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Individual movements between local coastal populations of bottlenose dolphins (*Tursiops truncatus*) in the northern and eastern Black Sea

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*The Black Sea subspecies of the bottlenose dolphin (*Tursiops truncatus ponticus*) is threatened and has a small range. Its population structure is little known: it possibly includes a few local coastal populations. We assessed connectivity between coastal groupings in six localities along 800 km of the coastline based on records of photo-identified animals between 2004 and 2014. Abundance of these groupings, as estimated, ranged between 76 and 174 individually distinctive dolphins. In total, there were 350 identified individuals, of which 91 (26%) were resighted within the same areas. However, only three cases of individual movements between local coastal populations were recorded at the distances between 135 and 325 km. Therefore, despite the absence of physical barriers, the coastal Black Sea population is fragmented into numerous resident or locally migrating groupings with site fidelity. These local populations are loosely connected to each other with rare movements between them. This fragmentation can be a factor contributing to short-term fluctuations in abundance of Black Sea bottlenose dolphins and their decline in some localities, despite the potentially high population growth rate.*

Keywords: bottlenose dolphin, population structure, mark-recapture study, connectivity, fragmented range

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INTRODUCTION

Common bottlenose dolphins (*Tursiops truncatus*) are widely distributed in temperate, subtropical and tropical waters and are known for their diverse and variable population structure, social organization and ecological strategies providing a robust basis for the species survival (Wells & Scott, 1999). However, there are populations of bottlenose dolphins which are considered to be threatened. One of them is located in the Black Sea, where a morphologically and genetically distinct subspecies was identified, *Tursiops truncatus ponticus* Barabash-Nikiforov, 1940 (Viaud-Martinez *et al.*, 2008). The population structure of the Black Sea bottlenose dolphins is little known; it possibly includes offshore and inshore (or coastal) populations (Bushuev, 2002; Mikhalev, 2005; Gol'din & Gladilina, 2015), and among the latter there can be resident groups (Shpak *et al.*, 2006; Gladilina, 2012; Gladilina & Gol'din, 2016), but their number, size, structure, relations and the extent of exchange are virtually unknown; an exception is a local population near Sudak which abundance was recently estimated (Gladilina & Gol'din, 2016).

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Here we assess contacts between local coastal populations of Black Sea bottlenose dolphins in six localities along 800 km of the coastline, based on records of photo-identified animals, and discuss the role of isolation of local populations in their stability and vulnerability.

MATERIALS AND METHODS

Study areas

The research was conducted in coastal waters of the northern and eastern Black Sea less than 200 m deep between Fiolent Cape (44°29′N 33°29′E) and Imereti Bay (43°22′N 39°57′E), in six local study areas:

(1) Balaklava, waters between Fiolent Cape and Aya Cape (between 44°29′N 33°29′E and 44°25′N 33°39′E).
(2) Sudak, waters between Choban-Kule Cape and Meganom Cape (between 44°48′N 34°44′E and 44°47′N 35°02′E).
(3) Opuk, waters between Chauda Cape and Opuk Cape (between 44°59′N 35°53′E and 44°59′N 36°12′E).
(4) Taman Gulf and adjoining area of the eastern Kerch Strait (between 45°12′N 36°35′E and 45°17′N 36°58′E).
(5) Gelendzhik Bay and adjoining area (between 44°35′N 37°56′E and 44°28′N 38°07′E).

(6) Sochi, waters between the Sochi River estuary and Imereti Bay (between 43°34′N 39°42′E and 43°22′N 39°57′E) (Figure 1).

The maximum along-shore distance between the two most distant areas was 800 km.

Boat surveys (N = 17) and occasional coastal-based observations in Balaklava were conducted in 2012–2014, in an area of 56 km²; the surveys were conducted less than 1 km from the coastline. In Sudak, the surveys were conducted in 2009 and 2011–2014 (N = 27), in an area of 208 km², less than 10 km from the coastline. The surveys near the Opuk Cape were conducted in 2009 (N = 8), in an area of 65 km², 6–15 km from the coastline. The surveys in the Taman Gulf were conducted in 2004 and 2005 (N = 7), in an area of 262 km², surveys covered the whole gulf. The surveys in Gelendzhik were conducted in 2004 (N = 2), in an area of 81 km², within 5 km of the coastline. In Sochi, the surveys were conducted in 2004 and 2005 (N = 23), in an area of 163 km², also within 5 km of the coastline.

