ACTA ZOOLOGICA BULGARICA

Acta Zool. Bulg., Supplement 20 (August 2024), +

Proceedings, Fourth International Conference on One Health and Zoology
Hisar, Bulgaria, 27-29 September 2023

Biodiversity, Ecology,
Conservation Zoology and Zoonozes

https://www.acta-zoologica-bulgarica.eu/2024/Suppl_20_21

Where do Cetaceans Spend their Summers in the Bulgarian Black Sea?

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Abstract: All three Black Sea cetacean species are nominated as endemic subspecies for the basin listed in the IUCN Red List of Endangered species: the Black Sea harbour porpoise (*Phocoena phocoena relicta*) and Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) as Endangered (EN), while the Black Sea common dolphin (*Delphinus delphis ponticus*) as Vulnerable (VU). In addition, all three species are protected at national and international levels. Effective conservation of protected and endangered species requires robust data on their distribution to delineate important habitats. We present data on the summer distribution of cetaceans in Bulgarian shelf waters, derived from a series of vessel line transect distance sampling surveys, conducted in the summer months during the period 2020-2023. Harbour porpoise density estimates ranged from 0.156 individuals.km^{-2} (CV=43%) in territorial waters in 2020 to 2.83 ind.km^{-2} (CV=27%) in deeper waters in 2022. Bottlenose dolphin density estimates ranged from 0.226 ind.km^{-2} (CV=49%) in territorial waters in 2023 to 0.542 ind.km^{-2} (CV=35%) in 2020, also in territorial waters. Common dolphin density ranged from 0.032 ind.km^{-2} (CV=80%) in territorial waters in 2023 to 0.699 ind.km^{-2} (CV=41%) in deep shelf waters in 2022. The distribution of porpoises has shown a clear preference for deep waters (80-100 m), indicating a shift from the coastal waters that are their preferred habitat in the spring. The density of common dolphin has also shown a gradient towards deeper waters of the shelf, while bottlenose dolphins show a preference for coastal waters. Here, we propose updated threshold values of Descriptor 1's criteria 2 and 4 of the Marine Strategy Framework Directive and identify important habitats for harbour porpoises and bottlenose dolphins that remain outside of NATURA 2000's scope.

Key words: Black Sea, Black Sea harbour porpoise, Black Sea bottlenose dolphin, Black Sea common dolphin, Marine Strategy Framework Directive, NATURA 2000.

Introduction

The Black Sea is the largest enclosed basin of the World Ocean and is connected to the Mediterranean Sea via the Bosphorus and the Sea of Marmara. Due to its isolation and specific characteristics, such as lower salinity and anoxic waters below 100-150 m depth, it is considered a highly vulnerable ecosystem. The cetaceans in the Black Sea are represented by three endemic for the basin subspecies (Tonay et al. 2017; Moura et al. 2013; Rosel et al. 1994) – Black Sea harbour porpoise (*Phocoena phocoena relicta*, Abel, 1905), Black Sea bottlenose dolphin (*Tursiops truncatus ponticus* Barabash-Nikiforov, 1940) and Black Sea common dolphin (*Delphinus delphis ponticus* Barabash-Nikiforov, 1935). Their limited range, historical commercial exploitation and numerous ongoing threats are the main reasons

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that all three species are listed on the IUCN Red List of Endangered species: the former two as Endangered (Birkun & Frantzis 2008; Birkun 2008) and the latter as Vulnerable (Birkun 2012). Cetaceans are apex predators in the Black Sea on the top of the trophic pyramid and play an important role in maintaining the ecosystem's structure (Morissette et al. 2006).

The European Union's Habitats Directive 92/43/EEC (HD) and Marine Strategy Framework Directive 2008/56/EC (MSFD) are the two main legal instruments for conserving the marine environment and species inhabiting it. These are binding for all member states including Bulgaria and Romania that border the Black Sea. HD aims to achieve a favourable conservation status of species and requires regular monitoring with a subsequent reporting cycle of six years. MSFD aims to develop measures to achieve the good environmental status of the marine environment using 11 qualitative descriptors and has a 6-year reporting cycle. Despite using different terminology, both directives overlap in requirements for conserving of cetaceans and their habitat. All three Black Sea cetaceans are included in Descriptor 1 – Biodiversity of MSFD and Annex IV of the HD. In addition, the harbour porpoise and bottlenose dolphin are listed in Annex II of the HD, meaning the member states must designate Special Areas of Conservation (SACs) to protect their important habitats as part of the NATURA 2000 ecological network. Requirements imposed by the described EU legislation have been the main reason for the increase in cetacean studies in the Black Sea over the past two decades to fill the knowledge gap and identify conservation measures to ensure their favourable status. For these to be effective, different threats' impact must be assessed, but data on the abundance and distribution of populations of the different cetacean species must be collected first (Hammond et al. 2013).

The most comprehensive surveys on the abundance and distribution of cetaceans in the Black Sea were made in the summers of 2013 and 2019. The first one covered the North-western Black Sea (waters of Bulgaria, Romania and partly Ukraine) and included a vessel survey for territorial waters and an aerial survey for the rest of the Exclusive Economic Zones (Birkun et al. 2014). The second survey, involving all coastal states, was entirely aerial and covered 62% of the Black Sea, except waters around Crimea and Abkhazia (Paiu et al. 2021). Bulgaria's Marine Strategy (MSFD implementation) was developed in 2015 and divided the marine area into three zones, based on bathymetry: coastal (0-30 m), shelf (30-200 m) and offshore (>200 m). Its monitoring program for cetaceans adopted the estimations for Bulgarian territorial waters derived from the vessel survey in 2013 as threshold values for D1C2 Abundance and D1C4 Density in the coastal and shelf zones (Panayotova et al. 2020).

