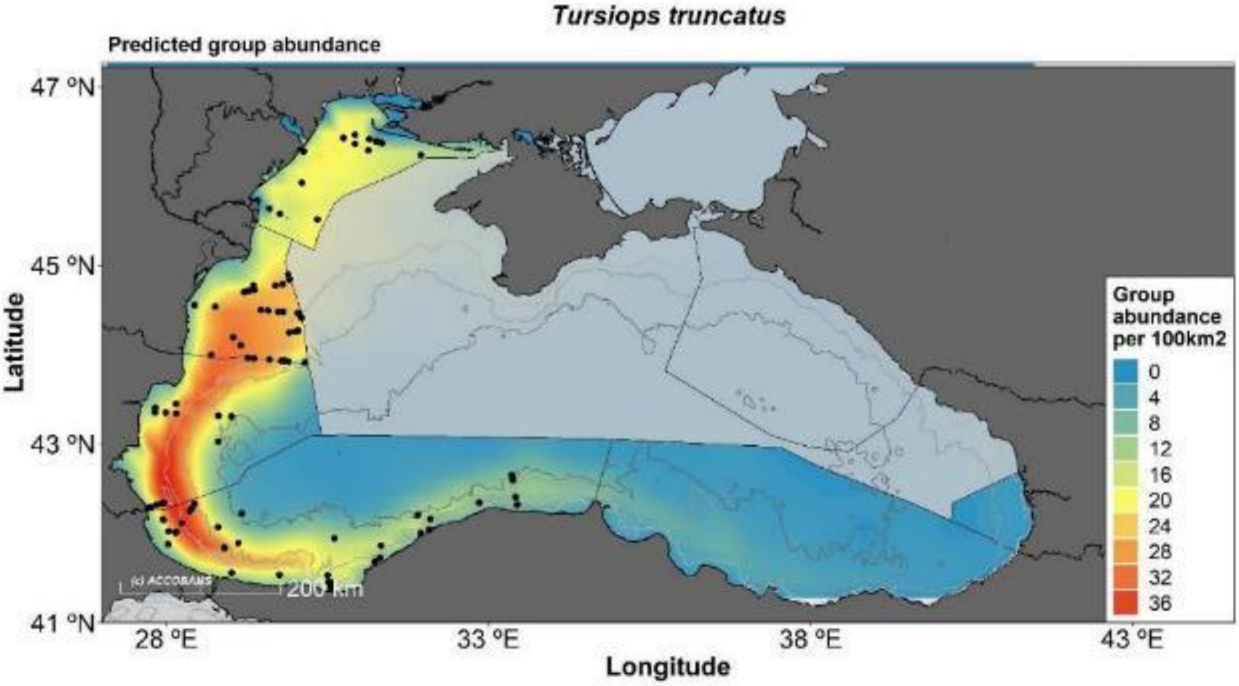


Fig. 38 - Prediction of abundance of groups for bottlenose dolphins modelling only CeNoBS blocks.

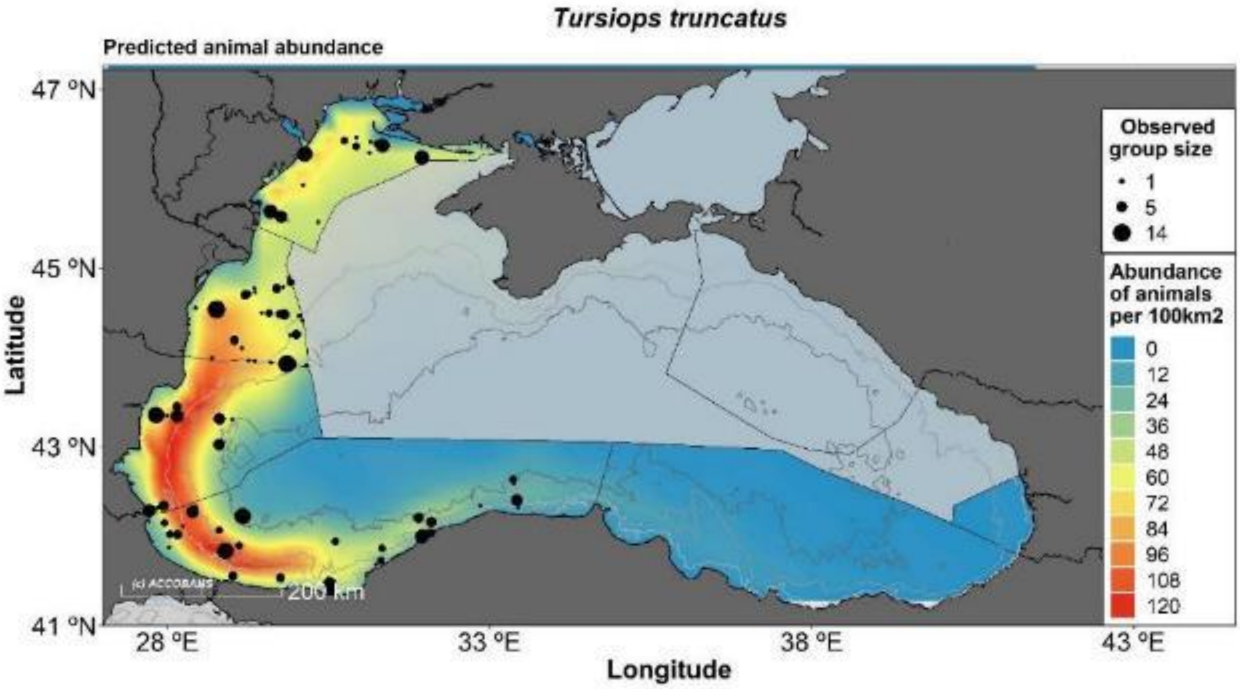


Fig. 39 - Prediction of abundance of animals for bottlenose dolphins modelling only CeNoBS blocks.

