PLOVDIV UNIVERSITY
"PAISII HILENDARSKI"

FACULTY OF BIOLOGY
ZOOLOGY DEPARTMENT

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Abundance and distribution of cetaceans (Cetacea) in Bulgarian territorial waters of the Black Sea

ABSTRACT

Of PhD thesis
for awarding the educational and scientific degree "Doctor"

Field of higher education:
4. Natural sciences, mathematics and informatics
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Science major: Zoology

Scientific supervisors:
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The PhD thesis contains 334 pages and includes: 105 tables, 20 photos, 205 figures, 4 appendices and 205 literary sources, of which 55 are in Cyrillic and 155 are in Latin.

The dissertation was discussed and proposed for public defense at an extended meeting of the Department of Zoology, Faculty of Biology at the Plovdiv University “Paisii Hilendarski”. (Protocol № 490 from 26.06.2023).

The defense of the dissertation will take place on 3 October 2023 at 11:00 am in the Faculty of Biology at PU “Paisii Hilendarski”, 2 Todor Samodumov St.

The materials related to the defense are available to the interested parties at the Department of Zoology and in the library of PU “Paisii Hilendarski”.

Scientific jury:

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List of abreviations used

ACCOBAMS – Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area

CDS – Conventional Distance Sampling

CI – Confidence interval

CV – Coefficent of variation

EAFA – Executive agency on Fisheries and Aquaculture

EC – European Community

MCDS – Multiple Covariate Distance Sampling

MOEW – Ministry of Environment and Water

MSFD – Marine Strategy Framework Directive 2008/56/EC

SAC – Special Area of Conservation (Natura 2000 site)

1. INTRODUCTION

Infraorder Cetaceans (Cetacea) belongs to order Artiodactyla and is divided into two superfamilies: toothed whales (*Odontoceti*) with 78 species and and baleen whales (*Mysticeti*) with 15 species (Committee on Taxonomy, 2022). Three species of cetaceans inhabit the Black Sea that due to its isolation and on basis of morphological and genetic studies have been nominated as endemic subspecies. Representatives of the family *Delphinidae* are: Black Sea common dolphin (*Delphinus delphis ponticus* Barabash, 1935) Black Sea bottlenose dolphin (*Tursiops truncatus ponticus* Barabash-Nikiforov, 1940), and of family *Phocoenidae* is the Black Sea harbour porpoise (*Phocoena phocoena relicta* Abel, 1905), (Committee on Taxonomy, 2022).

Due to their status as threatened species and important role they have for the Black Sea ecosystem measures for their conservation are necessary. To be effective, as a first step assessment of impact of different threats is needed, but for that purpose data on abundance and distribution of different cetaceans' species populations should be collected (Hammond *et al.*, 2013).

Current dissertation presents the results of conducted distance sampling vessel surveys in Bulgarian territorial waters over a period of six years (2017–2022) in different seasons and assesses one of the most significant anthropogenic threats – bycatch in bottom set gillnets targeting turbot.

2. LITERATURE REVIEW

First records of marine mammals in the Black and Azov Seas date back to late 18th centurt but three cetacean species have not been described until 1840. In the beginning of 20th century data on the three cetacean species have been much more detailed describing their biology (Zernov, 1913). In the 1930s abundance of three species of cetaceans in the Black and Azov Seas was estimated to be between 800 000 (Malm, 1936) and 1.5–2 million individuals (Zemsky & Yablokov, 1974; Smith, 1982). In the period after industrial dolphin fishery has ceased (1966) scientific interest in Bulgaria has been maintained sporadically by individual researchers (Stanev, 1999). From start of 21st century scientific research of Black Sea cetaceans has oncreased due to their high conservation status and adopted international legislation for their protection. The largest study so far is international aerial survey conducted in summer 2019 that covered approx. 60% of Black Sea (Paiu *et al.*, 2021a).

3. GOAL AND OBJECTIVES

Goal of the dissertation is:

Seasonal study of abundance, density and distribution of three cetacean species (Cetacea): Black Sea common dolphin (*Delphinus delphis ponticus* Barabash, 1935), Black Sea bottlenose dolphin (*Tursiops truncatus ponticus* Barabash-Nikiforov, 1940), and Black Sea harbour porpoise (*Phocoena phocoena relicta*

Abel, 1905) in Bulgarian internal and territorial waters of the Black Sea for a period of six years (2017–2022).

For achievement of this goal, following objectives were set:

1. Condcuting dedicated seasonal distance sampling vessel surveys for estimation of abundance, density and distribution of cetaceans in Bulgarian territorial waters of the Black Sea;
2. Study of one of main threats for Black Sea cetaceans – bycatch in bottom set gillnets targeting tubot – in the context of abundance estimates;
3. Collection of additional data for two dolphin species by photo identification to detect residency in certain areas of dolphin groups;
4. Detection of seasonal dynamics in presence of cetaceans in coastal waters by means of passive acoustic monitoring;
5. Analysis of collected data to understand seasonal and spatial distribution of cetaceans in Bulgarian territorial waters of the Black Sea.

4. MATERIAL AND METHODS

4.1. STUDY AREA

Black Sea is the largest internal sea basin in the world with maximum depth of 2 212 m, area of 421 638 km² and volume of 530 000 km^3 (without Azov Sea). Its solitary link to the World Ocean is via narrow and shallow srat – Bosphorus – connecting it to the Marmara and Mediterranea Seas. Due to large volume of river waters intake (including some of the largest European rivers – Danube, Dnepr and Don), Black Sea water salinity is lower (16–18‰) compared to the Mediterranean Sea and the World Ocean that have salinity of 36‰ (Rozhdestvenskiy, 1986). Important characteristic of the Black Sea is presence of hydrogen sulphide with concentration 0.2–9.6 mg/l at depths from 150–200 m to the bottom (Sorokin, 1982), that is resulting of no life except some specialized anaerobic bacteria. Study area includes territorial sea of Bulgaria including internal waters and 12-nautical mile marine area with total area of 6 358 km^2 opposite Bulgarian Black Sea coastline from Cape Sivriburun in the north to Rezovska River in the south. Depth in territorial sea varies between 0 and 80 m. Bottom substrate in the study area is divers and includes: mediolitoral rocks and sediments; shallow sublittoral silts; small and medium sands including underwater seagrass meadows, rocks and reefs; shelf sublittoral reefs, sands and silts.

4.2. BIOLOGICAL AND ECOLOGICAL CHARACTERISTICS OF TARGET SPECIES

4.2.1. BLACK SEA HARBOUR PORPOISE (*Phocoena phocoena relicta* Abel, 1905)

Harbour porpoise is the the smallest cetacean species in the Black Sea with body length of 1.3–1.5 m, max. 1.8 m, and average weight of 30 kg. Females are slightly bigger than males. Abundance estimate of porpoises in Bulgarian waters (Paiu *et al.*, 2021a) is 48 294 ind. (95% CI: 42 190 – 58 986).

4.2.2. BLACK SEA BOTTLENOSE DOLPHIN (*Tursiops truncatus ponticus* Barabasch-Nikiforov, 1940)

Bottllenose dolphin is the largest Black Sea cetacean species reaching max. length of 3.3 m and weight of 300 kg. Life span is 25–30 years but reproduction is relatively low. години, но репродуктивността е сравнително ниска. Abundance estimate in Bulgarian waters (Paiu *et al.*, 2021a) is 10 262 ind. (95% CI: 6094 – 17537).

4.2.3. BLACK SEA COMMON DOLPHIN (*Delphinus delphis ponticus* Barabasch-Nikiforov, 1935)

Black Sea subspecies is the smallest representative of the species globally: average length is 1.5–1.7 m (max. 2.0 m) for adult females and 1.7–1.8 m (max 2.2 m) for males. Weight is 50–55 kg with max. 100 kg. Abundance estimate in Bulgarian waters (Paiu *et al.*, 2021a) is 14 231 ind. (95% CI: 11506 – 18433).

4.3.1. METHOD FOR ABUNDANCE AND DENSITY ESTIMATION OF CETACEANS' POPULATIONS

4.3.1.1. SAMPLING

Observations were conducted in daylight during sea state not more than 3 according Beaufort scale from a motor-sailing yacht keeping a constant speed of 6–7 knots along the pre-defined transects. Surveys were conducted by two teams of two observers each rotating every hour or thirty minutes during cold months. Both observers scanned frontal view field of 180° and each observer covered 100°: from 90° on the side with the bow of the vessel at 0° to 10° on the opposite side. When sighting is registered, the observer measured radial angle (θ) and distance to object (r) with reticle binocular Pentax Marine 7x50 with built-in compass, defines species and group size, presence of calves and reports while the other team member records the data in a field form. Perpendicular distance (x) between sighting and transect line is calculated by triginmetry: $x = r.\sin\theta$

4.3.1.2. SURVEY DESIGN

Automated Survey Design Engine of DISTANCE 7.3 software was used. The design included 13 transects with total length of 442 km ensuring coverage of 7%.

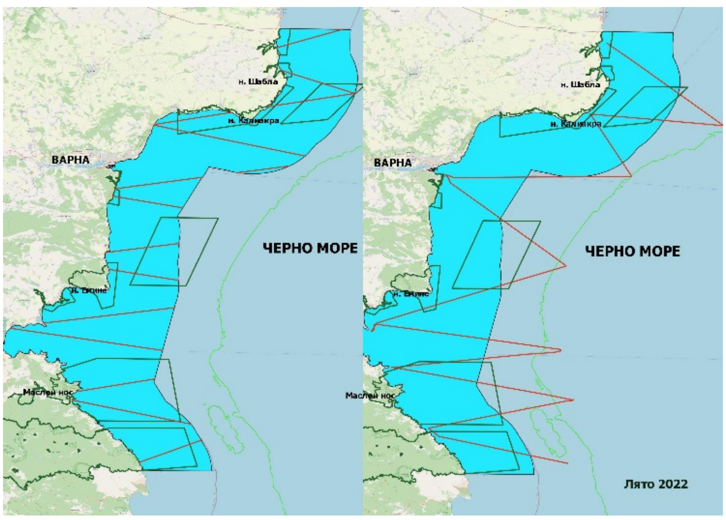


Figure 4.3.1.2.1: Survey design

The last survey, conducted in the summer of 2022 study area was enlarged to include shelf waters up to 100 m depth. During data analysis post-stratification was applied with two sub-areas: territorial waters and shelf area. Total length of transects was 617 km. Situation of transects is shown on fig. 4.3.1.2.1

4.3.1.3. METHODS OF STATISTICAL ANALYSIS

Data collected during each survey has been analyzed in specialized software DISTANCE 7.3 (Thomas *et al.*, 2010) using both conventional (CDS) and multiple covariate distance sampling (MCDS). Covariates used in MCDS included group size, species, sea stae by Beaufort, observer and glare intensity. Selection of detection function was made by fillowing combinations of key unction and series extensions: uniform and cosine; half-normal and cosine; half-normal and hermite polynomial; hazard rate and simple polynomial (Thomas *et al.*, 2010) and using following selection criteria: **p**-value of CvM test above 0.2; mnimum value of AIC; lower value of CV or models where ΔAIC is between 0 and 2. Values of density are estimated by using **μ** (ESW) value of the selected model. Z-test was used for comparison of estimated densities between different surveys (Buckland *et al.*, 2001).