Data collection

Data for this study were collected in coastal waters of the northern and eastern Black Sea by three teams: in the areas near Taman Peninsula, Gelendzhik and Sochi in 2004–2005 (team 1), near the Opuk Cape and Sudak in 2009 (team 2) and near Sudak and Balaklava in 2011–2014 (team 3) (Figure 1). In 2009 the research was conducted on board a sprat trawling vessel, whereas the other studies were based on small motor boats or, sometimes, coastal-based platforms.

Spatial distribution, site fidelity and connectivity between localities of bottlenose dolphins were assessed using the method of photo-identification (Würsig & Würsig, 1977). Boat surveys were conducted under daylight conditions, at a Beaufort sea state less than 4, no precipitation and visibility of at least 1 km. Observations were conducted using 7, 8 or 10 × binoculars. Images for photo-identification were obtained using digital SLR cameras with telephoto lenses. In 2009 the observer recorded the dolphins which approached the trawler during fishing operations. In other surveys, the boat observers approached dolphin groups and took photos. Whenever possible, each dolphin was photographed from the left and right sides, dorsal fin perpendicular to the camera lens, preferably with no backlight (Würsig & Jefferson, 1990).

Data analysis

The total number of recorded individuals, the number of resightings within the same season and the number of resightings between the seasons were separately calculated for each of the six study areas. Only photos scored as good to excellent quality were added to the catalogue and used for analysis; photos of moderate quality were used only for exceptionally distinctive individuals (for example, partially white specimens), whereas all photos of poor quality were discarded. Dorsal fin images were classified in relation to severity of scarring and individual distinctiveness (Würsig & Jefferson, 1990; Wilson *et al.*, 1999; Urian *et al.*, 2015): distinctive fins (with permanent fin features: notches, cuts, deep scars and depigmented areas) and subtly marked fins (with temporary markings: scars, scratches, but without any notches on the edge of the fin), the latter ones further classified on Left and Right sides. Only distinctive and Left side subtly marked individuals were used for calculations. (Only Left or Right side subtly marked fins could be used for calculation in addition to distinctive individuals due to possible mismatching of the same subtly marked individual when matching its Left and Right sides. We chose using Left sides because the sample size of this group was higher: 50 Left *vs* 37 Right.) Total number of identified dolphins, as well as the number of sighted once or resighted individuals, was calculated for distinctive and Left side subtly marked individuals and separately for distinctive individuals (Table 2), whereas abundance estimates were calculated only for distinctive individuals.

The images of resightings were examined by three independent readers for confirmation of individual movements between different study areas. A sighting record was stated as *confirmed* after agreement of all three readers. If two of three readers positively identified the resighting, it was stated as *possible*. Single positive opinions were discarded.

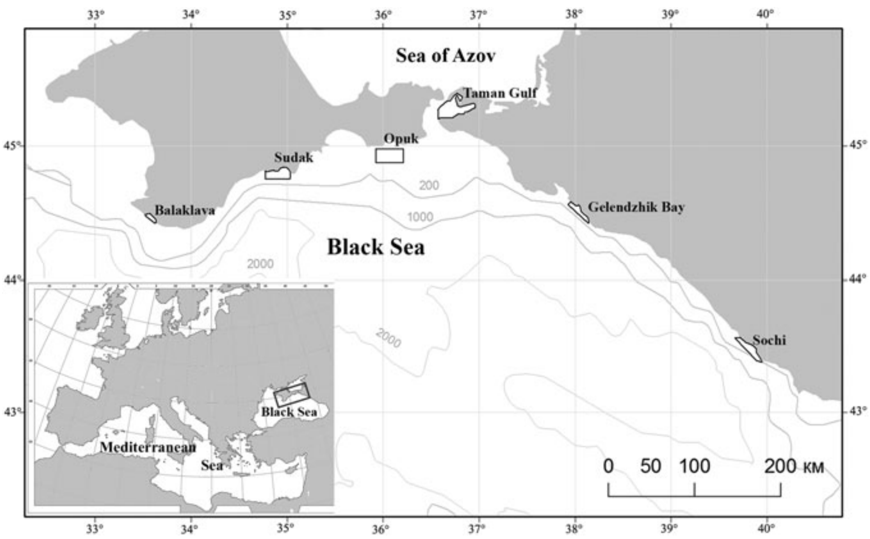

Fig. 1. Areas of research of bottlenose dolphins in coastal waters of the northern and eastern Black Sea.