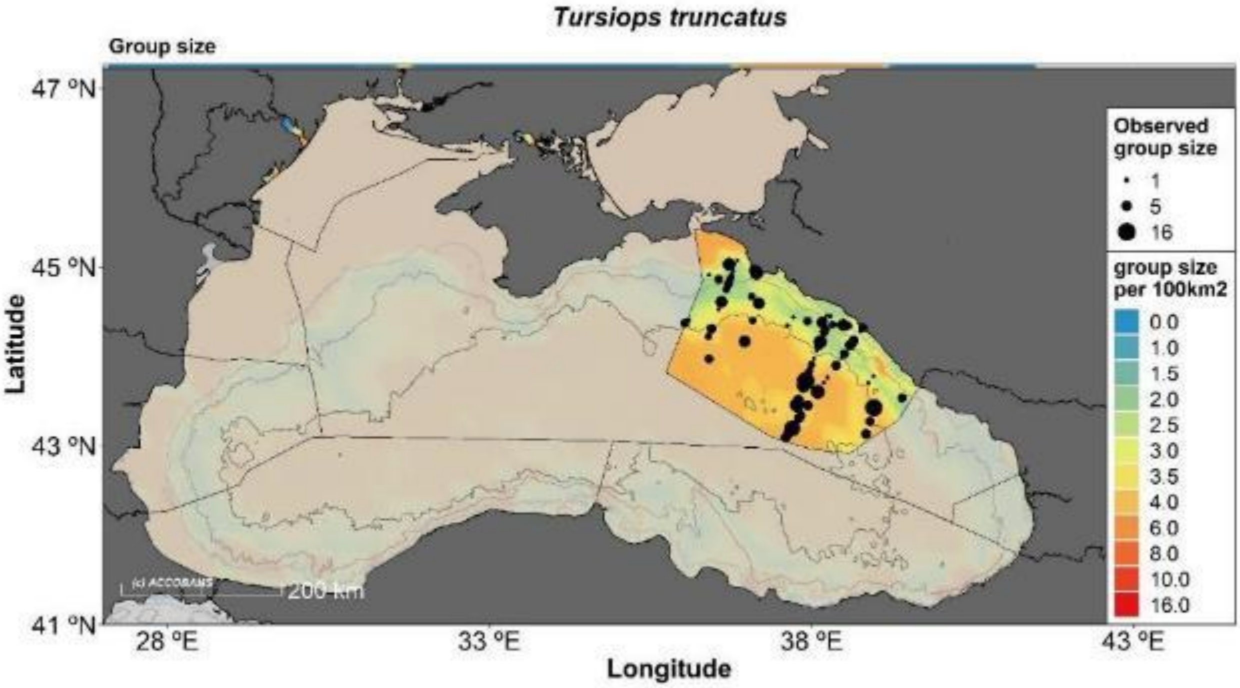


Fig. 40 - Prediction of group sizes for bottlenose dolphins modelling only EMBLAS-Plus block.

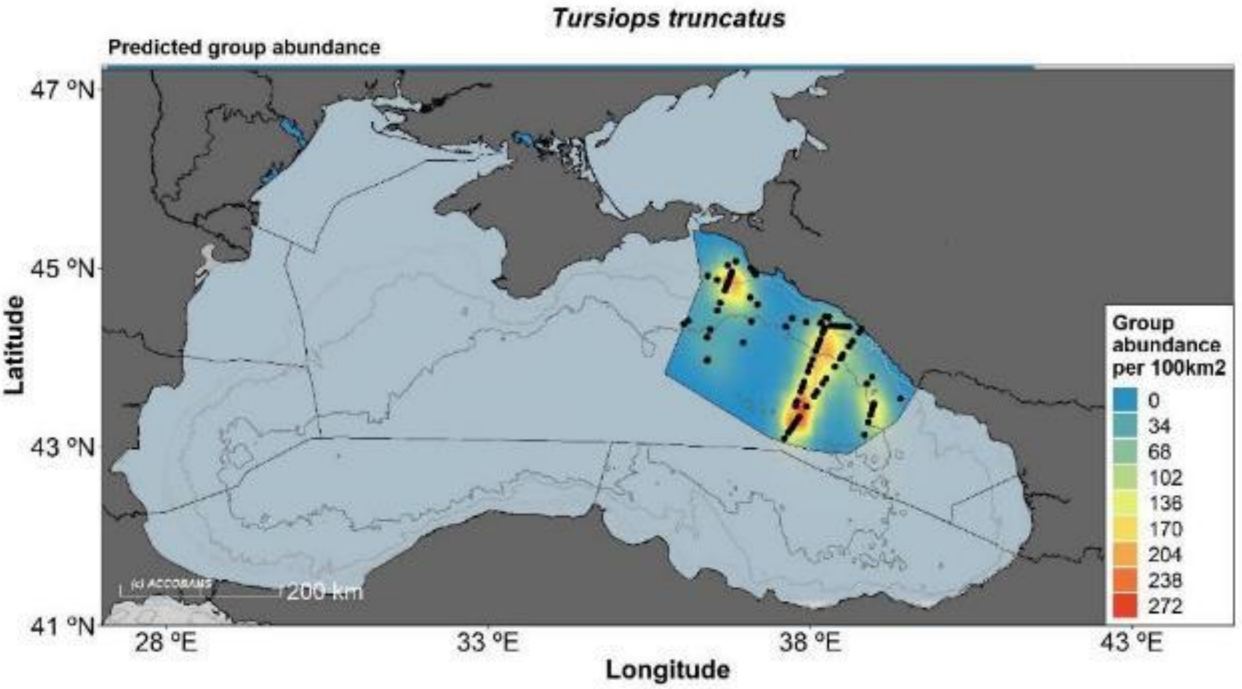


Fig. 41 - Prediction of abundance of groups for bottlenose dolphins modelling only EMBLAS-Plus block.