Maps with concentrations of different species were produced in QGIS 3.16.5 through "Heatmap" function. Radius of 0.3 degrees around each sighting and pixel size of 0.001 x 0.001 degrees was used.

4.3.2. PHOTO-IDENTIFICATION OF DOLPHINS

4.3.2.1. SAMPLING

This is a "mark – recapture" method but marking is made without physical contact but through photographing specific individual features of the dolphin. During photo sessions we aimed at following basic rules: good light; lowest possible angle; shooting in continuous mode; high shutter speed and small aperture value for sharp images; blank photos between sessions.

4.3.2.2. SURVEY DESIGN

Data from pilot study along Southern Bulgarian coast (Popov, 2013) conducted between Capes Emine and Maslen in 2012 was used. Additionally opportunistic data was collected during dedicated transect vessel surveys in 2015–2022 and onboard of trawlers.

4.3.2.3. DATA ANALYSIS

After completion of the field work, procedure included following steps: processing of photos; identification of individuals; preparation of catalog with all individuals and following information for each: individual code; code of file/photo; region; date; time; geographic coordinates; relation to other individuals (ex. same group); comparison of indivduals with existing ones in the catalog and comparison with other catalogs from the Black Sea.

4.3.3. METHODS FOR BYCATCH STUDY AND MITIGATION

4.3.3.1. SAMPLING

Cetcean bycatch rates were monitored during standard fishing operations for turbot fishing with anchored bottom gill nets over the period 2019–2022 condcuted mainly in two seasons: spring – before 15 April and summer – after 15 June. In total eight vessel took part at different stages of the study with legth between 7.6 and 15.8 m. Used gill nets had indivudal length of 50, 70 and 100 m and mesh size 400 mm (200 x 200 mm), connected in different number of sets with total length from 800 to 11 480 m. Soaking time varied between 7 and 31 days in spring and 7–26 days in summer. Depth of net setting was between 45 and 94 m. Bycatch was recorded by independent observers and in some cases (or smaller boats) it was reported by fishermen.

4.3.3.2. STUDY DESIGN

As part of the study, three models of pingers were tested as a mitigation measure to reduce and prevent cetacean bycatch. Two models by Future Oceans (FO) were used: 10 kHz, 132 dB and 70 kHz, 145 dB. Pingers from F3 Maritime Technologies were PAL 10 kHz, 132 dB model. In 2019, experiments with pingers (both FO models were used) were conducted by equipping part of the set of nets with them, while the rest of that set was left without pingers and used as a control. The FO 10 kHz was placed at each set of nets every 70, 100 and 140 m respectively. The FO 70 kHz model was placed every 280 m in spring and every 140 m in summer. In 2020, 2021 and 2022, the configuration was changed and pingers were placed on a full set of nets (active net) and a control set of nets without pingers was located in proximity (time and space) to the active nets. The distance between pingers was limited to 100/140 m for PAL and FO 10 kHz pingers, and 200 m for FO 70 kHz, according to the manufacturer's specification.

4.3.3.3. BYCATCH DATA ANALYSIS

Given different soaking time of nets as well as their different height – from 2; 2.6 and 3 m, standardization of effort was performed. It was calculated as km^2*days, and accordingly the bycatch level as ind./km^2*days. Non-parametric Mann-Whitney U-test was used for comparison of bycatch levels between seasons and when testing pingers, and for comparison between individual years, non-parametric Kruskal-Wallis test was used in the SPSS specialized software. An assessment of the total annual bycatch level based on the collected data was made using three methods: extrapolation of the average level by species for each of the surveyed seasons and years to the total length of nets used in this fishing segment; by the formulas of Northridge & Fortuna (2008) and by applying the median values for number of fishing operations and cetaceans caught per operation, which are multiplied by the total number of vessels fishing for turbot.

4.3.4. METHOD OF PASSIVE ACOUSTIC STUDY

4.3.4.1. SAMPLING

The passive acoustic survey was performed using FPOD detectors, which are autonomous devices detecting and recording a large number of clicks in the frequency range from 20 to 160 kHz. They are powered by batteries and record the information on memory cards (micro SD – up to 32 GB). They work at a maximum depth of 150–200 m. The detection radius of cetacean clicks varies from 500 m for porpoise to a minimum of 2,000 m for dolphins. The detectors are attached to a rope with a lead weight to ensure its vertical position in the water column at a distance of a minimum of 2 to 3 m from the bottom.

4.3.4.2. STUDY DESIGN

Agreements have been reached with three mussel farm operators (Kavarna, Ravda and Sozopol) to attach the detectors to existing floating facilities. The fourth detector is placed near a stationary pound net (dalyan), located near Balchik and the resort of Albena.

4.3.4.3. DATA ANALYSIS OF ACOUSTIC DATA

The analysis of the raw data is condcuted in the specialized software FPOD with the classifier KERNO-F using an algorithm that separates the clicks according to the following filters: porpoises and dolphins. Classified clicks are separated into quality classes – high, medium, low and uncertain, which represent the level of confidence in determining species affiliation. When reading the memory card, the software creates a file type .FP1 containing the raw data, which after analysis with the classifier creates a new file type .FP3. For both groups of cetaceans, the presence data obtained were analyzed as detections positive minutes per hour (DPM per hour), which were standardized. The mean number of DPMs was calculated by month and compared between stations using the Mann-Whitney U-test.

5. RESULTS AND DISCUSSION

5.1. ABUNDANCE, DENSITY AND DISTRIBUTION OF CETACEANS

A total of 12 vessel surveys were conducted for the period 2017–2022. The results of each survey were analyzed separately and presented by species.

5.1.1. ABUNDANCE, DENSITY AND DISTRIBUTION OF BLACK SEA HARBOUR PORPOISE (*Phocoena phocoena relicta*)

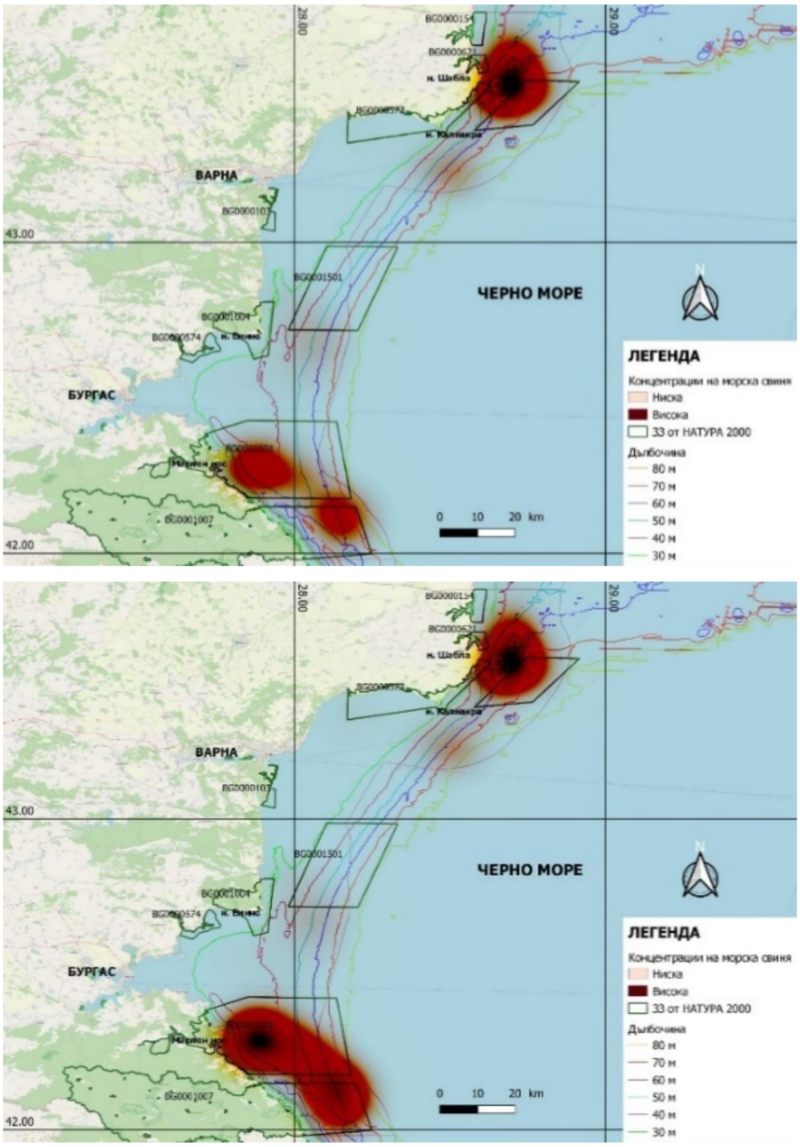
Spring

Spring surveys were conducted from April 30th to June 23rd and showed a large variation in porpoise density ranging from 0.416 (June 2018) to 2.366 ind./km^2 (June 2022). These two values can be considered as extreme, especially the maximum reported in 2022, which, hypothetically, is likely to be caused by Russia's war in Ukraine in the northern part of the Black Sea and increased noise pollution of the marine environment leading to displacement of marine mammals to areas providing more favorable living conditions.

Comparing changes porpoise density in spring between years using a z-test (Buckland et al., 2001) showed non-significant differences ($p>0.05$) between following years:

- 2017, 2019 and 2022 – these are years with the highest density;
- 2018 and 2021 – these are years with the lowest density;
- 2019 and 2020; 2020 and 2021 г.