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Tentative estimates of abundance within each of the localities were calculated as mark-recapture estimates, based on repetitive photo identifications, between two consecutive years of study in four regions: Balaklava, 2013–2014; Sudak, 2011–2012; Taman Gulf, 2004–2005; and Sochi, 2004–2005; the choice of two consecutive years for Balaklava and Sudak areas was conditioned by the greatest number of sampled animals. All calculations were based on two consecutive years to minimize the influence of birth and mortality rates; and the populations were presumed closed based on frequent resightings within the localities and rare resightings between the localities, as reported here (see also Shpak *et al.*, 2006; Gladilina & Gol'din, 2016). These conditions should be considered as preliminary assumptions, and thus the abundance estimates are only tentative. Only the category of photo-identified 'marked fins' (distinctive individuals) was used in abundance calculations. The mark-recapture estimate ($\hat{N}$) was calculated with the models by Chapman (Chapman, 1951; Caughley, 1977; Wilson *et al.*, 1999; Hammond, 2010):

$$\hat{N} = \frac{(n_1 + 1) \cdot (n_2 + 1)}{m_2 + 1} - 1$$

where n_1 = number of marked individuals which were photo-identified during the first time interval; n_2 = number of marked individuals which were photo-identified during the second time interval; m_2 = number of 'recaptured' marked individuals.

RESULTS

There were 84 surveys between 2004 and 2014 with 184 encounters of 1682 bottlenose dolphins (the cumulative number of animals seen over multiple encounters) (Table 1). The greatest number of encounters were recorded for Balaklava (N = 54, or 29%), Sudak (N = 51, or 28%) and Sochi (N = 34, or 18%). There were 8700 moderate to excellent photographs entered into the database.

Resightings

In total, 350 dolphins were photo-identified within the six study areas, of which 91 (26%) were seen within the same area on two or more occasions; 53 (15%) were resighted only within the same year, and 38 (11%) were resighted in 2 or 3 years. Most of the identified dolphins, 243 of 350 (69%), were distinctive ('marked'). The portion of resighted 'Marked' individuals was non-significantly larger than in the overall sample, 29%; and 14% of marked dolphins were resighted in 2 or 3 years within the same area (Table 2).

Table 1. Summary of boat surveys of bottlenose dolphins in coastal areas of northern and eastern Black Sea.

Area	Size, km²	Study period	No. of surveys	No. of sightings	No. of recorded dolphins
Balaklava	56	2012–2014	17	54	479
Sudak	208	2009–2014	27	51	464
Opuk	65	2009	8	20	NR
Taman	262	2004–2005	7	11	273
Gelendzhik	81	2004	2	5	27
Sochi	163	2004–2005	23	34	439

Table 2. Resightings of bottlenose dolphins across the study areas: data for Marked + Left side subtly marked individuals (and separately for Marked individuals in parentheses).

Area	No. of identified dolphins	Sighted once	Resightings		Total resightings
			Within only the same year	In two or more years	
Balaklava	98 (68)	87 (58)	8 (7)	3 (3)	11 (10)
Sudak	71 (58)	56 (44)	3 (2)	12 (12)	15 (14)
Opuk	18 (12)	14 (11)	4 (1)	0 (0)	4 (1)
Taman	51 (39)	32 (23)	14 (11)	5 (5)	19 (16)
Gelendzhik	9 (9)	9 (9)	0 (0)	0 (0)	0 (0)
Sochi	103 (57)	61 (28)	24 (15)	18 (14)	42 (29)
Total	350 (243)	259 (173)	53 (36)	38 (34)	91 (70)

Movements between the local coastal populations

Among all resightings there were only three records of the same individual in two different study areas (Table 3, Figures 2 and 3). Of them, one record was classified as *confirmed* (T1), and the other two were classified as *possible* (T2, T3).

The dolphin T1, ID 064-12W (Figure 2), had very distinct natural marks, large white spots on various body parts, which allowed it to be identified even on low quality photographs. This animal was recorded on 15 July 2012, near Sudak when approaching a sprat trawling vessel; later it was recorded on 31 July 2012, near the entrance to the Balaklava Bay; and finally, on 3 and 4 August 2012, it was sighted again in Sudak near a trawling vessel in association with other dolphins earlier observed in the same area. The minimum over-water distance between the sighting points of this individual near Sudak and Balaklava was 135 km.