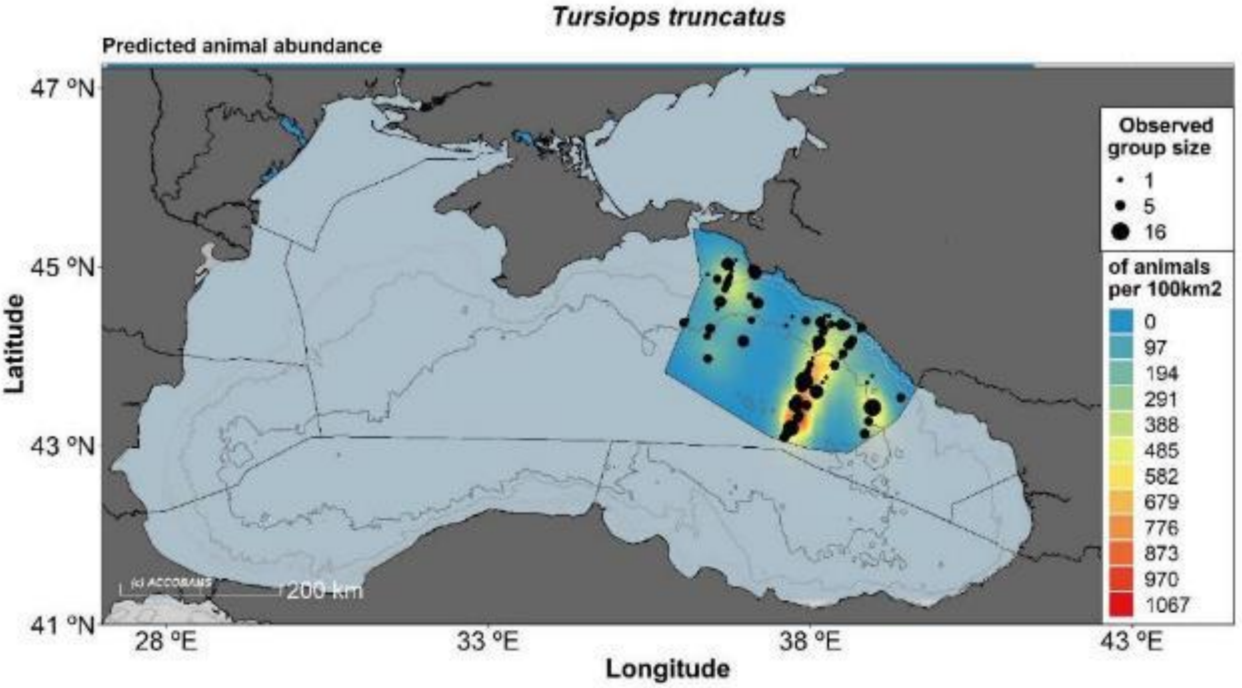


Fig. 42 - Prediction of abundance of animals for bottlenose dolphins modelling only EMBLAS-Plus block.

III.3.3. Predictive maps for harbour porpoise

Black Sea harbour porpoises were the most common species observed during the CeNoBS aerial surveys, with 884 sightings, totaling 1,522 individuals. On the contrary they were the least observed cetacean species during the Russian survey, with only 6 sightings.

The following maps present harbour porpoise predicted density and abundance in the surveyed area (Figs. 43-45).

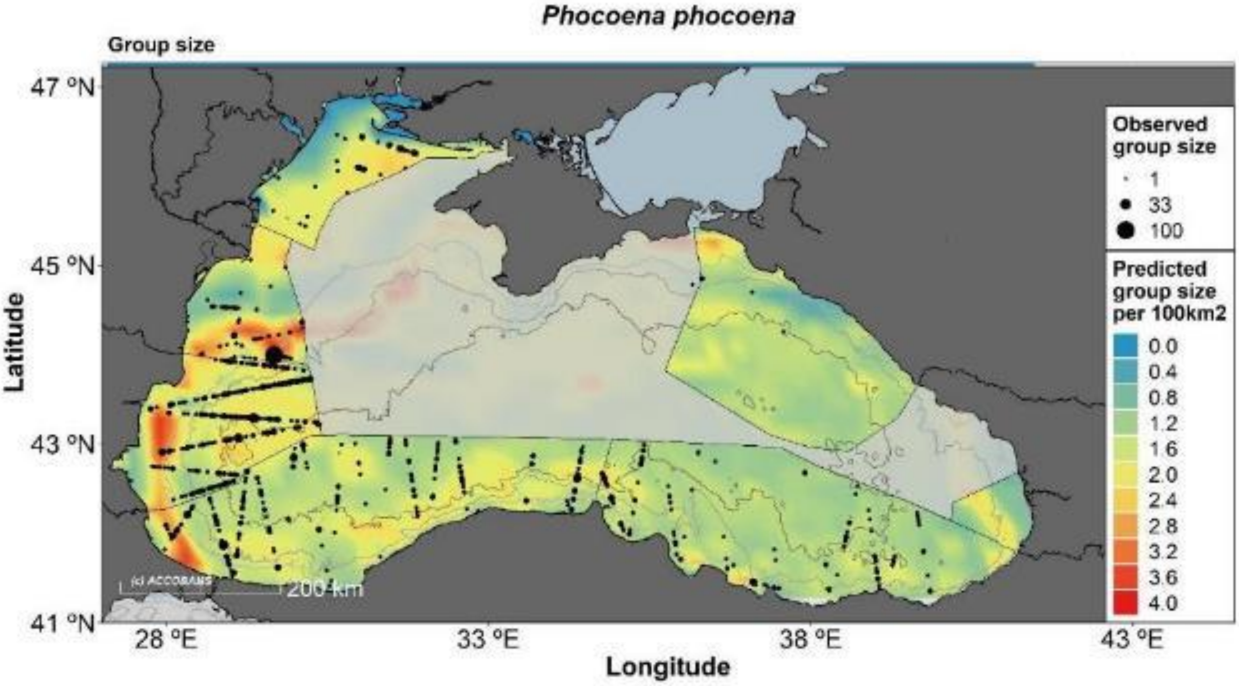


Fig. 43 - Prediction of group sizes for harbour porpoises modelling all blocks.