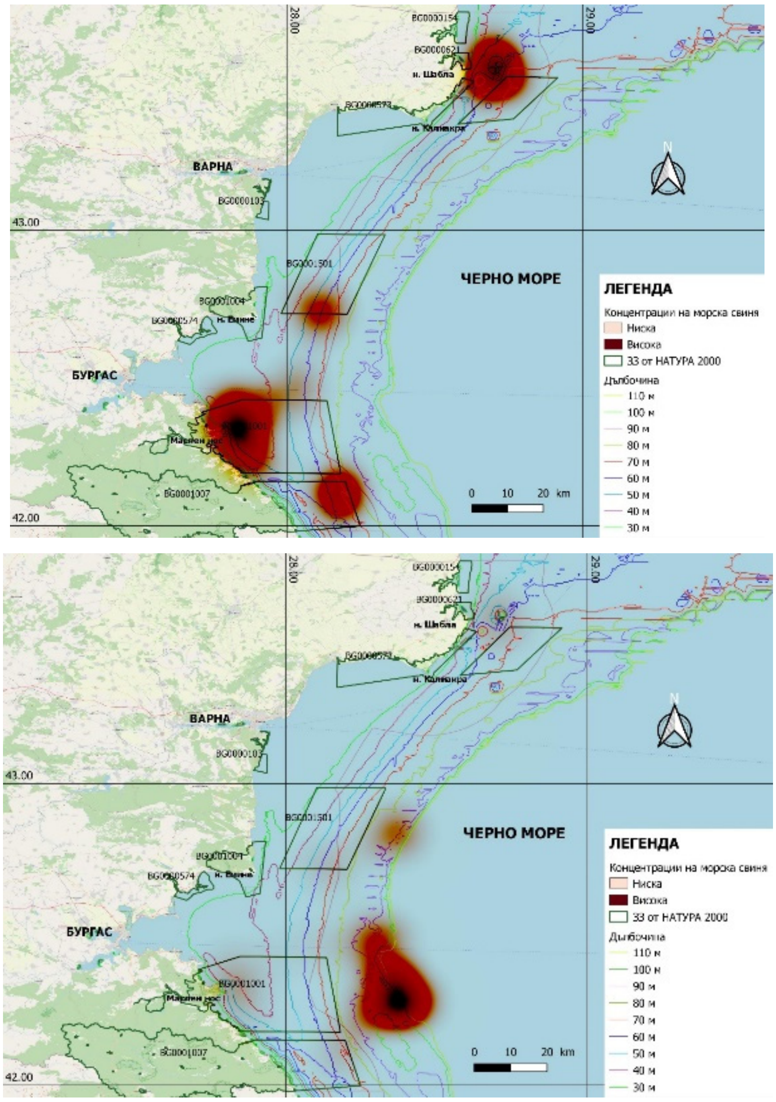
The spring distribution data are presented with two maps: only with the data from the described 12 surveys in the period 2017–2022 (Fig. 5.1.1.1) and supplemented with data from surveys in the SACs Ropotamo and Strandzha conducted in the spring of 2016. (Fig. 5.1.1.2). In both cases, the concentrations are identically located in front of Cape Shabla in the north between 60 to 70 m depth and in SAC Ropotamo in the south from 40 to 50 m. The concentration in SAC Strandzha is at a depth of 60 m and is of a slightly lower order compared to the first two. Two secondary ones are observed in front of Cape Emine (SAC Emona) at a depth of 50–60 m.



Figures 5.1.1.1-2: Concentrations of poproises in spring for the periods 2017–2022 and 2016–2022.

Summer

The summer surveys were conducted from 2020 to 2022, in almost identical periods between July 22nd and August 6th, and showed variation in density. The largest difference was observed in 2022, when a larger area covering the shelf up to 100 m depth was also surveyed. The difference in density estimate between the territorial waters and the shelf is more than threefold, indicating a significant shift of porpoises to the offshore waters and greater depths in summer. Within the limits of the territorial waters, the changes in the population density in the summer for the period 2020–2022 are not significant (z-test, $p > 0.05$). No significant difference in density was found (z-test, $p > 0.05$) between summer and winter 2020 either. Summer is the only season for which comparable data are available from a past vessel survey (July 2013): density 0.144 ind./km^2 (CV = 49.11%) and a number of 1,003 individuals (Birkun et al., 2014), which were adopted as threshold values for the coastal and shelf area in the national monitoring strategy under the MSFD of Descriptor 1,4 Biodiversity – Marine mammals. Concentrations show differences depending on whether all observations are analyzed or only those in territorial waters.

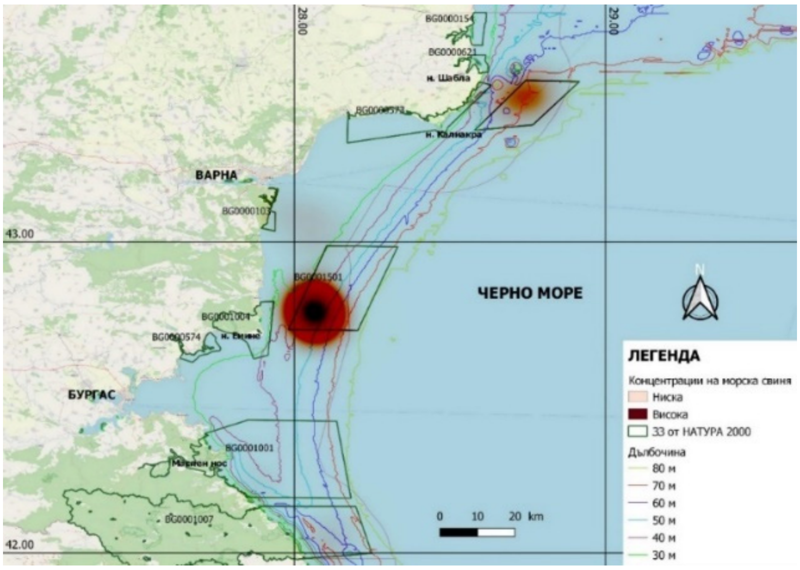


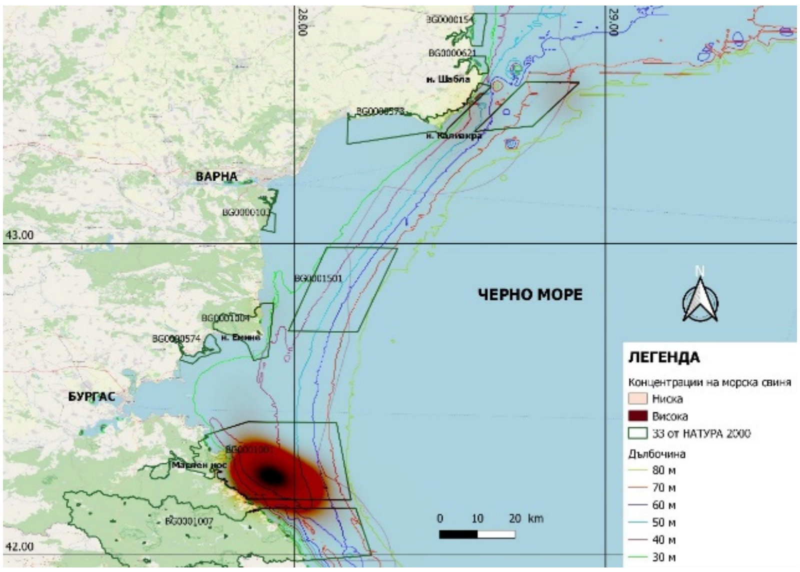
Figures 5.1.1.3-4: Concentrations of poproises in Bulgarian territorial waters and shelf in summer for the period 2020–2022.

Within the limits of the territorial waters, the greatest concentrations are observed in SAC Ropotamo in front of Cape Maslen and in front of Sape Shabla at depths of 40–50 and 50–60 m, respectively. Smaller concentrations were reported in the southern part of the SAC Emona and in the shelf water area of the SAC Strandzha at depths of 60 and 70 m, respectively (Fig. 5.1.1.3). When combining all summer observations, the above-described concentrations acquire a secondary character and the most significant are those recorded in 2022 in the southern and central offshore parts of the shelf at a depth of 90–100 m (Fig. 5.1.1.4).

Autumn and winter

Cold season surveys were conducted between October and February in 2018–2020. The highest density was recorded during the winter survey and it was almost twice as high as the autumn maximum recorded in 2018. In boundaries of territorial waters, changes in population density in autumn for the period 2018–2019 are not significant (z-test, $p > 0.05$). The only significant difference (z-test, $p < 0.05$) in the autumn-winter season was found between the autumn of 2019 and the winter of 2020. In autumn (Fig. 5.1.1.5), the greatest concentration was in the southwestern part of SAC Emona at a depth of 40–50 m and in the SAC Kaliakra at a depth of 60–70 m. In winter, the most important concentration overlaps with that identified in spring in the SAC Ropotamo at a depth of 40–50 m (Fig. 5.1.1.6).





Figures 5.1.1.5-6: Concentrations of porpoises in autumn and winter.

Spring is the season with the highest recorded density and abundance of the harbor porpoise population in Bulgarian territorial waters, while in summer the tendency is towards a decrease as a result of a shift to the deeper parts of the shelf. This trend also persists during the autumn-winter period, coinciding with the well-documented migrations of the species at that time from the western to the eastern/southeastern parts of the Black Sea in Turkish and Georgian waters (Kopaliani et al., 2015; Özsandıkçı, 2021). The concentrations of the species generally coincide with the existing SACs of NATURA 2000 for the conservation of the species with little gap within the boundaries of the SAC Kaliakra Complex, which only partially covers the important area at a depth of 60 to 70 m opposite Cape Shabla. However, the significant shift of the species in summer to the deeper part of the shelf remains completely outside the scope of the national ecological network. The deep-water part of the Bulgarian shelf was identified as the area with the highest concentration of the species in the Black Sea during the large-scale aircraft survey in the summer of 2019 (Paiu et al., 2021a). Summary results of all studies in territorial waters for the period 2017–2022 are presented in Table 5.1.1.1.

