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Harbour porpoises in the Aegean Sea, Eastern Mediterranean: the species' presence is confirmed

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Abstract

Results are presented from the first systematic visual and acoustic line-transect survey for harbour porpoises in the Thracian Sea, northern Aegean Sea. During the vessel survey, undertaken in summer 2013, porpoises were observed on nine occasions and detected acoustically 16 times, with a total of 21 distinct encounters recorded. Harbour porpoises were encountered in three discrete blocks: north of the Island of Thasos, Greece; south and west of the city of Alexandroupolis, Greece; and in Saros Bay, Turkey. Saros Bay exhibited the highest relative acoustic encounter rate of harbour porpoises, and porpoises were observed visually there on two occasions 14 days apart, in small groups, one of which included a mother-calf pair. A comprehensive review of stranding records is also presented. The three areas identified as harbour porpoise habitat in this study coincide with the highest number of recorded stranded animals. This paper is the first to report free-swimming harbour porpoises in the Aegean Sea since 1993, and the first time ever in Turkish Aegean waters. Now that the presence of harbour porpoises has been documented, international cooperation towards long term monitoring and management measures are urgently required in order to conserve this vulnerable population.

Keywords: *Phocoena phocoena*, Harbour porpoise, Acoustic survey, Aegean Sea, Mediterranean Sea, Endangered, Zoogeography

Background

Harbour porpoises (*Phocoena phocoena,* Linnaeus 1758) are distributed widely throughout continental shelf waters of the Northern Hemisphere and are present in the eastern North Atlantic Ocean and Black Sea (Gaskin 1984; Read 1999; Hammond et al. 2013). The historical presence of harbour porpoises in the Mediterranean Sea has been debated in the past (Frantzis et al. 2001, 2003; Notarbartolo di Sciara 2002; Rosel et al. 2003; Viaud-Martínez et al. 2007; Fontaine et al. 2012). Prior to this study there were 21 published records of harbour porpoises documented in the Mediterranean Sea dating back to 1981 (Frantzis et al. 2001; Bellido et al. 2006; Frantzis 2009; Tonay et al. 2009; Notarbartolo di Sciara & Birkun 2010; Tonay & Dede 2013) with all but two reported from the Aegean Sea; the remaining two records were from the Strait of Gibraltar and the waters of Tunisia. These previous records are mostly intermittent strandings, although in 1993 there was a confirmed report of free-swimming porpoises followed by three strandings in the north of the Thracian Sea, including a live-stranded animal (Frantzis et al. 2001).

It is likely that the increase in harbour porpoise records in the Aegean Sea during the last two decades is due to an increased effort in reporting of stranded animals from coordinated stranding networks and improved public awareness of marine mammals (Rosel et al. 2003), although a genuine increase in the number of individuals in the region cannot be excluded. In Greece, the port-police have been responsible for collating stranding records from the public since 1991. Since 2000 it has been mandatory to report stranded cetaceans; this has increased the number of cetacean strandings reported from 50 to 75 each year to around 100. Since 2010, the Pelagos Cetacean

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Research Institute has systematically recorded Greek cetacean strandings through a national stranding network involving port-police authorities and volunteers, with an average of 125 events reported per year since this date. Although Turkey does not have a systematic stranding scheme, Istanbul University/Turkish Marine Research Foundation collates stranding records opportunistically. With the development of the internet and smart phones over the last 10 years, there has been an increase in the public awareness of the importance of reporting strandings in Turkish waters.

Results from a molecular genetic study indicate that the Black Sea population of harbour porpoises is distinct from the Atlantic population, having been isolated by the Mediterranean Sea over 5000 years ago (Fontaine et al. 2010). Due to the very limited geographic area within the Mediterranean Sea where sightings and strandings have been recorded in the past (Aegean Sea and close to the Strait of Gibraltar), the presence of a continuous population of harbour porpoises linking the Atlantic and Black Sea populations is considered very unlikely (Frantzis et al. 2001). From genetic analyses of stranded specimens, harbour porpoises in the Aegean Sea have been found to share common haplotypes with harbour porpoises in the Black Sea as well as in the Turkish Straits System (Viaud-Martínez et al. 2007; Tonay et al. 2014). It is therefore thought that these Aegean porpoises are migrants from the Black Sea population (Rosel et al. 2003; Viaud-Martínez et al. 2007; Tonay et al. 2012, 2014). The possibility still exists however, that Black Sea and Aegean Sea harbour porpoises could form a single random-mating (panmictic) population (Fontaine et al. 2012), or that harbour porpoises sighted in the northern Aegean Sea are from a small isolated Mediterranean population (Rosel et al. 2003; Notarbartolo di Sciara & Birkun 2010). Indeed, five harbour porpoises found stranded in the Marmara Sea, between the Black Sea and the Aegean Sea, exhibit a unique haplotype, suggesting that these individuals may comprise a distinct and isolated population (Viaud-Martínez et al. 2007; Tonay et al. 2012, 2014). However, with sample sizes as small as those reported from the region, caution must be exhibited in interpreting the genetic results.