The current paper presents results from four dedicated line transect distance sampling surveys on the abundance and density of cetaceans in Bulgarian shelf waters. It aims to provide more extended time-series data on abundance and density during summer and use that as scientific evidence for the proposed update and revision of adopted values for criteria D1C2 (Abundance) and D1C4 (Distribution) of Descriptor 1 Biodiversity – Marine mammals of Bulgarian Marine Strategy.

Materials and Methods

Study area

The study area included coastal, territorial and shelf waters up to 100 m depth. Territorial waters fully encompass coastal regions and parts of the shelf. The first two surveys conducted on 29 July – 3 August 2020 and 26 July – 1 August 2021, covered only territorial waters with a total area of 6.358.09 km^2. This stratum includes a variety of bottom substrates, including fine and coarse sands, silts, and rocks. The coastline is varied, with two larger bays near Varna and Burgas. The most prominent capes are Kaliakra, Emine and Maslen, where constant currents occasionally provide suitable conditions for localised upwellings. Depth varies from 0–30 m inshore to 30–80 m offshore as follows: 50 m close to the border with Romania, 80 m opposite Cape Kaliakra, 30 m opposite Varna, 70 m opposite Cape Emine, 60 m opposite Cape Maslen and 80 m at the border with Turkey. The surveys in 2022 (22 July – 6 August) and 2023 (21 – 24 June) covered coastal and shelf waters from the coast to 100 m isobath offshore with a total area of 12,090.09 km^2. Thus, the territorial and coastal waters have been thoroughly surveyed four times, while the remaining deeper part of the shelf only twice. There are 14 SACs of NATURA 2000 in the study area, including harbour porpoise and bottlenose dolphins in their conservation objectives.

Survey design

The design of the first two surveys, which covered only the Bulgarian territorial waters, was made using the Distance 6.0 package. It included 13 transect lines with a total length of 442 km, assuring coverage of 7% and equal coverage probability (Fig.

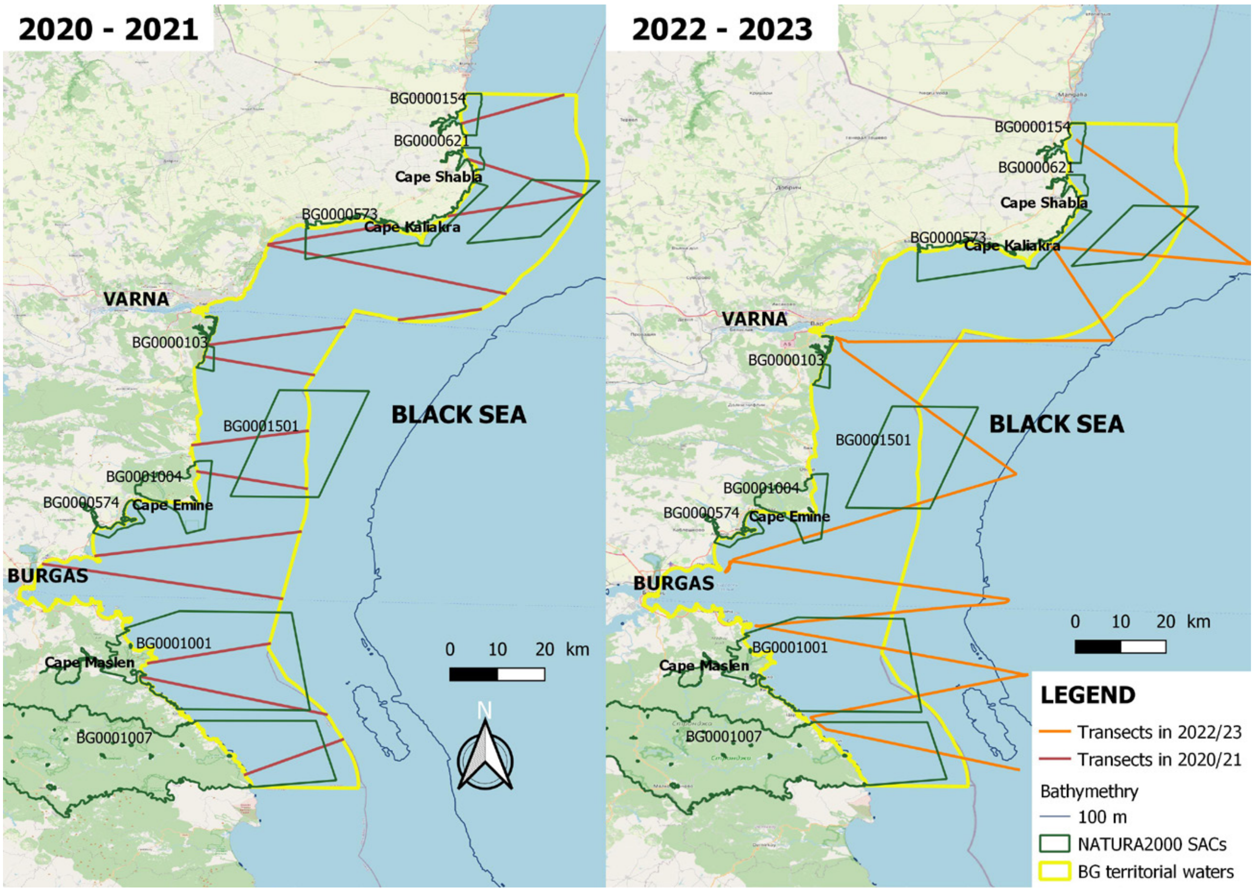

Fig. 1. Map of survey design

1). For the surveys in 2022 and 2023 the design was adapted to comply with logistical constraints and the limited available periods with favourable weather conditions required for such visual surveys. Pre-determined transects were placed close to available ports on the coast and were in continuous mode to avoid time-consuming transits. Eleven transects were designed with a total length of 617 km, covering shelf up to 100 m depth and ensuring coverage of 5%. The design was a zigzag shape in an east-west orientation, perpendicular to the coast to assure sampling across a potential density gradient (depth) to reduce encounter rate variability.