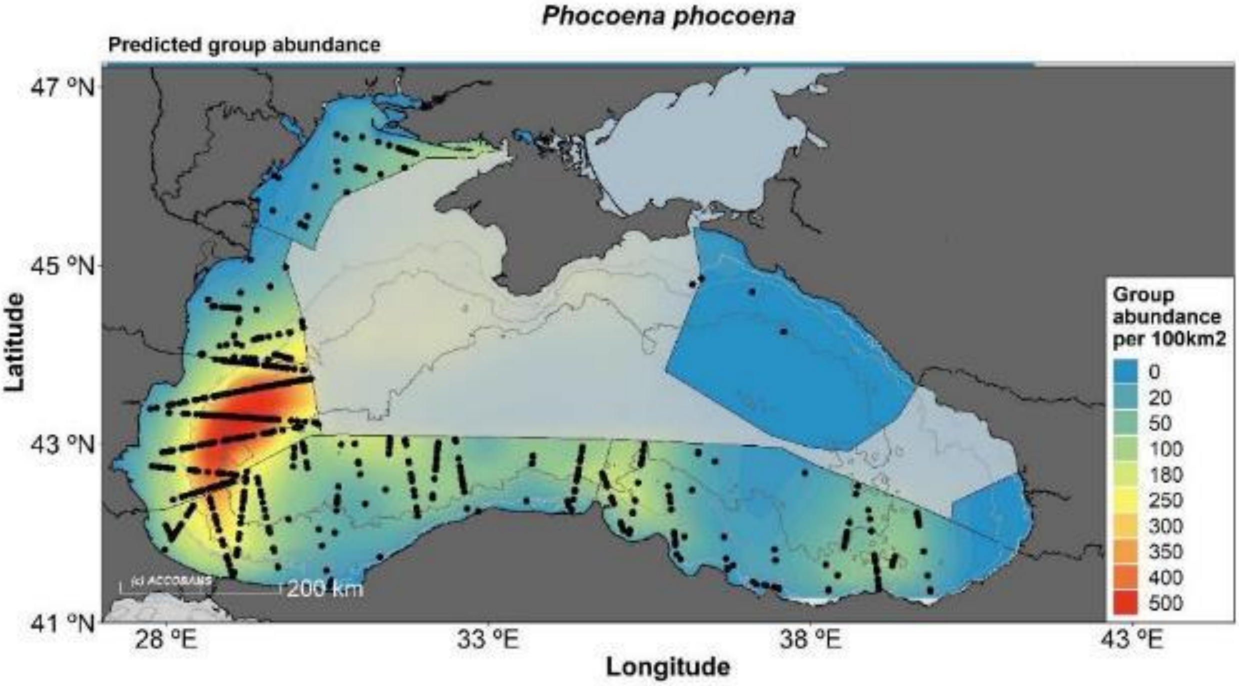


Fig. 44 - Prediction of abundance of groups for harbour porpoises modelling all blocks.

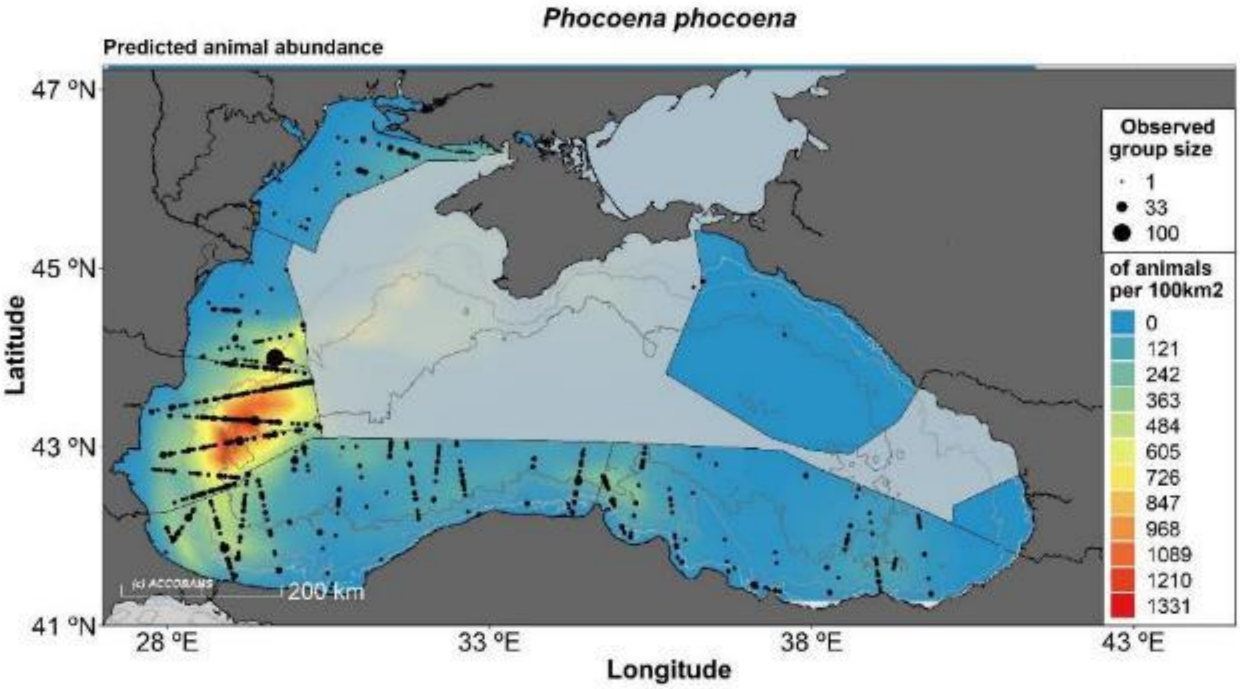


Fig. 45 - Prediction of abundance of animals for harbour porpoises modelling all blocks.

IV. DISCUSSION

IV.1 METHODOLOGICAL ASPECTS

The abundance estimates provided in this report are underestimates, in that they have not yet been corrected for availability or perception bias. It may be possible to collect data in the future that will allow for such correction. To give an indication of the extent by which the estimates may be negatively biased, we provide information on corrections factors derived from a similar effort in European Atlantic waters (SCANS-III).