The Black Sea harbour porpoise (*P. phocoena relicta*, Abel 1905) subspecies has recently been listed on the IUCN Red List as Endangered (Birkun & Frantzis 2008), both genetically and morphologically distinct from the eastern North Atlantic population (Rosel et al. 1995, Rosel et al. 2003; Fontaine et al. 2007, 2010; Viaud-Martínez et al. 2007; Galatius & Gol'din 2011; Tonay et al. 2014). The Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area (ACCOBAMS) noted four "priority" species in the Mediterranean and Black Seas (Notarbartolo di Sciara 2002) which were at greatest risk of declining or disappearing. The harbour porpoise was among them. Over the last 50 years the Black Sea harbour porpoise population is thought to have been reduced to just 10 % of its former size (Fontaine et al. 2010, study based on genetics). This has been attributed to a commercial dolphin fishery which continued until 1983, in addition to high mortality from bycatch in bottom set gillnets, habitat degradation (Birkun & Frantzis 2008) and pollution (Notarbartolo di Sciara 2002; Ozturk 2013). This sub-species clearly requires urgent protection from anthropogenic impacts throughout its range, including the Aegean Sea.

In order to document the presence and distribution of harbour porpoises in the Thracian Sea, a simultaneous visual and acoustic survey was conducted in the northern Aegean Sea. The results from this first systematic survey for harbour porpoises in the Greek and Turkish waters of the Thracian Sea are presented here, together with an update on stranding records.

Materials and methods

A simultaneous visual and acoustic survey for harbour porpoises was conducted in the Thracian Sea, northern Aegean, between 7 and 26 July 2013, planned to coincide with an aerial survey of cetaceans in the western Black Sea (Birkun et al. 2014) (Table 1).

Study area

The Thracian Sea is located in the northern Aegean Sea (Fig. 1) and extends from the Chalkidi Peninsula in Greece in the west to the Turkish Gelibolu (Gallipoli) Peninsula in the east, and the Greek and Turkish mainland in the north to the island of Lemnos in the south (see Fig. 1). The Thracian Sea is connected to the Black Sea through the Turkish Straits System; currents carry the less saline waters of the Black Sea near the surface through the straits, with the more saline Thracian Sea water flowing in the opposite direction in the deeper

Table 1 The designed survey blocks and line lengths for the study site in the north Aegean Sea

Block/survey	Area (km^2)	Designed line length (km)
Low resolution survey area	16,409	2,176
Block 1	1,693	332
Block 2	595	175
Block 3	712	141
Block 4	500	116
Block 5[a]	1,151	239 + 240
Block 6	890	72
Block 7	695	139