Data collection

Data were collected during all the surveys by using the standard line-transect distance sampling (Buckland 2004; Buckland et al. 2001) methodology and deploying a single platform (2 observers and one data recorder). That method includes traversing along predetermined transect lines and whenever an object of interest (cetacean in our case) is observed, distance to the object is recorded together with radial angle (angle between object and transect line). The perpendicular distance from the transect to the object can then be calculated using simple trigonometry (Buckland et al. 2001).

All surveys were done with the same 12.8 m motor-sailing yacht equipped with navigation equipment, including autopilot. The observer's eyesight height varied between 214 and 318 cm above sea level depending on the individual observer's height and whether seated or standing. The core of observers that conducted all four surveys was the same to minimize individual bias. Effort during different surveys varied depending on weather conditions. The average speed along all searched transects was 6-7 knots. Surveys were conducted during appropriate weather conditions (sea state less than 4 on the Beaufort scale and good visibility – more than 5 km). Data on environmental conditions (sea state in Beaufort scale, glare from to and intensity, visibility and sightability – subjective estimation of overall sighting conditions) and effort were also recorded during surveys – at the start of a transect, rotation of observers or if a change in weather conditions occurred. Detailed information was recorded for each sighting, including GPS waypoint, time, species, group size, distance and angle of observation, behaviour and presence of calves. Observers scanned from abeam (90°) on their side to 10° on the opposite side with the naked eye and binoculars were used to identify probable sightings and measure the distance to them. Distance and angle of observations were measured using PENTAX Marine 7x50 reticle binoculars and by angleboard. GPS (Garmin GPSMap 64st) recorded geographic coordinates of sightings and survey tracks.

Data analysis

The abundance and density of individuals and groups were estimated by analytical tools based on detection probability functions for distance sampling (Buckland et al. 2001) using Distance 7.4 software (Thomas et al. 2010).

Density was calculated using the following formula (Buckland et al. 2015):

$$\hat{D} = \frac{n}{2wL\hat{P}_a} = \frac{n}{2\hat{\mu}L} = \frac{n\hat{f}(0)}{2L}$$

where is density; n is the number of observed objects; L is the sum of the lengths of all transects; w is the perpendicular distance from the line; is the probability for detection; μ is the effective strip (half) width, and f(0) is the probability density function.

Abundance of animals occurring in clusters is calculated using the following Horvitz-Thompson estimator (Thomas et al. 2010):

$$\hat{N} = \sum_{i=1}^{n} \frac{s_i}{\hat{P}_i}$$

where n is the number of observations; is the estimated inclusion probability for animal i and is the size of cluster i, i=1, …, n.

Encounter rate was defined as the number of sightings (groups) per kilometre of effort. The population density was estimated as the number of individuals per square kilometre. Only sightings of effort along transects were used in the analysis. The group size estimation was made by the size bias regression method when regression was significant at an alpha level of 0.15; otherwise, the mean of observed group size was used. The minimum value of the Akaike Information Criterion, or AIC (Buckland et al. 2001; Akaike 1974), was used to choose between models. The AIC provides a relative measure of fit. The model with the smallest value best fits the data (Thomas et al. 2010). A difference of more than 2 for AIC values shows a better-fitting model. Selection of the most appropriate model of detection function, including a combination of key function and series expansions, was based on a procedure involving comparison of results of quantile–quantile plots, Cramer-von Mises goodness-of-fit tests, where "p" had the highest values and AIC's lowest value. In addition, for models where the delta AIC was below 2, the model with a lower coefficient of variation was selected as the optimal. In this way, the most reliable density and abundance estimations were achieved. In surveys, when a number of sightings for certain species was low, a global detection function was used with post-stratification by species. Both conventional distance sampling (CDS) and multiple covariate distance sampling (MCDS) with glare, sight ability, observer and sea state used as covariates were executed. Selected models for each species and year are shown in tables with results. As the surveys in 2022 and 2023 covered a more extensive study area, stratification was applied, dividing it into two strata: territorial waters of the shelf that entirely overlap with the study area in 2020 and 2021 and the offshore shelf. Relative densities and encounter rates were calculated for separate strata, global density and abundance for the entire shelf. Maps of distribution and concentrations per species were created with the Heatmap tool in QGIS 3.16.5.

Results

All three cetacean species have been recorded in each of the four conducted surveys. Number of sightings varied between the years: 55 in 2020; 71 in 2021; 155 in 2022 and 192 in 2023 (Figure 2).

Black Sea harbour porpoise

The Black Sea harbour porpoise was the most frequently encountered species during all surveys, except for the first survey in 2020 when it came second to bottlenose dolphins. A total of 332 sightings with 595 individuals were recorded. The highest number of harbour porpoise sightings was of single animals (203 sightings, 61%), followed by groups of 2 (80 sightings, 24%) and 3 individuals (20 sightings, 6%). Groups of 4 and 5 animals were encountered on 13 and 8 occasions in 2021-2023. Groups of 6, 10, 15, and 21 porpoises were each recorded once. However, groups of 7 animals were only encountered four times, in 2022 and 2023, during surveys of deeper waters beyond territorial waters. Population parameters, including the abundance and density of groups and individuals, encounter rates, effective strip widths, are presented in Table 1.