During the SCANS-III survey, the circle-back or "racetrack" method of Hiby (1999) was used to collect data from which correction could be made for animals missed on the transect line (Hammond *et al.*, 2017). In this approach, on detecting a group of animals, the aircraft circles back to resurvey a defined segment of transect, thus providing information on whether or not a group was resighted. These data are then analysed in a similar way to data collected on two platforms on a ship survey to estimate the probability of detecting a group of animals on the transect line, known as g(0). The same method was used in SCANS-II (Hammond *et al.*, 2013) and an equivalent method developed for tandem aircraft (Hiby & Lovell 1998) was used in SCANS (Hammond *et al.*, 2002). Further details regarding implementation of this method can be found in Scheidat *et al.* (2008).

In previous surveys, the circle-back method was only used for harbour porpoise. In SCANS-III, this method was also implemented for delphinids (including bottlenose and common dolphins), with the aim of correcting for animals missed on the transect line for these species.

The following table 13 presents estimates of g(0) for harbour porpoise and all dolphin species combined obtained from the SCANS-III aerial surveys, for good and moderate sighting conditions classified based on sea conditions, water turbidity and glare (Hammond *et al.*, 2017). Note that these estimates of g(0) should correct for both availability and perception bias.

Table 13- estimates of g(0) from the SCANS-III aerial surveys (Hammond *et al.*, 2017)

	g(0)	
Conditions	**Good (CV)**	**Moderate (CV)**
Harbour porpoise	0.364 (0.16)	0.279 (0.17)
Dolphins (all species)	0.805 (0.13)	0.414 (0.14)

Correction for such biases, whilst important to obtain estimates of absolute abundance, is not essential for trend analyses (for which the estimates can be treated as indices of abundance), provided that it can be assumed that the levels of bias remain constant over time. This requires surveys to be conducted using equivalent aircraft, observers and field protocols and this is the case for the surveys presented in this study.

IV.2 COMMON DOLPHINS

According to the results of these aerial surveys, Black Sea common dolphins are quite abundant in the southern part of the Blacks Sea, along the transects off the coasts of Turkey and Bulgaria. They seem to be rather scarce in the north-western part, as only few sightings were reported from the Ukrainian and Romanian waters. The number of sightings increases with a gradient from North to South in the western portion of the Black Sea, with a higher number of sightings starting from the border between Romania and Bulgaria.

Depth seems to be the driving factor mainly related to their distribution, with a marked preference for deeper waters during the summertime, when the aerial survey occurred, thus justifying the lack of sightings in the north-eastern portion of the Black Sea. They also seem to be less frequent closer to shore, where waters are clearly shallower. These findings well concur with all the available historical evidence (Kleinenberg, 1956; Mikhalev, 2008; Birkun *et al.*, 2014). Whereas common dolphins are present in the shallow north-western waters, their density and abundance evidently reach maximum in pelagic areas (Birkun, 2008; Dede and Tonay, 2010; Notarbartolo di Sciara, 2002; Paiu *et al.*, 2019).

The aerial survey off the Russian coast presents a similar situation, with results in line with knowledge on common dolphins' presence and distribution. Common dolphins appear to be fairly abundant in the surveyed waters, with a general even distribution in the study area, with no specific high-density concentrations.

Group size varied during the aerial surveys, with observed groups ranging from 1 to 32 individuals. Dolphin groups were evenly distributed in Romanian, Bulgarian, Turkish and Georgian waters, without specific trends or patterns. Black Sea common dolphins appear to concentrate in groups more in the Russian waters compared to the rest of the surveyed areas. This pattern, too, concurs with historical reports (Kleinenberg, 1956; Mikhalev, 2008), who reported the greatest aggregations in the north-eastern Black Sea. However, in July groups of more than 50 individuals were only reported prior to 1981, and in earlier studies the group size was found to fluctuate within seasons, with maximum levels during spring (Mikhalev, 2008).

The prediction maps (Figs. 25-33) derived from the observations tend to reflect common dolphins' presence and preferred habitats, with a strong model preference for the Russian waters, where several sightings occurred. The model is therefore biased by the Russian sightings. In order to address this potential bias and to factor the uneven distribution of Black Sea common dolphins, prediction models were run also without the Russian data, and the relative maps show two main areas as high-density ones, in the south-west portion of the Back Sea and off the central part of Turkey.

IV.3 BOTTLENOSE DOLPHINS

Black Sea bottlenose dolphins presented a rather uneven distribution pattern throughout the study areas. On one hand, the species present a more uniform distribution in Ukraine, Romania and Bulgaria's waters. In these countries they showed marked preference for shallower and coastal waters, as expected for this species. Along the coast of Turkey, this species has been also observed in coastal areas in the western part, whereas no sighting occurred east of longitude 34° E, including the waters of Georgia. Numbers of sightings of the Bottlenose dolphin in the CeNoBS area were lower compared with the other Black Sea cetacean species, with many sightings at shallow depths. The shallow depth preference generally concurs with some historical evidence (Kleinenberg, 1956; Birkun, 2012). There are data available from earlier surveys in Georgian waters: abundance of bottlenose dolphins was found to be low, 100 to 150 individuals, and they were unevenly distributed (Kopaliani *et al.*, 2015).

According to Çelikkale *et al.* (1989), the bottlenose dolphins were found in the western and central Turkish Black Sea coast, but rarely seen in the eastern Black Sea coast and no sighting east of longitude 36° E (Samsun). However, there were very few sighting records in the eastern Turkish Black Sea and Georgia between March and May 2010 (Sánchez-Cabanes *et al.*, 2017) and also strandings have been recorded around longitude 35° E (Sinop) by Özsandıkçı *et al.* (2019). This well explains the absence of sightings of this species during the CeNoBS surveys.