Resightings T2 and T3, although classified as *possible*, are still reported here, as they are notable and potentially important (Figure 3). Both dolphins were first encountered on 29 July 2005, within the same group near Sochi (ID 0167 and 0171). Then they were 'possibly' resighted together near the Opuk Cape, on 30 August 2009 (ID 009-09W and 010–09S). The

Table 3. Movements between local coastal populations of bottlenose dolphins across the study areas.

Dolphin	Sighted first	Distance between sightings, km	Sighted next
T1	15 July 2012, Sudak	135	31 July 2012, Balaklava3 August 2012, Sudak 4 August 2012, Sudak
T2	29 July 2005, Sochi	325	30 August 2009, Opuk Cape
T3	29 July 2005, Sochi	325	30 August 2009, Opuk Cape

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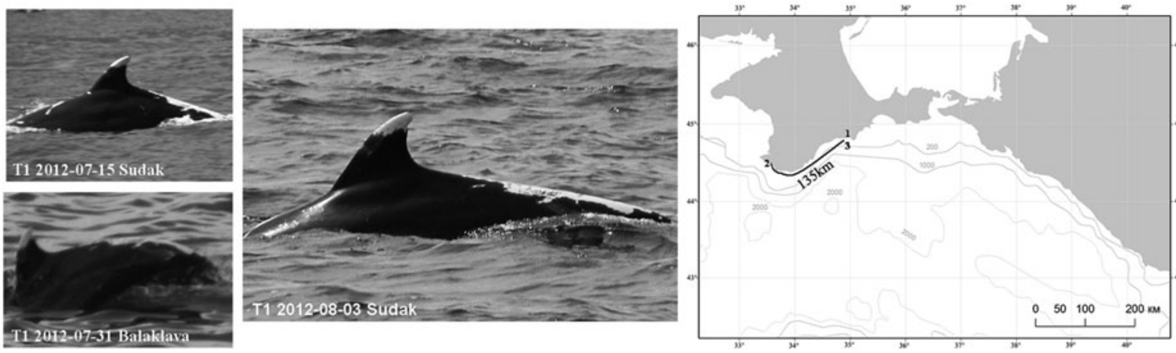

Fig. 2. Lateral view of the dolphin T1 which was recorded near Sudak and Balaklava. The records of the individual observed across the different regions are joined with a line, and the distance between the records are indicated below the line. 1, Balaklava; 2, Sudak; 3, Opuk Cape.

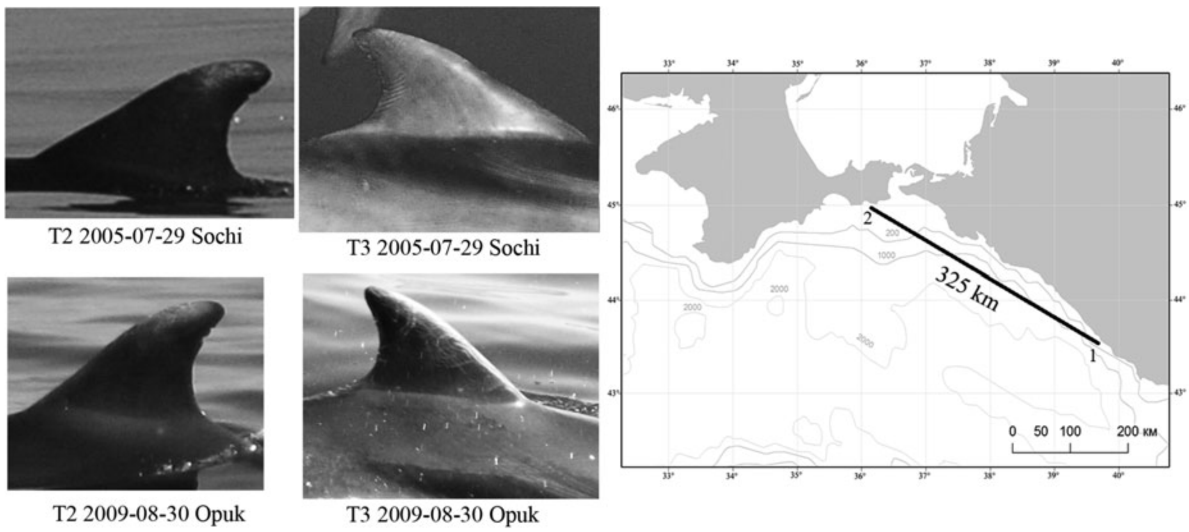

Fig. 3. Dorsal fins of dolphins T2, T3 which were recorded near Sochi and Opuk. The records of individuals observed across the different regions are joined with a line, and the distance between the records are indicated below the line. 1, Balaklava; 3, Opuk Cape.

distance between the points of sightings of these animals near Sochi and Opuk was ~325 km.