The distribution of Black Sea harbour porpoises during summer on the Bulgarian shelf suggests higher sighting numbers (200 in 2 years) and larger groups

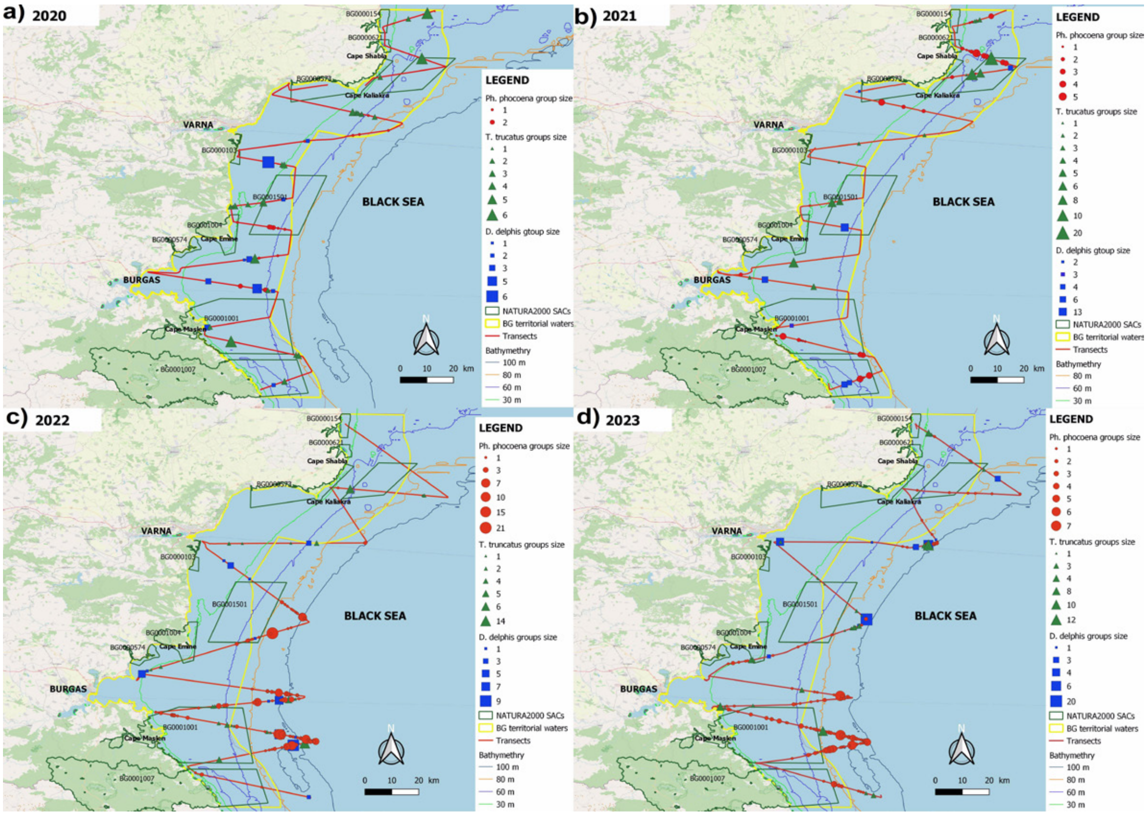

Fig. 2. Sightings in: a) 2020, b) 2021, c) 2022, d) 2023.

in deeper waters, compared to territorial waters (132 in 4 years). In territorial waters, the highest concentration was near Cape Maslen at depths of 30-60 m, overlapping with SAC Ropotamo BG0001001 (Fig. 3a). Higher densities were also observed in spring (POPOV et al. 2021). A smaller secondary concentration was found in northern waters opposite Cape Shabla at a depth of 60 m. The deeper waters outside territorial waters were considered important due to the only concentration defined in the entire shelf at depths of 80-100 m, just east of SAC Ropotamo BG0001001, lying outside NATURA 2000's scope (Fig. 3b). This importance was emphasised by the surveys conducted twice on the shelf and four times in territorial waters during the study period.

Black Sea bottlenose dolphin

It was the most often encountered species during the first survey in 2020 and the second most frequently observed in the other three surveys. The highest number of bottlenose dolphin sightings was of pairs (33 sightings, 35%) followed by single animals (27 sightings, 29%) and groups of 3 individuals (12 sightings, 13%). Groups of 4 and 5 dolphins were recorded on 4 occasions each, and groups of 6 at 6 encounters. Larger groups consisting of 8 and 10 dolphins were encountered twice each, while the largest groups of 14 and 20 were observed only once. Mixed groups of bottlenose and common dolphins were observed twice only in 2023: the first one was of 12 bottlenose and 6 common dolphins, and in the second, these were respectively 3 and 2. Estimated population parameters are presented in Table 2.

The distribution of Black Sea bottlenose dolphins in the Bulgarian shelf during summer was studied. Sightings in territorial waters (70 in 4 years) surpassed those in deeper shelf waters (26 sightings in 2 years). Heatmaps displayed areas with higher encounter rates and density, revealing similar distribution patterns in territorial and shelf waters. The largest concentration of dolphins in territorial waters was observed in the northern waters, spanning from the border with Romania along Cape Shabla to south of Cape Kaliakra, at depths of 30 to 70 metres (Fig. 4a). The second concentration was found in the central shelf, between Varna and Cape Emine, at depths of 30 to 40 metres, overlapping with SAC Emona BG0001501 (Fig. 4b). A third concentration of dolphins was observed at a depth of 40 metres east of Burgas Bay. All three concentrations extended further eastwards into the shelf waters. The northern hotspot areas, although partially covering fragments of SAC Kompleks Kaliakra BG0000573, were not included in the NATURA 2000's scope.

Table 1. Results for estimations of abundance and density of Black Sea harbour porpoise.