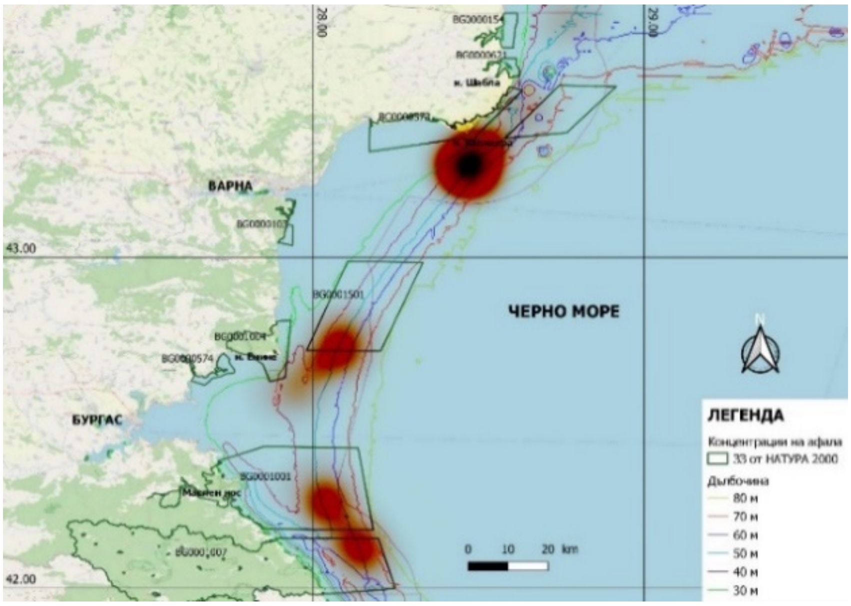
Table 5.1.1.1: Sumamrized results for abundance and density of Black Sea harbour porpoise in Bulgarian territorial waters for the period 2017–2022.

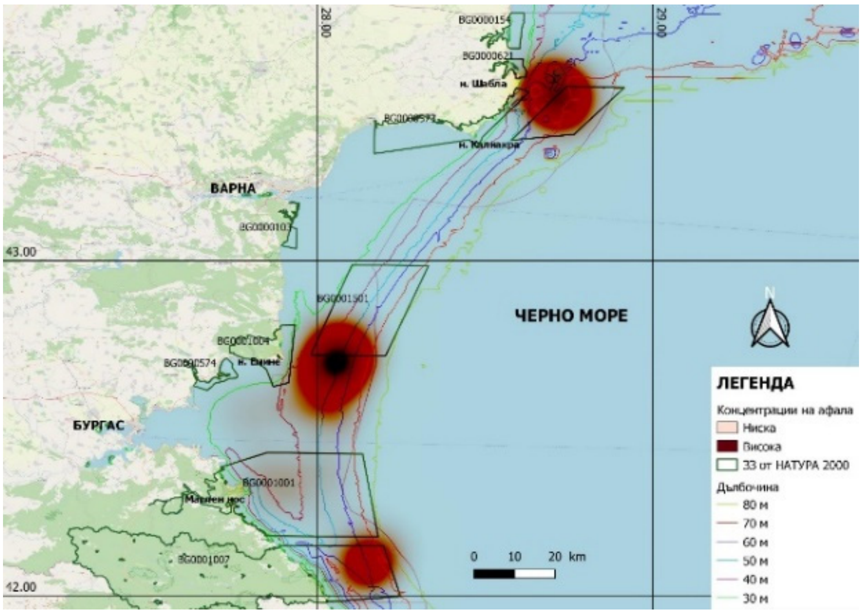
Parameters	**Spring 2017**	**Spring 2018**	**Autumn 2018**	**Spring 2019**	**Autumn 2019**	**Spring 2020**
Effort, km (L)	421	419.8	424.2	444.4	409.4	425.1
Sightings (n)	166	39	18	112	10	116
Encounter rate (n/L)	0.394	0.093	0.042	0.252	0.024	0.273
Density (D, ind./km^2)	**1.423**	**0.416**	**0.163**	**1.752**	**0.063**	**0.769**
95% confidence interval (CI)	0.834 – 2.427	0.216 – 0.801	0.058 – 0.459	0.803 – 3.823	0.032 – 0.119	0.493 – 1.199
Coefficient of variation (CV), %	25.4	32.39	51.68	38.49	31.32	21.56
Abundance (N)	**9 045**	**2 645**	**1 039**	**11 137**	**399**	**4 889**
95% confidence interval (CI)	5 301 – 15 433	1 373 – 5 093	370 – 2 917	5 103 – 24 310	193 – 526	3 134 – 7 626
Coefficient of variation (CV), %	25.4	32.39	51.68	38.49	31.29	21.56
Parameters	**Summer 2020**	**Winter 2020**	**Spring 2021**	**Summer 2021**	**Spring 2022**	**Summer 2022**
Effort, km (L)	423	374	430.9	438.2	426.7	331.75
Sightings (n)	17	26	57	47	221	24
Encounter rate (n/L)	0.04	0.07	0.132	0.107	0.518	0.072
Density (D, ind./km^2)	**0.156**	**0.328**	**0.475**	**0.511**	**2.366**	**0.432**
95% confidence interval (CI)	0.065 – 0.371	0.141 – 0.767	0.269 – 0.842	0.202 – 1.291	1.479 – 3.788	0.184 – 1.013
Coefficient of variation (CV), %	42.62	43.78	28.52	46.57	22.43	41.45
Abundance (N)	**991**	**2 088**	**3 023**	**3 246**	**15 046**	**2745**
95% confidence interval (CI)	416 – 2 360	895 – 4 874	1 708 – 5 351	1 284 – 8 211	9 401 – 24 082	1 170 – 6 441
Coefficient of variation (CV), %	21.56	43.78	28.52	46.57	22.43	41.45

5.1.2. ABUNDANCE, DENSITY AND DISTRIBUTION OF BLACK SEA BOTTLENOSE DOLPHIN (*Tursiops truncatus ponticus*)

Spring

Surveys in spring showed a large variation in the density of the species ranging from 0.051 (spring 2020) to 0.607 ind./km^2 (June 2022). The species is the least frequently seen in spring of the three, with the exception of the reported maximum, which, as with the porpoise, can be considered an extreme value. The difference is significant only when comparing with 2022 ($p < 0.05$). Comparing population density changes between spring and other seasons within a calendar year, they are insifnigicant in 2018 and 2019 (spring and autumn) and in 2022 (spring and summer).





Figures 5.1.2.1-2: Concentrations of bottlenose dolphins in spring for the periods 2017–2022 and 2016–2022.

The spring distribution data are presented with two maps: only with the data from the described 12 surveys in the period 2017–2022 (Fig. 5.1.2.1) and supplemented with data from surveys in the SACs Ropotamo and Strandzha from the spring of 2016 (Fig. 5.1.2.2).

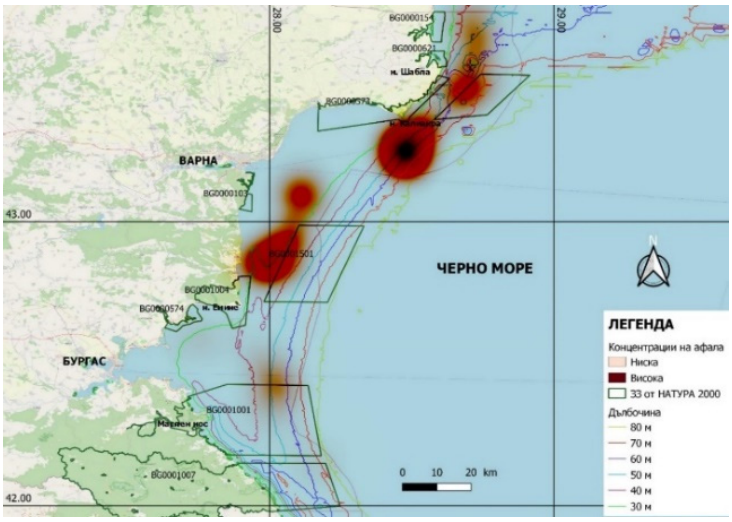
In the period 2017–2022, the most significant concentration of the species is south of Cape Kaliakra at depths of 40 to 60 m outside the scope of the ecological network NATURA 2000. Three secondary concentrations fall within the boundaries of the SAC Emona at depths also of 40 to 60 m, SAC Ropotamo between 50 and 60 m and SAC Strandzha from 60 to 70 m. When supplementing the observations with those recorded in the spring of 2016, the concentration in the northern sector shifts from Cape Kaliakra to the north in front of Cape Shabla at a depth of 60 to 70 m. The one in the SAC Emona becomes the most significant, while the one in the SAC Ropotamo acquires a much lower order. Only the concentration in SAC Strandzha is retained.

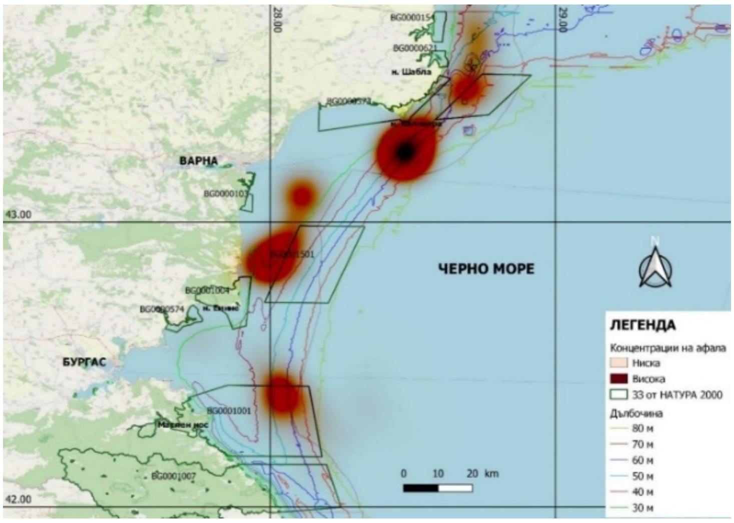
Summer

Surveys in the summer showed little variation in density and a difference was only observed in 2022 when a larger area was also surveyed, but the difference between territorial waters and the shelf total was insignificant.

This is also supported by the statistical analysis (z-test, $p > 0.05$), where no significant differences were reported between density values during the three summer surveys.