Abundance

Abundance estimates for the marked portion of the population were obtained for local populations in four examined localities (Table 4). Resulting estimates varied between 76 ± 9 and 174 ± 76 marked individuals in each stock across the regions. The smallest estimate was calculated for Sochi, and the greatest estimate was obtained for the Taman Gulf (Table 4).

Table 4. Abundance of marked bottlenose dolphins across the study areas.

Area	Abundance = calculated number of 'marked' dolphins, Chapman estimator	±SD	CV
Balaklava	169	64	0.38
Sudak	98	31	0.32
Opuk	n/a	n/a	n/a
Taman	174	76	0.44
Gelendzhik	n/a	n/a	n/a
Sochi	76	9	0.12

DISCUSSION

Bottlenose dolphins are distinct for their division into inshore and offshore populations throughout their worldwide range (Ross, 1977; Duffield *et al.*, 1983; Wells *et al.*, 1987; Mead & Potter, 1995; Natoli *et al.*, 2004; Waring *et al.*, 2014). Among the inshore populations there are resident and migrating stocks (Waring *et al.*, 2014). Resident stocks are local groupings which occupy relatively small areas and are characterized by high site fidelity of individuals and tight social networks. Many of them occupy estuaries, gulfs or narrow straits. Local resident stocks were described from the coastal waters of the Mediterranean Sea (Bearzi *et al.*, 1997, 2011; Gnone *et al.*, 2011), the north-eastern and western Atlantic (Speakman *et al.*, 2006; Robinson *et al.*, 2012; Waring *et al.*, 2014), the Gulf of Mexico (Wells *et al.*, 1987), Hawaii (Baird *et al.*, 2009) and waters of Australia and New Zealand (Möller *et al.*, 2002; Lusseau *et al.*, 2003). There is some degree of exchange with neighbouring stocks,

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sometimes involving long individual migrations (Wood, 1998; Robinson *et al.*, 2012). Another category of coastal populations is migrating stocks with complex group structures and large home ranges (Rosel *et al.*, 2009; Waring *et al.*, 2014). Within these stocks, there are frequent individual movements for more than 100 km or even 1000 km (Defran *et al.*, 1999). For example, in Californian waters the local groupings form a metapopulation in which the inter-stock exchange rate is 43% (Defran *et al.*, 1999; Hwang *et al.*, 2014). However, resident stocks can also be connected within a metapopulation structure, although with higher site fidelity and lesser frequency of inter-stock movements, as in north-western and central Mediterranean areas (Bearzi *et al.*, 2011; Gnone *et al.*, 2011; Carnabuci *et al.*, 2016; Genov *et al.*, 2016), which was also confirmed by genetic studies (Gaspari *et al.*, 2015). Owing to such a structure with a great number of individual transfers within a metapopulation, many coastal stocks of bottlenose dolphins gain a relative sustainability in the long-term, despite their low reproductive rate (Stolen & Barlow, 2003).