Parameters	**2020**	**2021**	**2022 – ter. waters**	**2022 – shelf**	**2022 – total shelf**	**2023 – ter. waters**	**2023 – shelf**	**2023 – total shelf**
Density, D (ind.km^{-2})	0.156	0.511	0.432	2.83	1.569	0.442	2.17	1.261
95% Confidence Interval	0.065 – 0.371	0.202 – 1.291	0.184 – 1.013	1.641 – 4.881	0.841 – 2.29	0.245 – 0.796	0.922 – 5.11	0.617 – 2.579
Coefficient of variation (CV), %	42.62	46.57	41.45	26.59	23.79	28.03	40.78	34
Abundance, N (ind.)	991	1 512	2745	16220	18965	2810	12440	15249
95% Confidence Interval	416 – 2 360	1 284 – 8 211	1 170 – 6 441	9 404 – 27 976	10 166 – 27 692	1560-5061	5282-29294	7455-31190
Coefficient of variation (CV), %	42.62	46.57	41.45	26.59	23.79	28.03	40.78	34
Density of groups, DS (groups.km^{-2})	0.128	0.267	0.269	1.276	0.769	0.322	1.284	0.778
95% Confidence Interval	0.054 – 0.301	0.106 – 0.668	0.105 – 0.692	0.704 – 2.311	0.382 – 1.116	0.181 – 0.573	0.548 – 3.003	0.392 – 1.543
Coefficient of variation (CV), %	41.65	45.84	46.11	27.94	23.7	27.07	40.12	32.34
Area, km²	6358.09	6358.09	6358.09	5732	12090.09	6358.09	5732	12090.09
Observation effort, km	423	438.2	331.75	248.45	580.2	341.8	219.4	561.2
Sightings/individuals	17/23	47/90	24/38	85/190	109/228	44/60	115/194	159/254
Encounter rate (groups per km)	0.04	0.17	0.072	0.342	0.188	0.126	0.501	0.273
Effective strip width, ESW (m)	156.98	201.13	134.48	134.09	134.17	195.32	195.32	195.32
Selected model of detection function	CDS Half-normal + cosine with post-stratification by species	MCDS Hazard rate + simple polynomial and sea state as covariate	MCDS Hazard rate + simple polynomial and sea state as covariate and bootstrap			CDS Hazard rate + simple polynomial with 400 m truncation		

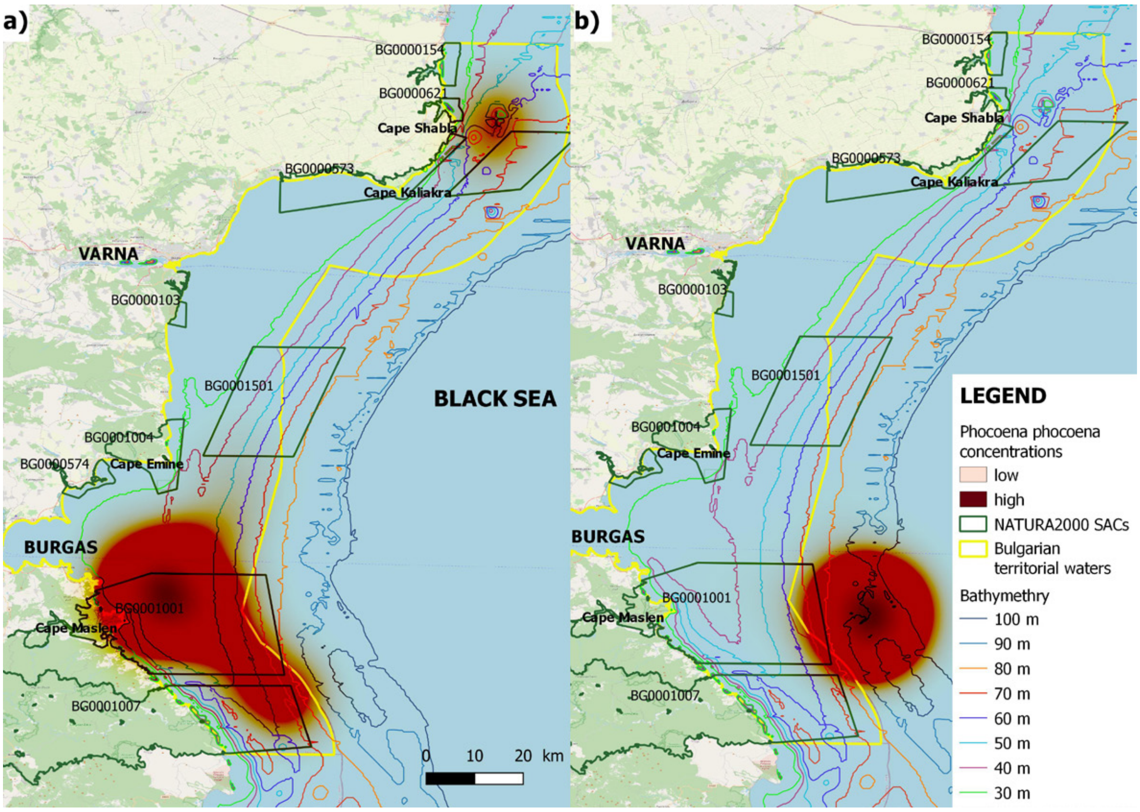

Fig. 3. Map of concentrations of harbour porpoises in: a) territorial waters and b) shelf waters.

Black Sea common dolphin

The species encountered the least during all surveys was the common dolphin. Solitary animals were the most frequently sighted (12 sightings, 29%), followed by groups of 2 (8 sightings, 20%) and 3 dolphins (7 sightings, 17%). Groups of 4 were recorded on four occasions, while groups of 5 and 6 dolphins were encountered two and three times, respectively. Larger groups, consisting of 7, 8, 9, 13, and 20 dolphins, were each encountered only once. Table 3 presents the estimated population parameters.