Summer is the only season for which comparable data are available from a past vessel survey (July 2013): density 0.696 ind./km^2 (CV = 27.73%) and abundance of 4,861 individuals (Birkun et al., 2014) , which have been adopted as threshold values for the coastal and shelf area in the national monitoring strategy under the MSFD of Descriptor 1.4 Marine mammals. The population density value estimated in this study is higher than those reported in the period 2020–2022 for the same area and is rather an exception to the typical value of this indicator for the summer season in Bulgarian waters. The distribution of bottlenose dolphins in summer shows small differences depending on whether all observations are analyzed or only those in territorial waters. The most significant concentration of the species in summer is south of Cape Kaliakra at water depths of 50 to 70 m. The second most important is the concentration in the central part, between the coast near the town of Byala and the western part of the SAC Emona, at a depth of 30 m and continuing north towards Cape Galata (Fig. 5.1.2.3). The third most important is the concentration of the species between 60 and 70 m opposite Cape Shabla, partially covering the water area of the SAC Complex Kaliakra. The concentration in the northern part of SAC Ropotamo, between 50 and 60 m, is smaller in degree, but it increases in weight when combining all observations in the shelf (Fig. 5.1.2.4).



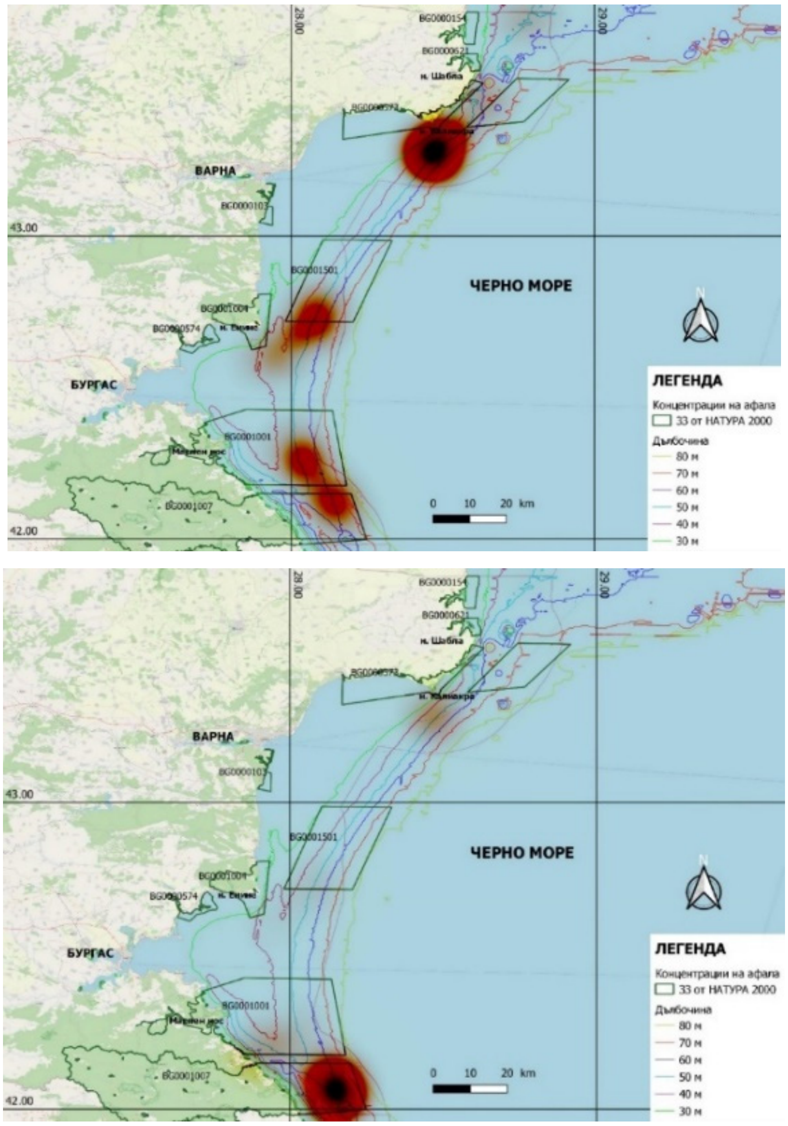


Figures 5.1.2.3-4: Summer concentrations of bottlenose dolphins in Bulgarian territorial waters and shelf in 2020–2022.

Autumn and winter

Cold season surveys conducted between October and February in 2018–2020 show higher densities compared to spring. The highest value was recorded during the winter survey and was almost twice as high as the summer maximum recorded in 2020 and 2021. Population density in autumn was stable and showed no significant changes (z-test, $p > 0.05$). Only between autumn 2018 and winter 2020 the difference is significant (z-test, $p < 0.05$). A survey in the Bulgarian shelf in November-December 2017 estimated density of 0.187 ind./km^2 (CV = 52.13%) in territorial waters and 0.119 ind./km^2 (CV = 45.52%) for the entire shelf (Popov et al., 2023). Another pilot study in the central Bulgarian shelf (2540.13 km^2) between Capes Galata and Emine in November 2015 (Panayotova et al., 2017) estimated density of 0.323 ind./km^2 (CV = 43.46%) – a value close to the estimate for October 2019. In October 2019, a survey adjacent to our study area, covering the western territorial waters of Turkey from the border to Eregli (Paiu et al., 2021b), estimated a population density of 0.593 ind./km^2 (CV = 41.2%), which is almost twice as high as compared to Bulgarian waters at the same time. Areas of concentrations of the species in autumn differ significantly depending on the period considered. When analyzing the data for the period 2017–

2022, the largest concentration of the species is south of Cape Kaliakra at a water depth of 40 to 60 m, coinciding with the one identified for the summer season. The remaining more significant concentrations of the species fall in the southern part of the SAC Emona at a depth of 40–60 m, in the SAC Ropotamo from 50 to 60 m and in the SAC Strandzha at a depth of 60–70 m (Fig. 5.1.2.5). When supplementing autumn data with those from a pilot training survey in November 2015, the most significant concentration of the species shifts to SAC Strandzha at a depth of 60 to 70 m, while the concentration under Cape Kaliakra becomes secondary along with that in SAC Ropotamo at a depth of 40–50 m (Fig. 5.1.2.6).



Figures 5.1.2.5-6: Concentrations of bottlenose dolphins in autumn for the periods 2017–2022 and 2015–2022.

The results for the winter season have minimal difference, depending on whether they cover only the observations from the 2020/2021 survey or are supplemented with those from February 2016. Logically, the increased effort in the south increases the weight of the identified concentration in the SAC Ropotamo of 40 up to 50 m deep (Fig. 5.1.2.7).

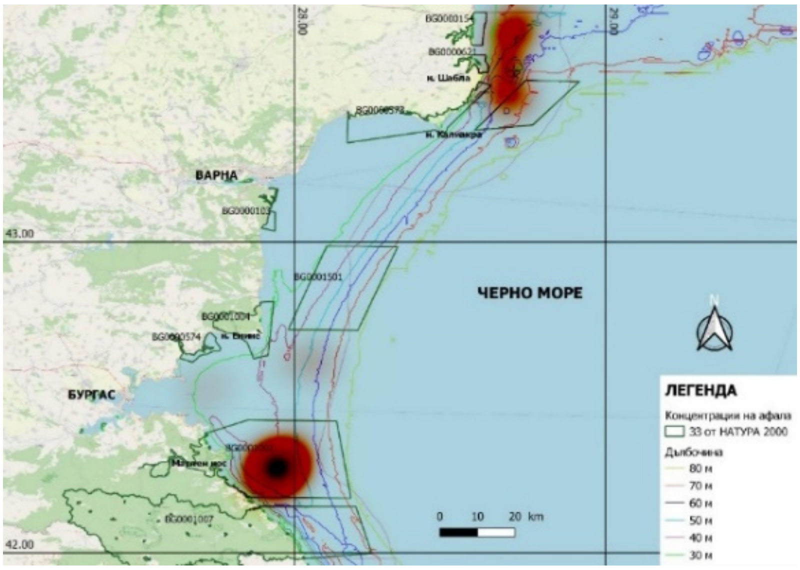


Figure 5.1.2.7: Concentrations of bottlenose dolphins in winter for the period 2016–2022

Spring is the season with the lowest recorded densities and, accordingly, abundance of bottlenose dolphins in Bulgarian territorial waters, and in summer the tendency is towards an increase.

Table 5.1.2.1: Sumamrized results for abundance and density of Black Sea bottlenose dolphin in Bulgarian territorial waters for the period 2017–2022.

Parameters	**Spring 2017**	**Spring 2018**	**Autumn 2018**	**Spring 2019**	**Autumn 2019**	**Spring 2020**
Effort, km (L)	421	419.8	424.2	444.4	409.4	425.1
Sightings (n)	27	7	19	16	18	8
Encounter rate (n/L)	0.035	0.002	0.004	0.04	0.04	0.019
Density (D, ind./km^2)	**0.211**	**0.094**	**0.297**	**0.224**	**0.696**	**0.096**
95% confidence interval (CI)	0.076 – 0.587	0.029 – 0.301	0.116 – 0.762	0.088 – 0.573	0.259 – 1.875	0.033 – 0.275
Coefficient of variation (CV), %	52.15	59.29	48.34	46.57	50.5	53.71
Abundance (N)	**1340**	**598**	**1 887**	**1 427**	**4 427**	**609**
95% confidence interval (CI)	481 – 3 735	187 – 1 913	734 – 4 847	558 – 3 646	1 644 – 11 923	212 – 1 746
Coefficient of variation (CV), %	52.15	59.29	48.34	46.57	50.5	53.71
Parameters	**Summer 2020**	**Winter 2020**	**Spring 2021**	**Summer 2021**	**Spring 2022**	**Summer 2022**
Effort, km (L)	423	374	430.9	438.2	426.7	331.75
Sightings (n)	27	34	8	17	23	12
Encounter rate (n/L)	0.064	0.091	0.019	0.107	0.054	0.036
Density (D, ind./km^2)	**0.542**	**1.048**	**0.151**	**0.541**	**0.607**	**0.263**
95% confidence interval (CI)	0.265 – 1.108	0.481 – 2.285	0.065 – 0.353	0.249 – 1.175	0.311 – 1.184	0.123 – 0.562
Coefficient of variation (CV), %	35.22	39.73	42.81	39.54	33.03	38.01
Abundance (N)	**3 447**	**6 663**	**960**	**3 439**	**3 856**	**1 670**
95% confidence interval (CI)	1 686 – 7 046	3 056 – 14 527	411 – 2 242	1 583 – 7 469	1 975 – 7 530	781 – 3 573
Coefficient of variation (CV), %	35.22	39.73	42.81	39.54	33.03	38.01

This trend also persists during the autumn-winter period, coinciding with the traditional migration of some fish species like blufish, mullet, bonito and horse mackerel.