Bottlenose dolphins, however, were the most observed species off the coast of Russia, with groups of dolphins observed evenly throughout the surveyed area, with no clear habitat preferences. Bottlenose dolphin's sightings extended in offshore waters, distant from the coast and in deeper waters, compared to the other surveyed areas. This pattern well fits the earlier findings by Mikhalev (2005), who found the maximum number of sightings in that area in July.

Group size for bottlenose dolphins ranged from 1 to 16 individuals, with larger groups randomly distributed across the study area; no gradients or trends in group sizes could be observed with the collected data. This also concurs with all the available historical evidence, with no long-term changes (Gladilina *et al.*, 2018; Paiu *et al.*, 2019).

Global prediction maps (Figs. 34 - 42) are also influenced by the high number of bottlenose dolphins observed in the Russian study area, where this species resulted as the most abundant one. Based on the high number of dolphins in the area, the model predicts higher densities in the eastern Turkish waters where no bottlenose dolphins were actually observed. In order to address this relevant bias, a model with only CeNoBS data was also been prepared and run, providing more conservative prediction maps in western Turkey, Bulgaria, Romania and Ukraine, where most of the sightings were actually recorded. For this species, it is best to consider the two models separately: "Without Russia" and "Russia", and not the "All Blocks".

In conclusion, summer distribution of bottlenose dolphins in the Black Sea seems to be influenced not only by environmental drivers. The best evidence for this conclusion is that there is an available summer habitat for this species in the eastern Turkish waters, which remained not occupied. Meanwhile, it is typical for bottlenose dolphins with their complex social organization that behavioural and cultural aspects can shape distribution and migration patterns for groups and societies. It was shown that the bottlenose dolphins form a metapopulation in the northern Black Sea, with a few coastal migrating stocks occupying the same summer habitats during long time periods (Gladilina *et al.*, 2018; Paiu *et al.*, 2019), and this also can be the case for the southern and adjacent parts of the Black Sea such as the Istanbul Strait Black (Baş *et al.*, 2019).

IV.4 HARBOUR PORPOISES

Black Sea harbour porpoises were the most observed cetacean species during the CeNoBS survey. By contrast, they were the least observed cetacean during the Russian survey. Sightings of harbour porpoises peaked in Bulgarian waters, where the highest number of sightings was recorded. Sighting's frequency then decreased as the transects moved towards the north and the south-eastern sections of the Black Sea. Lesser sightings were recorded towards the eastern part of the study area, off Turkey and in Georgia. Similarly, the number of sightings decreased towards Ukraine, even if some sightings occurred in the northern part of the Ukrainian study area, in relatively shallow waters.

Group size of harbour porpoises tend to be rather small, with the predominance of sightings composed by one to three animals; however, in a few occasions larger groups were observed, with an extraordinary sighting of about 100 individuals, spotted offshore, along the border between Bulgarian and Romania waters.

Black Sea harbour porpoise distribution broadly follows habitat preferences of this species (Kleinenberg, 1956), with sightings close to shelf waters, 100-200 m deep. Nevertheless, overall preferences seem to be broader: sightings occurred as close to the coast, mainly in the western Black Sea and along the central-east Turkish coasts, as offshore, in deep Turkish waters. Historically, such a distribution was pointed out by Mikhalev (2005a).

No sightings of harbour porpoises were recorded in Georgian waters, even if this species has been observed in previous monitoring activities by local scientists (Kopaliani *et al.*, 2015). This can be an evidence for low density in the area: this concurs with evidence by Kopaliani *et al.* (2015) who found seasonal fluctuations in harbour porpoise occurrence, with the minimum sightings in summer. However, this clearly indicates low summer density of porpoises in the eastern Black Sea.

Moreover, during the Russian aerial survey, only six sightings of Black Sea harbour porpoise were recorded. This was an extremely unexpected finding, since historically the north-eastern Black Sea and, particularly, the waters off the north Caucasian coast, were considered as hotspots for porpoises (Kleinenberg, 1956; Mikhalev, 2005).

Prediction models (Figs. 43-45) follow nicely the results of raw distribution of sightings observed animals from the planes, with a peak in predicted presence off the coasts of Bulgaria, and less intense predicted areas in the south-western corner of the study area, close to the border between Turkey and Bulgaria. Similarly, the model predicts harbour porpoises' aggregations along the border between Bulgaria and Romania, where a large group of 100 individuals was observed. This distribution pattern concurs with the earlier evidence from the western Black Sea (Birkun *et al*., 2014); however, it differs from the historical evidence when there were at least three to four summer hotspots identified: the north-western, south-western, north-eastern and south-eastern ones (Mikhalev, 2005). Of them, only a single south-western peak was confirmed by this survey, the south-western, despite the surveys covered all the four areas of presumable historical maxima. The existence of a single population in the Black Sea is also supported by the genetic evidence (Ben Chehida *et al*., 2020).

V. CONCLUDING REMARKS

The first synoptic, collaborative and coordinated aerial survey for cetaceans in the Black Sea yielded comprehensive data and the first insights on global abundance, distribution and density for all three cetacean species of the Black Sea during the summer months. This systematic effort provides a robust background for estimating their current conservation status under the IUCN recommendations and assessing their population trends in line with ACCOBAMS provisions and to allow riparian countries to fulfill their commitments under different legal frameworks such as the European Union Marine Strategy Framework Directive (MFSD) and Habitats Directive.

In this perspective, the baseline estimates were obtained for the MSFD implementation. The results provide essential information for the assessment of the other Criteria under main Descriptor D1, marine biodiversity. In addition, the obtained results for the cetaceans as sentinel species for marine ecosystem contribute to establishing the underwater noise monitoring of the Black Sea (criterion D11), and the modelling data further support the bycatch assessment for Black Sea cetaceans (sub-criterion D1C1). Furthermore, additional data obtained during the aerial survey will enhance the assessment of marine litter (criterion D10).

Based on this work, a baseline proposal for cetacean related criteria threshold values was prepared within the CeNoBS project deliverable 2.2.2., in support of further development of Threshold Values for establishing the Good Environmental Status under the framework of the EU MSFD.