The distribution of the Black Sea common dolphin in the Bulgarian shelf during summer did not show a clear preference for coastal or deeper waters. The number of encounters was almost identical: 25 in 4 years and 18 in 2 years. This can be explained by the species generally preferring offshore habitats. Heatmaps for both coastal and deeper waters were almost identical, extending slightly into the shelf waters when all sightings are considered. The largest concentration of dolphins in territorial waters was south of Cape Emine and east of Burgas Bay, at depths between 30 and 60 metres (Fig. 5a). Another concentration was found in the central shelf, at shallower waters of 30 metres, between Varna and SAC Emona BG0001501 (Fig. 5b). These concentrations further extended into the shelf waters. The first concentration spread east and south, reaching a depth of 100 metres east of SAC Ropotamo. The second concentration extended southeast into SAC Emona, reaching a depth of 50 metres. A smaller concentration has formed on the territorial waters' boundary south of Cape Kaliakra, at depths between 80 and 90 metres.

Discussion

Cetaceans in the Black Sea are facing numerous challenges and threats nowadays, and the most important of these is undoubtedly bycatch in bottom gillnets targeting turbot, which is the main source of human-induced mortality, affecting mainly porpoises (Birkun et al. 2014; Tonay 2016; Popov et al. 2023). The importance of that threat is underlined by the fact that it is included as one of the criteria (D1C1) for the functional group of marine mammals in D1 Biodiversity of MSFD together with abundance (D1C2) and density (D1C4). All these population parameters are also used to assess the conservation status of species protected by HD, and cetaceans are among these. In order to be able to assess the level of impact of the threat posed by bycatch, obtaining robust estimates of abundance is a prerequisite. Only then would conservation status be realistically assessed. Dolphins and porpoises are highly mobile

Table 2. Results for estimations of abundance and density of Black Sea bottlenose dolphin

Parameters	2020	2021	2022 – ter. waters	2022 – shelf	2022 – total shelf	2023 – ter. waters	2023 – shelf	2023 – total shelf
Density, D (ind.km^{-2})	0.542	0.541	0.263	0.329	0.294	0.226	0.513	0.362
95% Confidence Interval	0.265 – 1.108	0.249 – 1.175	0.123 – 0.562	0.107 – 1.014	0.142 – 0.61	0.089-0.579	0.172-1.533	0.146-0.899
Coefficient of variation (CV), %	35.22	39.54	38.01	58.57	37.34	49.18	58.09	47.69
Abundance, N (ind.)	3 447	3 439	1 670	1 885	3 555	1 440	2 941	4381
95% Confidence Interval	1 686 – 7 046	1 583 – 7 469	781 – 3 573	611 – 5 812	1 713 – 7 378	564-3678	984-8788	1765-10876
Coefficient of variation (CV), %	35.22	39.54	38.01	58.57	37.34	49.18	58.09	47.69
Density of groups, DS (groups.km^{-2})	0.203	0.116	0.099	0.121	0.109	0.096	0.16	0.127
95% Confidence Interval	0.102 – 0.406	0.062 – 0.22	0.049 – 0.197	0.053 – 0.273	0.062 – 0.191	0.041 – 0.227	0.059 – 0.437	0.056 – 0.288
Coefficient of variation (CV), %	33.41	31	33.43	39.32	28.09	44.18	51.72	42.56
Area, km²	6358.09	6358.09	6358.09	5732	12090.09	6358.09	5732	12090.09
Observation effort, km	423	438.2	331.75	248.45	580.2	341.8	219.4	561.2
Sightings/individuals	27/72	17/79	12/32	11/30	23/62	14/33	15/48	29/81
Encounter rate (groups per km)	0.064	0.039	0.036	0.044	0.04	0.04	0.07	0.05
Effective strip width, ESW (m)	156.98	166.65	183.6	183.6	183.6	213.18	213.18	213.18
Selected model of detection function	CDS Half-normal + cosine extension model with post-stratification by species	CDS Half-normal + cosine extension model with post-stratification by species	CDS Half-normal + cosine extension			CDS Hazard rate + simple polynomial extension		

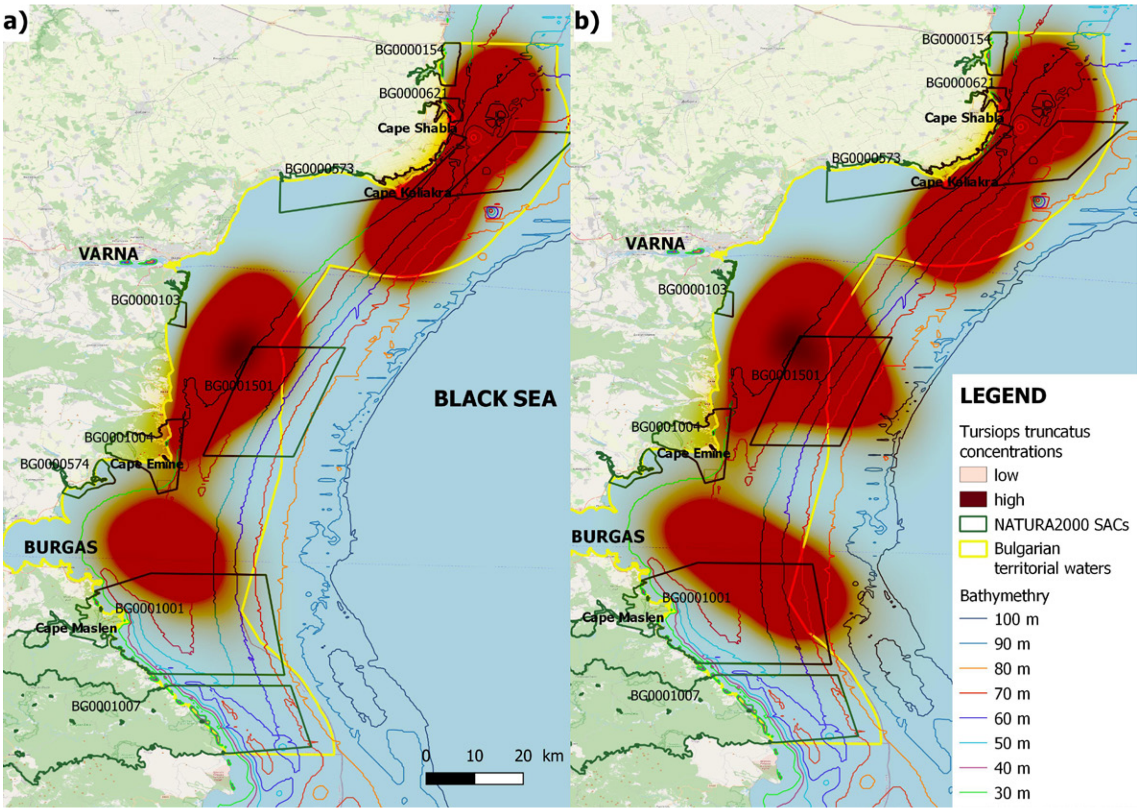

Fig. 4. Map of concentrations of bottlenose dolphins in: a) territorial waters and b) shelf waters.