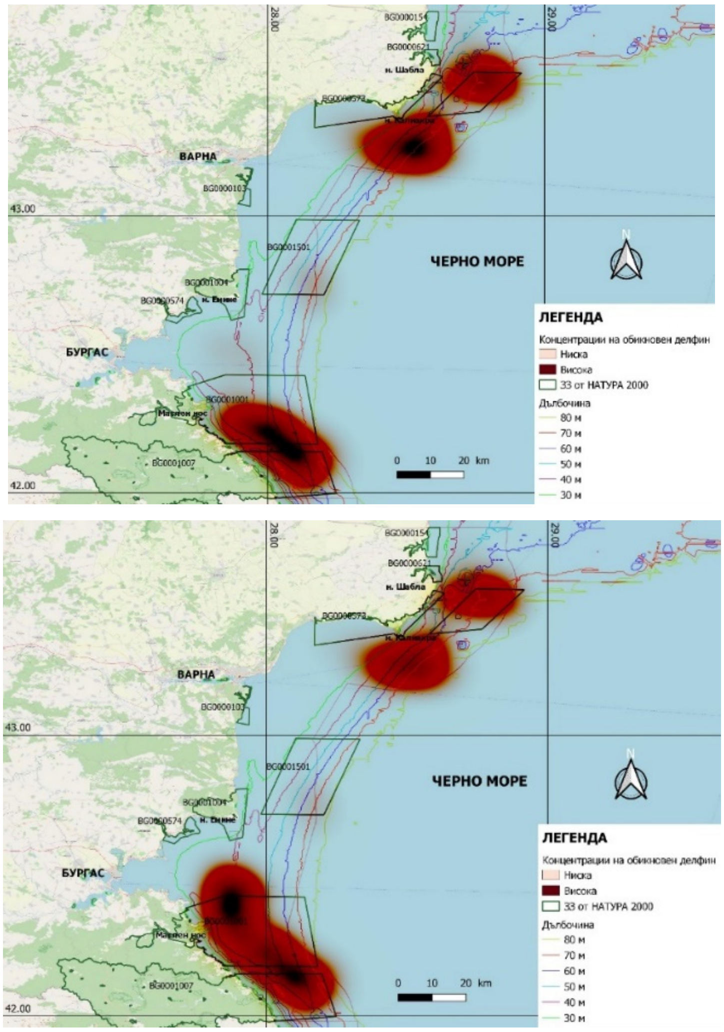
Bottlenose dolphin concentrations generally coincide with existing NATURA 2000 SACs designated for the species' conservation, the area south of Cape Kaliakra, where concentrations were recorded in all seasons.

As with the porpoise, there is little gap observed in the boundaries of the SAC Kaliakra Complex, which only partially covers the important area at 50 to 70 m depth opposite Cape Shabla. Summarized results for the abundance and density of the Black Sea bottlenosed dolphin for the studied period are presented in Table. 5.1.2.1.

5.1.3. ABUNDANCE, DENSITY AND DISTRIBUTION OF BLACK SEA COMMON DOLPHIN (*Delphinus delphis ponticus*)

Spring

Spring surveys show a large variation in density ranging from 0.1 (Spring 2018) to 0.761 ind./km^2 (June 2021). Unlike the other two species, the peak is in May 2021, and in the remaining surveys it is the second most frequently observed of the three.



Figures 5.1.3.1-2: Black Sea common dolphin concentrations in Bulgarian territorial waters for the periods 2017–2022 and 2016–2022.

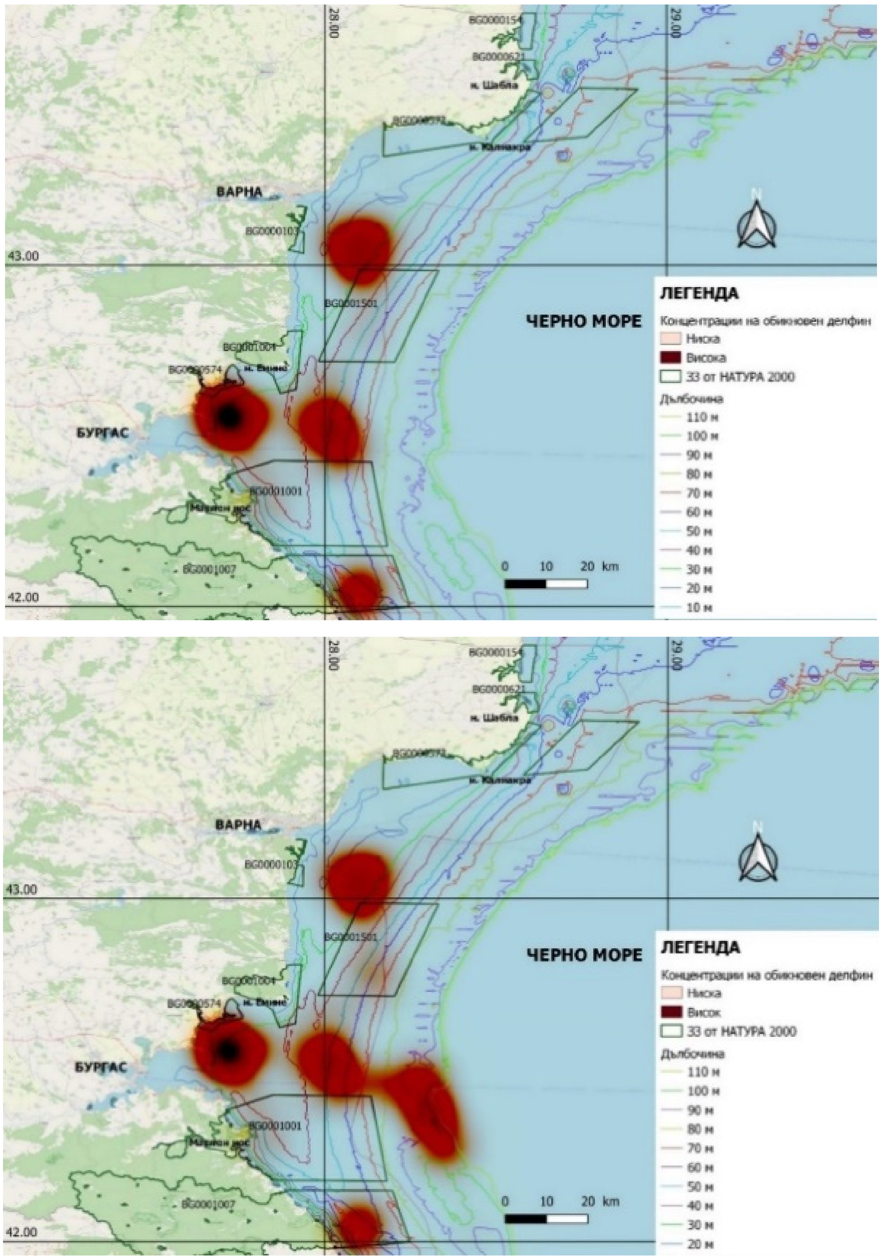
The statistical analysis shows a large variation between the individual years: in 53% of the possible combinations and comparisons the differences are significant.

Comparing changes in population density between spring and other seasons within a calendar year, the only significant difference is in 2022 (spring and summer). The spring distribution data are presented with two maps: only with the data from the described 12 surveys in the period 2017–2022 (Fig. 5.1.3.1) and supplemented with data from surveys in the SACs Ropotamo and Strandzha from the spring of 2016 (Fig. 5.1.3.2). In the period 2017–2022, the largest in terms of area and weight is the concentration overlapping the southern part of SAC Ropotamo and the northern part of SAC Strandzha at depths of 40 to 60 m, followed by a second one, south of Cape Kaliakra, at depths of 60 to 80 m and a third opposite Cape Shabla at the same depths. When supplementing the observations with the data from the spring of 2016, the weight and size of the concentration in southern waters increased, extending to the northern part of the SAC Ropotamo and depth of 40 m. The two concentrations in the northern sector are retained, but the weight of the one south of Cape Kaliakra is relatively reduced.

Summer

Summer surveys showed a difference only in 2022, when the difference in density between territorial waters and the entire shelf was almost four times, indicating the greater importance of deep water for the species. There were no significant differences (z-test, $p > 0.05$) between years.

Summer is the only season for which comparable data are available from a past vessel survey (July 2013): density 0.718 ind./km^2 (CV = 34.59%) and abundance of 5,019 individuals (Birkun et al., 2014) which have been adopted in the national monitoring strategy under the MSFD of descriptor 1.4 Marine mammals. The population density estimated in that study is significantly higher than those reported in the period 2020–2022 for the same area and is rather an exception to the typical summer season in Bulgarian waters. The summer distribution of the common dolphin showed no differences when all observations were analyzed and when only those in territorial waters were analyzed. The most significant concentration in the summer is located near Pomorie and Burgas Bay at a depth of 30 m. The remaining three concentrations are of equal weight and are all located south of Varna: southeast of Cape Galata (20 to 40 m), east of the most significant (40 to 70 m) and in southernmost Bulgarian waters (60 to 70 m at SAC Strandzha (Fig. 5.1.3.3). Adding the observations in the shelf area from the summer of 2022 leads to the expansion of the central secondary concentration in the southeastern direction, to depths of 90–100 m (Fig. 5.1.3.4).