The cetacean aerial survey is shown to be the most effective (in terms of time, effort and cost), comprehensive approach for environmental monitoring at the regional level. The seasonal dynamics of the species and habitats, together with the movement/migratory characteristics and patterns of these highly mobile species pose a need of a constant and systematic monitoring effort, to be established both at national and regional level. At least a replication of this large-scale effort should be considered every 6 years, in the framework of the MSFD, to allow the creation of a robust time series, to be used for identification of trends, both in time and space.

This regional cooperation and collaboration, which saw several research institutes coming from six different Black Sea countries, managed with great success and achieved through this important initiative represents a milestone for future effort, which will need to replicate the regional coordination with riparian countries. Further regular concerted basin-wide effort involving all the Black Sea riparian countries and based on inclusive cooperation are therefore necessary for sustainable effective monitoring of cetaceans during each MSFD cycle within the legal EU framework. It is highly recommended that future effort should try to warrant a higher coverage of the Black Sea and the inclusion of areas which could not be covered during this large scale aerial survey.

Distribution data, abundance and densities estimates are vital information for any conservation or management process. This was a knowledge gap for the Black Sea that CeNoBS and EMBLAS-Plus projects managed to fill for the Black Sea odontocetes under the umbrella of the ACCOBAMS Survey Initiative. This collaborative process, which started with these two research projects, needs further support for its continuation in the future. A continuation would allow proper and robust dissemination of data, as well as addressing national and international requirements, such as those of the European Union Directives and other Environmental Conventions/Agreements within the Black Sea region.

VI. REFERENCES

Baş, A. A., Öztürk, B., & Öztürk, A. A., 2019. Encounter rate, residency pattern and site fidelity of bottlenose dolphins (*Tursiops truncatus*) within the Istanbul Strait, Turkey. *Journal of the Marine Biological Association of the United Kingdom*, *99*(4), 1009-1016.

Ben Chehida, Y., Thumloup, J., Vishnyakova, K., Gol'din, P., & Fontaine, M. C., 2020. Genetic homogeneity in the face of morphological heterogeneity in the harbor porpoise from the Black Sea and adjacent waters (*Phocoena phocoena relicta*). Heredity, 124(3), 469-484.

Birkun, A.A., Jr., Krivokhizhin, S.V., Glazov, D.M., Shpak, O.V., Zanin, A.V., Mukhametov, L.M., 2004. Abundance estimates of cetaceans in coastal waters of the northern Black Sea: Results of boat surveys in August-October 2003. In: Marine Mammals of the Holarctic: Collection of Scientific Papers after the 3rd Internat. Conf., pp.64-68, Koktebel, Ukraine, 11-17 October 2004, Moscow, 609.

Birkun, A., Jr., Glazov, D., Krivokhizhin, S., Nazarenko, E., Mukhametov, L. 2003. Species composition and abundance estimates of cetaceans in the Kerch Strait and adjacent areas of the Black and Azov Seas: The second series of aerial surveys (August 2002). In: Abstr. 17th Annual Conf. of the European Cetacean Society, pp.271-272, Las Palmas de Gran Canaria, 9-13 March 2003, 285.

Birkun, A., 2008. The state of cetacean populations. State of the environment of the Black Sea (2001-2006/7). Publications of the Commission on the Protection of the Black Sea Against Pollution (BSC), 3.

Birkun, A. Jr., Northridge, S.P., Willsteed, E.A., James, F.A., Kilgour, C., Lander, M., Fitzgerald, G.D., 2014. Studies for Carrying Out the Common Fisheries Policy: Adverse Fisheries Impacts on Cetacean Populations in the Black Sea. Final report to the European Commission, Brussels, 347p.

Birkun Jr., A.A., 2008. *Delphinus delphis* ssp. *ponticus*. The IUCN Red List of Threatened Species 2008: e.T133729A3875256. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T133729A3875256.en

Birkun, A., 2012. *Tursiops truncatus* ssp. *ponticus*. The IUCN Red List of Threatened Species 2012: e.T133714A17771698. https://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T133714A17771698.en

Birkun Jr., A.A. & Frantzis, A., 2008. *Phocoena phocoena* ssp. *relicta*. The IUCN Red List of Threatened Species 2008:e.T17030A6737111. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T17030A6737111 .en.

Birkun JR., A., Krivokhizhin, S., Komakhidze, A., Mukhametov, L., Shpak, O., Goradze, I., Komakhidze, G., Kryukova, A., 2006. Wintering concentrations of Black Sea cetaceans off the Crimean and Caucasian coasts. 20th Annual Conference of the European Cetacean Society. (Gdynia, 2-7 April 2006).

Birkun, A.A., Jr., Krivokhizhin, S.V., Glazov, D.M., Shpak, O.V., Zanin, A.V., Mukhametov, L.M., 2004a. Abundance estimates of cetaceans in coastal waters of the northern Black Sea: Results of boat surveys in August-October 2003. In: Marine Mammals of the Holarctic: Collection of Scientific Papers after the 3rd Internat. Conf., pp.64-68, Koktebel, Ukraine, 11-17 October 2004, Moscow, 609pp

Buckland ST (Ed.), 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press: Oxford; New York.

Buckland ST (Ed.), 2004. Advanced distance sampling. Oxford University Press: Oxford; New York.

Buckland ST, Rexstad EA, Marques TA, Oedekoven CS., 2015. Distance Sampling: Methods and Applications. Springer International Publishing: Cham.

Dede, A., Tonay, A.M., 2010. Cetacean Sightings in the Western Black Sea in Autumn 2007. Journal of Environmental Protection and Ecology, 11(4), 1491–1494.

Gladilina, E., Shpak, O., Serbin, V., Kryukova, A., Glazov, D., Gol'din, P., 2018. Individual movements between local coastal populations of bottlenose dolphins (*Tursiops truncatus*) in the northern and eastern Black Sea. Journal of the Marine Biological Association of the United Kingdom, 98(2), pp. 223-229.