Until now, spatial distribution and movements of bottlenose dolphins within the Black Sea have been little known. High summer concentration of dolphins in pelagic waters (Mikhalev, 2005) implies the existence of an offshore population. The morphological data support this hypothesis: there can be co-existing offshore and inshore putative populations in the Black Sea (Gol'din & Gladilina, 2015), as has been demonstrated for Mediterranean waters (Gaspari *et al.*, 2015a). A few local coastal groupings have already been reported from the northern and eastern Black Sea which occur in coastal waters all year round and thus are probably resident local populations (Shpak *et al.*, 2006; Gladilina, 2012; Gladilina *et al.*, 2013; Gladilina & Gol'din, 2016). This study supports the earlier reports. In fact, coastal Black Sea bottlenose dolphins form local groupings of a few hundreds of animals (Table 4), with individual site fidelity within, at least, some of them (Table 2) (see also: Shpak *et al.*, 2006; Gladilina & Gol'din, 2016). There are four to six such localities (depending on the status of groupings near the Opuk Cape and Gelendzhik) only along the coastal area studied here. Notably, there are some other areas along the Caucasian coast (between Taman and Gelendzhik) which are also known for stable occurrence of bottlenose dolphins (Mikhalev, 2005), and another coastal local population was earlier described from the waters of the Tarkhankut Peninsula (north to the Balaklava) (Belkovich, 1978). Therefore, there can be even greater variety of local populations in the region. Each of these groupings can occupy a local area (some of them probably up to several hundred square kilometres) and tends to have loose connections with other coastal groupings: there are only rare individual movements between the localities. As seen from Tables 2 and 3, the number of resightings within the study areas across various time periods is notably greater than the number of movements between the areas. Thus, this structure is the most similar to coastal resident stocks of the Mediterranean semi-enclosed gulfs (such as the Gulf of Amvrakikos), West Atlantic estuaries or Hawaii (Speakman *et al.*, 2006; Bearzi *et al.*, 2008, 2011; Baird *et al.*, 2009). It is strikingly similar to the metapopulation structure of bottlenose dolphins in the north-western Mediterranean waters (Carnabuci *et al.*, 2016), but differs from it in looser connectivity and longer distances between local groupings. However, as opposed to these regions, there is no distinct physical or biotic factor causing isolation of dolphins in the coastal Black Sea. Furthermore, the inter-population movements in the Black Sea seem to be rarer than between semi-enclosed gulfs of the Ionian Sea (Bearzi *et al.*, 2011). Notably, genetic studies (Natoli *et al.*, 2005; Gaspari *et al.*, 2015, 2015a) found that genetic structuring and divergence of Mediterranean populations at a larger geographic scale were also not connected to physical factors, and our study, as well as some other photo-identification research (Genov *et al.*, 2016), supports this idea.

Our results show that there are dolphins travelling long distances along the Black Sea coast, but such cases are rare rather than regular or usual. The T1 dolphin travelled a minimum 135 km west and returned back to the place of its initial sighting (Sudak) within 3 weeks. It can be an example of individual activity of Black Sea bottlenose dolphins. An example of another strategy is 'possible' movement of two dolphins from Sochi to Opuk: therefore, there may be a hypothetical grouping in this area with a wide 300 km range which matches the category of a coastal migrating stock (Waring *et al.*, 2014). Thus, two types of coastal stocks, resident and migrating, may be present in the Black Sea across the studied area, and this hypothesis requires further confirmation.

The population structure with numerous distinct groupings, a fairly usual scenario for bottlenose dolphins, can be one of the factors increasing short-term fluctuations in abundance while also increasing the mid-term stability as persistence: some local populations become extinct and replaced by other emerging or spreading groupings (Holling, 1973; Roff, 1974). Interannual fluctuations of this kind were reported for the Black Sea bottlenose dolphins by earlier studies (Bushuev, 2002; Mikhalev, 2005). In the past, in some years the occurrence of bottlenose dolphins was extremely low: their total abundance in the Black Sea was estimated at 7000 ± 3000 specimens (Sokolov *et al.*, 1990; Yaskin & Yukhov, 1997), and in the waters of Ukraine it has been reported to be as low as 1000 specimens (Shcherbak, 1994), which meant the Black Sea bottlenose dolphins were critically endangered. Such a trend seems most unusual so far as coastal bottlenose dolphins in the Black Sea are distinct for their rapid body growth, which is indirect evidence for a high rate of generation change and rise of population abundance (Gol'din & Gladilina, 2015). However, these fluctuations seem to be logical if the metapopulation is fragmented into small portions. In this case an adverse impact can lead to the extinction of some local groupings; hence the total abundance could drastically fall in a short time and rapidly recover after an event of dispersal or recolonization. Now, coastal bottlenose dolphins in the Black Sea are characterized by rapid growth, possibly early maturation, and loosely connected resident local populations. Historical causes for establishment of such a fragmented structure and genetic relationships between the local populations, as well as the origin of each of them, require further research.

Ethical statement

This study did not involve capture or handling of dolphins. All surveys were conducted with minimal disturbance to the animals. The boat slowly approached dolphins in parallel to their course; groups with neonates and calves were not approached closer than 50 m. Funding agencies and supporters did not affect the presentation of results and discussion for this study.

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