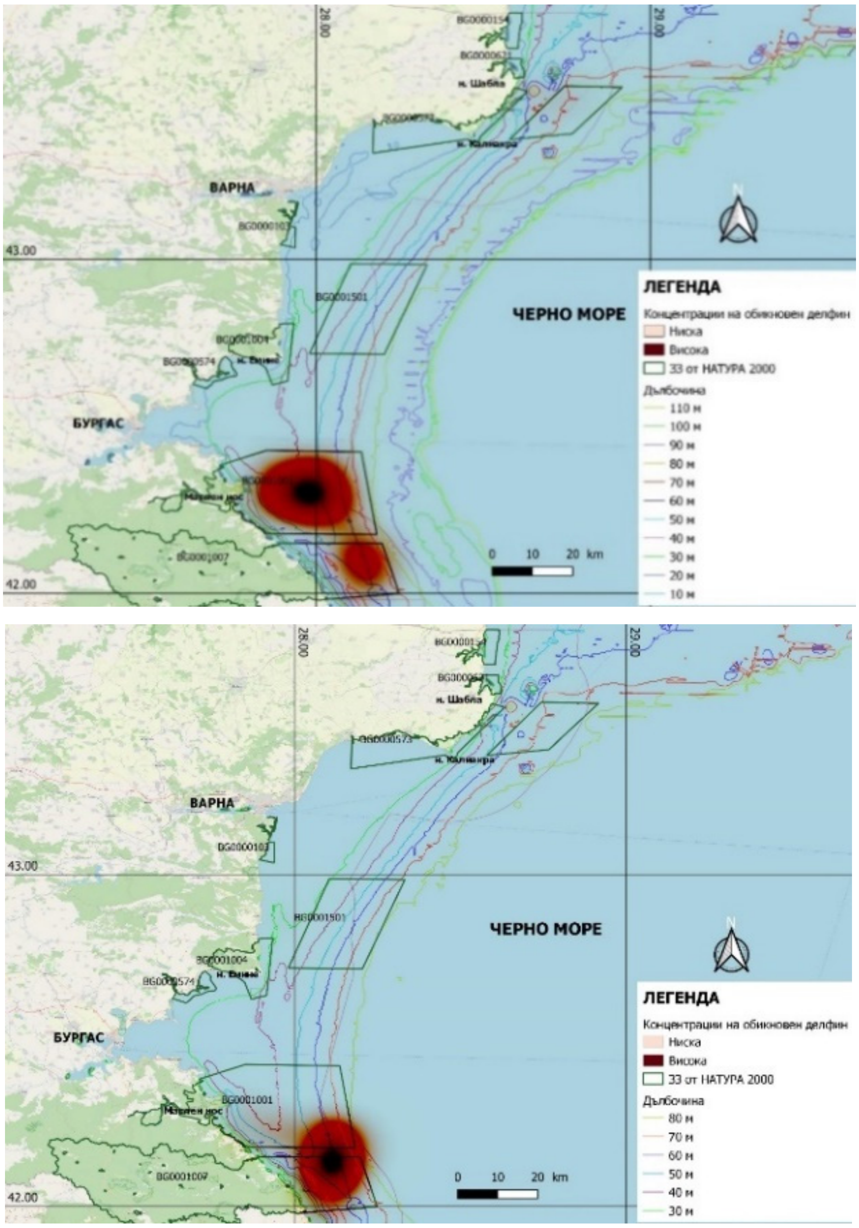


Figures 5.1.3.3-4: Black Sea common dolphin summer concentrations in Bulgarian territorial waters and shelf in 2020–2022.

Autumn and winter

Cold season surveys conducted between October and February in 2018–2020 show higher densities compared to spring and summer, excluding the peak in May 2021.

The two surveys in October show almost identical values, while winter has some decrease, but without statistical significance (z-test, $p > 0.05$). A survey in the Bulgarian shelf in November-December 2017 estimated density to be 0.138 ind./km^2 (CV = 48.59%) in territorial waters and 0.088 ind./km^2 (CV = 42.13%) for the entire shelf (Popov et al., 2023), while during a pilot study in the central Bulgarian shelf in November 2015 (Panayotova et al., 2017) the species was not observed at all. These results differ significantly from the observations in the present study. In October 2019, a survey in a neighboring study area covering the western territorial waters of Turkey from the border to Eregli (Paiu et al., 2021b) estimated the population density at 0.763 ind./km^2 (CV = 43.4%), which is about 50% higher compared to Bulgarian waters at the same time.



Figures 5.1.3.5-6: Black Sea common dolphin concentrations in autumn in 2017–2022 and winter of 2020/21.

The concentrations of the species in autumn are located in the southern waters: the largest is that in the SAC Ropotamo at depths of 40 to 50 m, followed by the second one in the SAC Strandzha at a depth of 60–70 m (Fig. 5.1.3.5), which increases its weight in winter (Fig. 5.1.3.6).

Summarized results for the abundance and density of the Black Sea bottlenosed dolphin for the studied period are presented in table 6.1.3.1.

Table 5.1.3.1: Sumamrized results for abundance and density of Black Sea common dolphin in Bulgarian territorial waters for the period 2017–2022.

Parameters	Spring 2017	Spring 2018	Autumn 2018	Spring 2019	Autumn 2019	Spring 2020
Effort, km (L)	421	419.8	424.2	444.4	409.4	425.1
Sightings (n)	39	7	29	15	22	9
Encounter rate (n/L)	0.093	0.02	0.07	0.034	0.054	0.021
Density (D, ind./km²)	**0.391**	**0.1**	**0.56**	**0.41**	**0.574**	**0.124**
95% confidence interval (CI)	0.187 – 0.814	0.039 – 0.26	0.192 – 1.62	0.193 – 0.882	0.233 – 1.416	0.05 – 0.308
Coefficient of variation (CV), %	36.84	48.19	55.9	37.67	45.81	45.02
Abundance (N)	**2 484**	**638**	**3 547**	**2 626**	**3 650**	**791**
95% confidence interval (CI)	1 192 – 5 177	146 – 1 656	1 220 – 10 310	1 229 – 5 608	1 480 – 9 002	319 – 1 961
Coefficient of variation (CV), %	36.84	48.19	55.9	37.67	45.81	45.02
Parameters	**Summer 2020**	**Winter 2020**	**Spring 2021**	**Summer 2021**	**Spring 2022**	**Summer 2022**
Effort, km (L)	423	374	430.9	438.2	426.7	331.75
Sightings (n)	11	12	25	7	28	5
Encounter rate (n/L)	0.026	0.032	0.058	0.016	0.066	0.015
Density (D, ind./km²)	**0.226**	**0.306**	**0.761**	**0.26**	**0.435**	**0.107**
95% confidence interval (CI)	0.099 – 0.511	0.087 – 1.072	0.318 – 1.819	0.097 – 0.699	0.228 – 0.832	0.02 – 0.479
Coefficient of variation (CV), %	40.83	64.49	45.06	50.23	31.9	79.7
Abundance (N)	**1 436**	**1 946**	**4 838**	**1 654**	**2 769**	**682**
95% confidence interval (CI)	634 – 3 252	556 – 6 814	2 023 – 11 569	616 – 4 444	1 450 – 5 288	1 170 – 6 441
Coefficient of variation (CV), %	40.83	64.49	45.06	50.23	31.903	79.7

5.2. PHOTO-IDENTIFICATION OF DOLPHINS

5.2.1. PHOTO-IDENTIFICATION OF BLACK SEA BOTTLENOSE DOLPHINS (*Tursiops truncatus ponticus*)

Within the framework of the study, a total of 35 photo-sessions of bottlenose dolphins were made in the period 2012–2022. The catalog includes 491 photos of 83 individuals. Out of all 83 individuals included in the catalogue, only 4 individuals (4.8%) were recorded as recaptures. Individuals TT_BGBS_0007 and TT_BGBS_0008 were observed and added to the catalog on February 9th 2016 as part of a group of about 20 dolphins feeding around fishing trawlers in the waters of SAC Ropotamo BG0001001. The two individuals were observed again together after 3 years, 9 months and 10 days on November 19th, 2019 again feeding near fishing trawlers, but in the waters of the SAC Kaliakra Complex BG0000573, 146 km from the first sighting (Fig. 5.2.1.1).

Individuals TT_BGBS_0025 and TT_BGBS_0026 were observed on 18th and 19th October 2018 in the immediate vicinity of Cape Kaliakra (SAC Kaliakra Complex BG0000573). Possible hypotheses for the low rate of bottlenose dolphin recaptures are relatively low effort and a large population size, but the latter has a low level of confidence. The presence of resident groups of bottlenose dolphins in the Black Sea have been partially confirmed in its northeastern part: the waters around the Crimean peninsula (Gladilina & Gol'din, 2016) and the Russian coast between Sochi and Gelendzhik (Shpak et al., 2006). For the western part of the Black Sea, there are no reports of resident groups, which is also confirmed by our results.

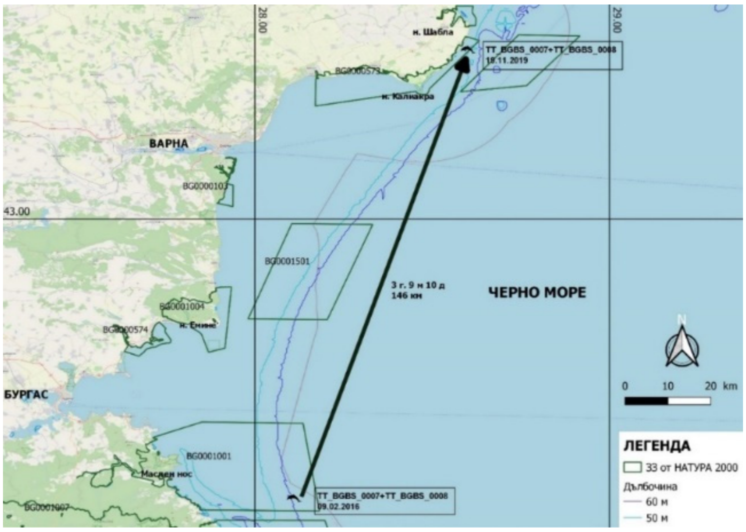


Figure 5.2.1.1: Map of observations of TT_BGBS_0007 and TT_BGBS_0008.

6.2.2. PHOTO-IDENTIFICATION OF BLACK SEA COMMON DOLPHINS (*Delphinus delphis ponticus*)

Within the study, a total of 17 common dolphin photo-sessions were conducted in the period 2012–2022. The catalog includes 147 photos of 41 individuals. 58% (24) of individuals in the catalog were captured during observations from a fishing vessel during trawl haul. Only for two dolphins recaptures were recorded, but they are within the same day for a period of 2 to 4 hours: DD_BGBS_0007 was observed and photographed on 16th December 2019 in the waters of SAC Strandzha. The first capture was at 8:38 a.m. and the second was two hours later at 10:31 a.m. during the second fishing operation of the day. DD_BGBS_0037 was observed and photographed on December 5th, 2021 in the waters of SAC Ropotamo. The first capture was at 12:00 p.m., and the second was four hours later at 4:11 p.m.