apex predators in the vulnerable Black Sea ecosystem, and variations in their distribution patterns are, therefore, defined by their prey availability and distribution (Bushuev 2000). The first MSFD cetacean survey in Bulgaria, conducted in November – December 2017, covering coastal and shelf waters up to 100 m depth, has concluded that the status of D1 Biodiversity – Marine mammals was "Not Good" and prescribed further scientific surveys for updating of indicators and thresholds, used in assessment (Panayotova et al. 2020). Its results were further analysed and compared with a survey in June 2017, revealing significant seasonal variations (Popov et al. 2023), and showed the need for updated threshold values for different seasons. The four surveys we have conducted in 2020 – 2023 establish a good scientific basis for an update of the threshold values of D1C2 and D1C4 for the summer season.

Black Sea harbour porpoise

The current threshold values for the species are D1C2 – 1.003 individuals and D1C4 – 0.144 ind.km^{-2}. These values are similar to our results in summer 2020, while in the other three years, we observed higher density and abundance. To compare properly, the same study area is essential, as a larger or smaller area may have different environmental factors affecting prey abundance and distribution. The study area for all four years included Bulgarian territorial waters. The threshold values used applied to both coastal and shelf waters up to a depth of 100 m. The survey in 2022 and 2023 revealed a significant shift of harbour porpoises from coastal to deeper shelf waters, with a significant difference in density between both areas. The highest densities of harbour porpoises in the Black Sea are found in smaller surveyed areas, such as Southeastern Crimean waters (105 km^2) in April 2011, with a density of 4.86 ind.km^{-2} (Krivokhizhin et al. 2012), and southern Romanian territorial waters (1063 km^2) in June 2017, with a density of 5.359 ind. km^{-2} (Paiu et al. 2019). In 2022, the density in deeper waters of our study area was almost seven times higher than in coastal areas, and in 2023, it was almost fivefold. The proposed updated threshold values for D1C2 and D1C4 should be 18,965 ind. and 1.569 ind. km^{-2} for coastal and shelf waters up to 100 m depth, which have a total area of 12,090 km^2.

Black Sea bottlenose dolphin

The current threshold values for the species are: D1C2 – 4,861 individuals and D1C4 – 0.696 ind. km^{-2}. The highest density values (0.54 ind.km^{-2}) were observed in 2020 and 2021 when only territorial waters were surveyed. In 2022 and 2023, when the larger stratum

Table 3. Results for estimations of abundance and density of Black Sea common dolphin

Parameters	**2020**	**2021**	**2022 – ter. waters**	**2022 – shelf**	**2022 – total shelf**	**2023 – ter. waters**	**2023 – shelf**	**2023 – total shelf**
Density, D (ind.km^{-2})	0.226	0.26	0.107	0.699	0.388	0.032	0.311	0.165
95% Confidence Interval	0.099 – 0.511	0.097 – 0.699	0.02 – 0.479	0.309 – 1.576	0.184 – 0.816	0.007-0.148	0.079-1.217	0.046-0.588
Coefficient of variation (CV), %	40.83	50.23	79.7	41.05	37.73	79.97	73.41	67.79
Abundance, N (ind.)	1 436	1 654	682	4 005	4 688	206	1783	1989
95% Confidence Interval	634 – 3 252	616 – 4 444	1 170 – 6 441	1 776 – 9 033	2 228 – 9 860	45-942	456-6978	557-7108
Coefficient of variation (CV), %	40.83	50.23	79.7	41.05	37.73	79.97	73.41	67.79
Density of groups, DS (groups.km^{-2})	0.083	0.048	0.099	0.179	0.12	0.011	0.067	0.038
95% Confidence Interval	0.039 – 0.178	0.019 – 0.116	0.049 – 0.197	0.092 – 0.35	0.063 – 0.229	0.003 – 0.044	0.023 – 0.198	0.014 – 0.102
Coefficient of variation (CV), %	37.03	43.35	33.43	32.41	32.38	72.69	54.49	50.3
Area, km^2	6358.09	6358.09	6358.09	5732	12090.09	6358.09	5732	12090.09
Observation effort, km	423	438.2	331.75	248.45	580.2	341.8	219.4	561.2
Sightings/individuals	11/30	7/38	5/8	10/39	15/47	2/6	8/37	10/43
Encounter rate (groups per km)	0.026	0.016	0.015	0.04	0.026	0.006	0.04	0.02
Effective strip width, ESW (m)	156.98	166.65	112.33	112.33	112.33	271.01	271.01	271.01
Selected model of detection function	CDS Half-normal + cosine with post-stratification by species	CDS Hazard rate + simple polynomial	CDS Half-normal + cosine extension			MCDS Hazard rate + simple polynomial and sightability as covariate		