Gladilina, E. V., & Gol'din, P. E., 2016. Abundance and summer distribution of a local stock of Black Sea bottlenose dolphins, *Tursiops truncatus* (Cetacea, Delphinidae), in coastal waters near Sudak. *Vestnik zoologii*, 50, 49-56.

Gladilina, E. V., Vishnyakova, K. A., Neprokin, O. O., Ivanchikova, Y. F., Derkacheva, T. A., Kryukova, A. A., Savenko, O., & Gol'din, P. E., 2017. Linear Transect Surveys of Abundance and Density of Cetaceans in The Area Near the Dzharylgach Island in the North-Western Black Sea. *Vestnik zoologii*, *51*4, 335-342.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F., Øien, N., 2002. Abundance of harbour porpoises and other cetaceans in the North Sea and adjacent waters. J. Appl. Ecol. 39, 361–376.

Hammond, P.S, Macleod, K, Berggren, P, Borchers, DL, Burt, M.L, Cañadas, A, Desportes, G, Donovan, G.P, Gilles, A, Gillespie, D, Gordon, J, Hedley, S, Hiby, L, Kuklik, I, Leaper, R, Lehnert, K, Leopold, M, Lovell, P, Øien, N, Paxton, C, Ridoux, V, Rogan, E, Samarra, F, Scheidat, M, Sequeira, M, Siebert, U, Skov, H, Swift, R, Tasker, M.L, Teilmann, J, Van Canneyt, O Vázquez, J.A., 2013. Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation 164: 107-122.

Hammond, PS, Lacey, C, Gilles, A, Viquerat, S, Börjesson, P, Herr, H, Macleod, K, Ridoux, V, Santos, MB, Scheidat, M, Teilmann, J, Vingada, J & Øien, N., 2017. Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. SCANS-III project report 1, 39pp. https://synergy.st-andrews.ac.uk/scans3/files/2017/05/SCANS-III-design-based-estimates-2017-05-12-final-revised.pdf.

Hiby, AR & Lovell, P., 1998. Using aircraft in tandem formation to estimate abundance of harbour porpoise. Biometrics 54: 1280-1289.

Hiby, L., 1999. The objective identification of duplicate sightings in aerial survey for porpoise. In: Garner, GW *et al.* (Eds.) Marine Mammal Survey and Assessment Methods, Balkema, Rotterdam. pp 179-189.

Kleinenberg, S.E., 1956. Mammals of the Black Sea and the Sea of Azov: an experience of biological and fisheries research. Moscow: Izdatelstvo Akademii Nauk SSSR [In Russian]

Kopaliani, N., Gurielidze, Z., Devidze, N., Ninua, L., Dekanoidze, D., Javakhishvili, Z., Paposhvili, N., Qerdikoshvili, N., 2015. Monitoring of Black Sea Cetacean in Georgian Waters. Report. Supported by Kolkheti National Fund. Adopted by Ministry of Natural Resources and Environment Protection of Georgia

Mikhalev, Yu.A., 2005. The peculiarities of the distribution of the bottlenose dolphin, *Tursiops truncatus* (Cetacea), in the Black Sea. Vestnik Zoologii 39(3), pp.29–42 [In Russian]

Mikhalev, Yu.A., 2005a. The peculiarities of the distribution of the harbour porpoise, *Phocoena phocoena relicta* (Cetacea), in the Black Sea. Vestnik zoologii, 39(6): pp.25–35 [In Russian]

Mikhalev, Yu.A., 2008. Characteristics of distribution of the common dolphins, *Delphinus delphis* (Cetacea), in the Black Sea. Vestnik zoologii, 42(4): pp.325–337 [In Russian]

Notarbartolo di Sciara G. (Ed.), 2002. Cetaceans of the Mediterranean and Black Seas: state of knowledge and conservation strategies. A report to the ACCOBAMS Secretariat, Monaco, 259 p.

Ozsandikci, U., Tonay, A.M., Danyer, E., Dede, A., 2019. Cetacean stranding records on the central Turkish Black Sea coast in May 2017 - April 2019. World Marine Mammals Conference, 9-12 December 2019, Barcelona, 324-325.

Paiu R.M., Olariu B., Paiu A.I., Mirea Candea M.E., Gheorghe A. M., Murariu D., 2019. Cetaceans in the coastal waters of southern Romania: initial assessment of abundance, distribution, and seasonal trends. Journal of Black Sea / Mediterranean Environment. 25(3): 266–279.

Panayotova M., Todorova V., 2015. Distribution of three cetacean species along the Bulgarian Black Sea coast in 2006-2013. J. Black Sea/Mediterranean Environment, 21(1), 45-53.

Popov, D., Panayotova, M., Slavova, K., Marinova, V., 2017. Studying of the distribution and abundance of marine mammals in the Bulgarian Black Sea area by combination of visual and acoustic observations, Proceedings of the Institute of Fishing Resources, Volume 28, 2017.

R Core Team (2017) R: A Language and Environment for Statistical Computing. https://www.R-project.org/

Sánchez-Cabanes A., Nimak-Wood M., Harris N., de Stephanis R., 2017. Habitat preferences among three top predators inhabiting a degraded ecosystem the Black Sea. Scientia Marina, 81(2), 217-227.

SAMMOA 1.1.2. Système d'Acquisition des données sur la Mégafaune Marine par Observations Aériennes, Software developed by UMS 3462 Pelagis LRUniv-CNRS and Code Lutin (2012-2019).

Scheidat, M, Gilles, A, Kock, K.-H, Siebert, U., 2008. Harbour porpoise *Phocoena phocoena* abundance in the southwestern Baltic Sea. Endangered Species Research 5: 215-223.

Thomas L., Buckland S.T., Rexstad E.A., Laake J.L., Strindberg S., Hedley S.L., Bishop J.R.B., Marques T.A., Burnham K.P., 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. J. Applied Ecology, 47:5–14.

Wood, S.N., 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. J. R. Stat. Soc. (B) 73 (1), 3–36.