5.3. BYCATCH OF CETACEANS

5.3.1. ASSESSMENT OF BYCATCH LEVEL

Data were collected for a total of 85 fishing operations from 8 fishing vessels holding a turbot fishing quota in the period 2019–2022. In 56 (66%) of the fishing operations, the data was collected by an independent observer, and for the remaining 29 (34%) data was reported by fishermen with whom a prior agreement had been reached to collect information. The relative proportion of operations in which no bycatch was recorded was similar in both cases (34% for those with an observer and 44% for those reported by fishermen). Bycatch of cetaceans was recorded in a total of 53 operations (62% of all). The number of animals captured varies from 1 to 41 per operation. The distribution of bycatch by species, seasons and years, as well as in relation to the effort and length of the nets, is shown in Table. 5.3.1.1.

Table 5.3.1.1: *Registered* bycatch by species, season and year.

Year	Season	Nets, km	Effort (km²*days)	Pp	Tt	Dd	To-tal
2019	Spring	50.28	3.32	5	1		**6**
	Summer	51.65	3.35	99			**99**
2020	Spring	82.76	4.38	6	1	2	**9**
	Summer	71.8	2.51	37		1	**38**
2021	Spring	41.12	1.69	8	2		**10**
	Summer	50.2	2.11	21			**21**
2022	Spring	77.02	2.99	42	8		**50**
	Summer	52.1	1.97	17			**17**
TOTAL		**476.93**	**22.32**	**235**	**12**	**3**	**250**

Average levels of standardized seasonal bycatch over the years show opposite trends. The average value for the period 2019–2022 of 0.52 ind./km is higher than the reported 0.24 in the period 2010/11 (Mihaylov, 2011) and 0.31 for the period 2014–2018 (Zaharieva, 2020). Statistical analysis (non-parametric Kruskal-Wallis test) shows that there is a significant difference in bycatch levels between different years ($H = 9.441$, $p < 0.05$). There is no significant difference between spring and summer (Mann-Whitney U-test: $U = 755$, $p > 0.05$) within the entire four-year period from 2019 to 2022, but for the period 2019 to 2021, it is significant ($U = 266.5$, $p < 0.05$). A main reason for this result can be found in the extremely high level of bycatch observed in the spring of 2022. A moderate correlation ($R = 0.41$) was found only between the number of individuals caught per fishing operation and the length of the set of nets.

Assessment of the total annual level of bycatch in Bulgarian waters

As of 2017, gillnets with a total length of approximately 900 km were registered in EAFA (Zaharieva, 2020).

Table 5.3.1.2: Estimates of annual porpoise bycatch levels.

	2019	2020	2021	2022
Vessels*	116	124	126	126
Median dishing operations	2	5.5	6	3
Median bycatch	1	1	0.5	2
Total bycatch by median	232	682	378	756
Share of population	**2.08%**	**10.82%**	**11.65%**	**5.02%**
Total bycatch based on ind./km	1815	529	552	784
Share of population	**16.29%**	**10.82%**	**16.99%**	**5.21%**
Total bycatch by formulae of Northridge&Fortuna (2008)	2515±1176	1376±525	1246±476	1295±230
CV	46.75%	38.14%	38.18%	17.77%
Share of population	**22.58%**	**28.14%**	**38.39%**	**8.61%**

**Source: EAFA*

Regardless of which approach is adopted, the results clearly show that even the most conservative estimate of the bycatch level of the porpoise exceeds the accepted sustainable levels of 1 to 1.7% of the population abundance estimate and the urgent implementation of measures to protect the species is necessary.

5.3.2. TESTING PINGERS AS MITIGATION MEASURE

Results of conducted tests of different models of pingers are summarized in table 5.3.2.1

Table 5.3.2.1: Results of tested different models of pingers

Model	No	Years	No of fisher-men, бр.	Decrease in bycatch, %	Significance, U-тест
FO 10kHz	150	2019–2022	8	37.9	p > 0.05
FO 70 kHz	50	2019–2022	4	8.64	p > 0.05
PAL	40–80	2020–2021	1	85.93	p < 0.05

Of the three pinger models tested, only the PAL 10 kHz model showed a positive effect with a statistically significant reduction in bycatch of 86%. The results of the tests of the FO 10 kHz model in the present study are in coplete contrast to those reported from an earlier experiment in Bulgarian waters (Zaharieva, 2020), which reported a 100% reduction in bycatch in active nets. Possible reasons may be related to the length of the sets of nets (longer in our case) as well as the season, which for us covers spring and summer, and not only spring.

5.4. PASSIVE ACOUSTIC STUDY BY STATIONARY DETECTORS

The total duration of data collected from the four stations in the period from October 1 to February 3, 2023 is 66,847 hours.

1. Porpoises

Sozopol is the station with the rarest presence of the species for the entire study period, which is also significant when compared to the other stations (U-test, $p<0.05$). Seasonal dynamics for all stations except Kavarna show an increase in presence in spring with small differences in peak values at Balchik, where they are slightly later. A secondary increase is observed in autumn at Ravda and Balchik, while at Sozopol it is in winter. At Kavarna, two seasons with a high frequency of presence are observed – autumn and secondarily in spring.

2. Dolphins

The presence of dolphins in coastal waters was significantly lower than that of porpoises, which coincided with the results of visual distance sampling surveys. Ravda is the station with the most frequent presence of dolphins in spring. Seasonal dynamics for the southern stations are similar and show highest values in spring and autumn. In the northern sector, the highest frequency of presence was recorded in May 2022. Comparing the frequency of presence between individual stations (U-test, $p < 0.05$) showed significant differences between northern and southern stations.

6. CONCLUSIONS

1. The application of the line transect distance sampling method from a vessel is suitable for studying the abundance, density and distribution of cetaceans in the Bulgarian territorial waters of the Black Sea.
2. The abundance of porpoises in the Bulgarian territorial waters shows seasonal dynamics as follows: it is highest in spring with a tendency to decrease in summer, as a result of withdrawal to the offshore zone, and it is lowest in the cold seasons – autumn and winter
3. The abundance of bottlenose dolphing in Bulgarian territorial waters is lowest in spring with a tendency to increase in summer and highest values in autumn and winter.
4. The abundance of common dolphins in Bulgarian territorial waters shows large fluctuations in the spring. It is lowest in summer and highest in autumn.
5. The existing ecological network of SACs from NATURA 2000 in Bulgarian territorial waters covers the areas of importance for the porpoise and the bottlenose dolphin. Outside the scope of the ecological network remains an area of importance for the bottlenose dolphin, located south of Cape Kaliakra, at depths of 40 to 70 m, in which concentrations of the species have been found in spring, summer and autumn. Extending the boundaries of the SAC Kaliakra Complex BG0000573 to cover this area is an adequate measure to improve the conservation of this species.
6. The results of this six-year study of abundance, density and distribution of cetaceans in the Bulgarian territorial waters provides a scientifically sound basis for updating the currently accepted threshold values for the abundance and density of cetaceans according to criteria D1C2 and D1C4 from the Monitoring Program under Descriptor 1 – Biodiversity (marine mammals) under the MSFD.
7. The photo-identification method shows a significant range size for the bottlenose dolphin.
8. The assessment of the annual level of harbor porpoise bycatch in turbot fishing with anchored bottom gill nets in Bulgarian waters confirms the conclusions at the basin level that it is significantly exceeding even the highest allowable levels of removal of individuals from the population.
9. Of the three models of acoustic deterrent devices (pingers) tested, only one (PAL) showed a significant reduction in bycatch rates of porpoises in bottom set gill nets for turbot.
10. Passive acoustic monitoring is a suitable method for collecting information over a continuous period of time, albeit witin a limited range.

7. RECOMMENDATIONS

1. In order to protect the optimal habitat of the bottlenose dolphin in the Bulgarian territorial waters of the Black Sea, we propose to expand the

boundaries of the SAC Kaliakra Complex BG0000573 in the area south of Cape Kaliakra at depths of 40 to 70 m.

2. It is necessary to further investigate the established significant concentrations of porpoises in summer in the shelf waters, east of the SAC Ropotamo BG0001001.
3. Update of the threshold values of indicator number (N) according to criterion D1C2 and of indicator density (D) according to D1C4 from the Monitoring Program under Descriptor 1 – Biodiversity (marine mammals) according to MSFD as follows:

Species	spring		summer	
	D1C2 (ind.)	D1C4 (ind./km^2)	D1C2 (ind.)	D1C4 (ind./km^2)
Harbour porpoise	9 045	1.423	2 745	0.432
Bottlenose dolphin	1 427	0.224	3 439	0.541
Common dolphin	2 484	0.391	1 654	0.26

4. It is recommended to the Ministry of Defense that the traditional military exercises in the waters of the Shabla training ground should not be held at the beginning of June, but should be moved to the months of July or August, when the density of porpoises in the area significantly lower.
5. In order to reduce porpoise bycatch when fishing for turbot with bottom gill nets, the use of PAL pingers is recommended.
6. Increasing the scope of the passive acoustic survey through stationary FPOD detectors in all SACs of NATURA 2000 in order to provide continuous data on the presence of cetaceans in them. An important condition for the implementation of this recommendation is ensuring security for the devices .

8. CONTRIBUTIONS OF THE DISSERTATION

Contributions of an original scientific nature:

1. An up-to-date estimation of the abundance of the three cetacean species – porpoise, bottlenose dolphin and common dolphin – was made using line transect distance sampling method in Bulgarian territorial waters for the period 2017–2022.
2. The results of a long-term study of the abundance, density and distribution of cetaceans in Bulgarian territorial waters are summarized and analyzed.
3. Zones with concentrations of the three cetacean species in Bulgarian territorial waters during all four seasons have been identified.
4. For the first time, a long-term study (over 5 years) of the abundance, density and distribution of cetaceans was conducted in a certain area of the Black Sea.

5. For the first time in Bulgaria, the frequency of presence of cetaceans in the coastal waters of the Black Sea was studied using a passive acoustic method for a period of more than 20 months.

Contributions of an original scientific and applied nature:

1. For the first time, an assessment was made of the annual bycatch level of porpoise during turbot fishing in the Bulgarian waters of the Black Sea.
2. The only photo-identification catalog of dolphins in the Bulgarian waters of the Black Sea was created and maintained.
3. Three models of acoustic deterrent devices were tested and, based on the results, a recommendation was made to the competent authorities – EAFA and MOEW – to apply the PAL model as effective in reducing the level of porpoise bycatch in turbot fishing with bottom set gill nets.

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11. CITATION IN SCIENTIFIC PAPERS INDEXED IN GLOBAL DATA BASES

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