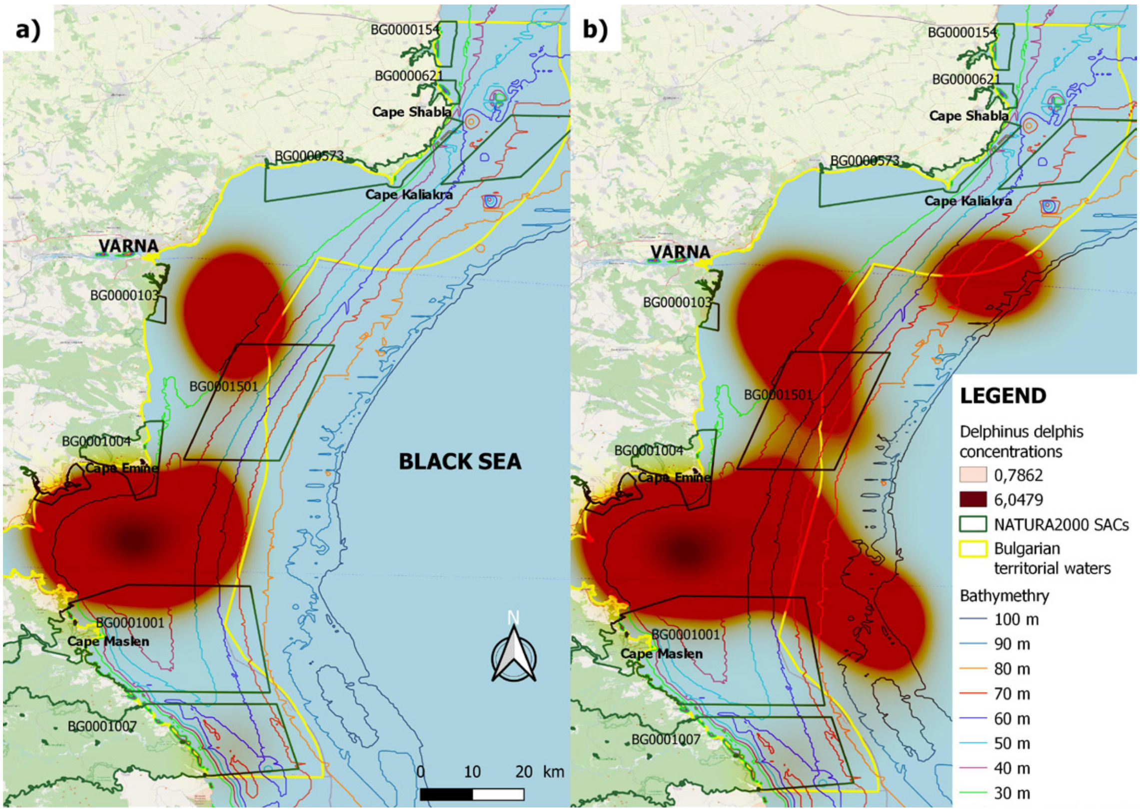

Fig. 5. Map of concentrations of common dolphins in: a) territorial waters and b) shelf waters.

was surveyed, the global density was lower: 0.294 and 0.362 ind.km^{-2}. Birkun et al. (2014) estimated a similar density (0.343 ind. km^{-2}) for a part of Ukrainian territorial waters that was 50% larger than our study area. The two heatmaps show major concentrations in the territorial waters, expanding slightly towards deeper waters in 2022 and 2023. There is an outlier in the density value for deep waters in 2023. The proposed updated threshold values for D1C2 and D1C4, based on robustness, are as follows: the coastal and shelf waters up to 100 m depth cover a total area of 12,090 km^2 and support a population of 3,555 ind. (95% CI: 1713 – 7378) with a density of 0.294 ind.km^{-2} (95% CI: 0.142 – 0.61).

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The current threshold values for the species exceed all results obtained in the four summer surveys. In 2022, the highest density value recorded was 0.388 ind.km^{-2} when the study area was enlarged. In 2020 and 2021, the density in the smaller stratum was lower and almost identical: 0.226 and 0.26 ind.km^{-2}. A similar density of 0.279 ind.km^{-2} was estimated for the Romanian territorial waters in July 2013 (Birkun et al. 2014). The two heatmaps show that major concentrations detected in territorial waters expanded into deeper waters. In 2022, the density in deeper waters of our study area was almost seven times higher than in coastal waters. In 2023, it increased further, achieving a factor of ten. Based on the robustness criteria, we propose updated threshold values for D1C2 and D1C4: 4,688 individuals (95% CI: 2228 – 9860) and 0.388 ind.km^{-2} (95% CI: 0.184 – 0.816) for the coastal and shelf waters up to 100 m depth, with a total area of 12,090 km^2.

Conclusions

The data collected provide current information on the abundance, density and distribution of Black Sea cetaceans in Bulgarian shelf waters during the summer. This study emphasises that the important habitat for the Black Sea harbour porpoise, located east of SAC Ropotamo BG0001001, is not protected under NATURA 2000. Similarly, the important habitat for the Black Sea bottlenose dolphin, located opposite Cape Shabla and south of Cape Kaliakra, also lacks protection. The Ministry of Environment and Water of the Republic of Bulgaria needs to take corrective action. Four surveys were conducted to update the threshold values for criteria D1C2 Abundance and D1C4 Density (in the summer season) of Descriptor D1 Biodiversity – Marine mammals of the Bulgarian Marine Strategy, which implements the EU

Marine Strategy Framework Directive 2008/56/EC. The abundance estimates obtained serve as a basis for assessing the impact of fishing gears on local populations of cetaceans, particularly the most affected species, the Black Sea harbour porpoise.

Acknowledgements: We would like to express our gratitude to the volunteers Nikolay Davidkov, Polina Hristova, Dragomir Dragiev and Teodora Ilieva for their invaluable assistance in data collection and to Captain Stoyan Georgiev for ensuring the smooth execution of the surveys. We are also grateful to OceanCare, Switzerland, for their continuous support, which made these surveys possible. Many thanks to reviewers for the valuable comments that improved the manuscript.

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