[a]had reciprocal tracks

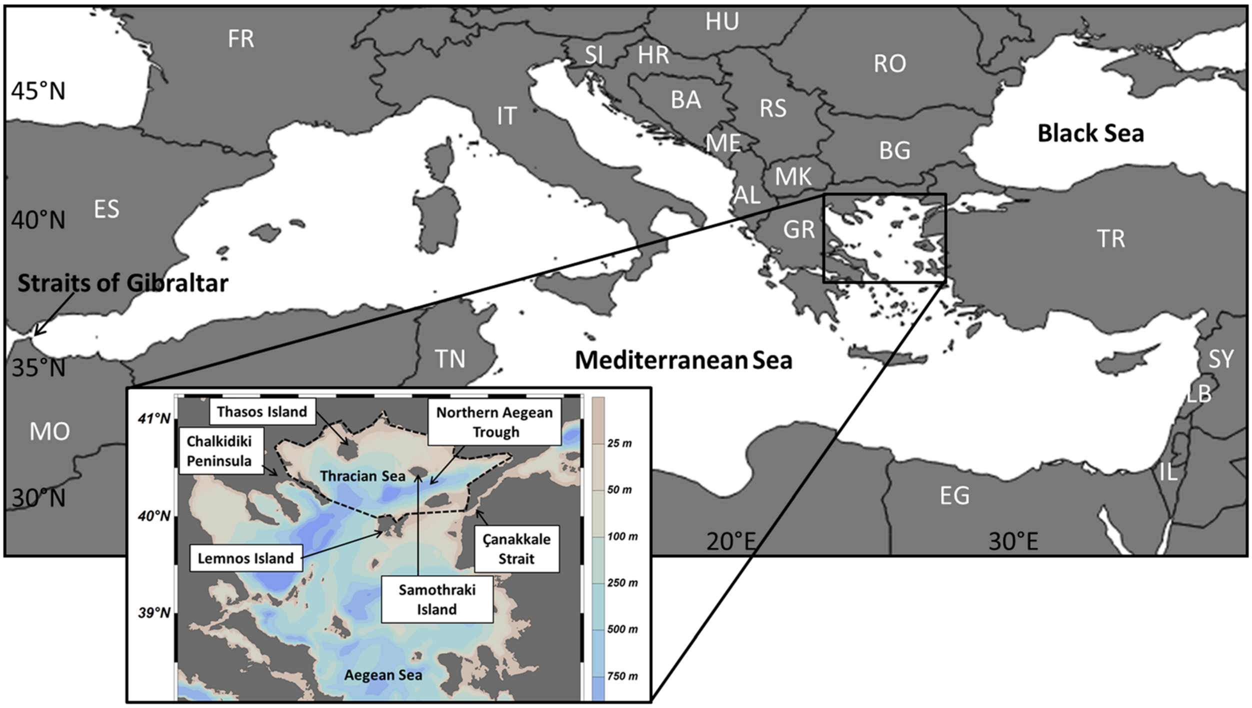


Fig. 1 Map showing the location of the Thracian Sea, in the north of the Aegean Sea and east of the Mediterranean Sea with an insert showing the location and bathymetry (taken from Data 2012) of the Thracian Sea (located within the *black dotted* polygon)

layer. The prevailing currents in the Thracian Sea move in a clockwise direction, from the Black Sea, and around Thasos Island (Lykousis et al. 2002). The Thracian Basin contains the islands of Samothraki and Thasos, an extended plateau, and the North Aegean trough, a 1600 m deep basin; excluding the deep basin, the majority of the Thracian Sea is relatively shallow, at less than hundred metres deep (see Fig. 1).

Visual and acoustic harbour porpoise survey

A double platform visual survey was conducted following Hammond et al. (2013) which, if sufficient sightings are achieved, allows for abundance estimation, corrected for perception bias and availability bias. However, as fewer than 60 groups were encountered, abundance estimation was subsequently deemed inappropriate using this method (Buckland et al. 2001). The survey tracks were designed using DISTANCE 6.0 (Thomas et al. 2010) and included both broad scale, low resolution survey tracks over the entire area and a number of higher resolution tracks close to the Greek and Turkish coastline. The low resolution tracks were designed to provide information about harbour porpoise presence across the North Aegean Sea and inform the subsequent high resolution tracks; these were designed to survey in more detail the typical harbour porpoise coastal habitat. The tracks were adjusted-angle zigzags designed randomly to ensure equal coverage probability of the survey blocks. The design axes were selected based on local prevailing winds to increase the potential for sailing. The research cruise was conducted from R/V *Song of the Whale* (SOTW), a 21 m auxiliary-powered cutter-rigged sailing research vessel.

During daylight hours and in sea state conditions of three and under, four observers divided equally between two independent platforms scanned for porpoises. Two naked-eye 'primary' observers logged sightings within a range of 500 m from a platform in front of the mast giving an approximate eye-height of 4 m. Two 'trackers', situated either side of the vessel on an A-frame with an approximate eye-height of 5.5 m above sea-level, scanned the trackline and in front of the vessel using 7×50 binoculars. Once the 'trackers' had seen a group of porpoises, one of the 'trackers' would follow the group as it passed the vessel in order to determine if any avoidance behaviour was observed. Whenever possible, photographs were taken by an off-effort individual to confirm species identification. However, if potential sightings of porpoise groups were too far away to confirm species identity, the vessel briefly went off-effort to break track and acquire species identification photographs, before resuming the survey where it had been interrupted. In sea state conditions four and above, only two observers using binoculars on the A frame were deployed. All details of sightings and acoustic detections were recorded by the data logger using Logger software (Gillespie et al. 2010). Additionally, the data logger recorded the survey effort and environmental data as well as the certainty of species identification. Only those sightings identified as harbour porpoise with 'definite' certainty were included in this analysis.

The acoustic survey was conducted simultaneously with the visual survey although an independence was maintained between the two (i.e. observers were not notified of acoustic detections). The acoustic survey was conducted in all sea states including the hours of darkness. Two towed arrays, each containing a pair of broadband elements with a bandwidth of 2 to 200 kHz spaced 25 cm apart, were towed 200 m behind the vessel 3 m apart, to allow for correction of left/right ambiguity of detections. Signals were passed through Seiche Measurements buffer boxes to internal National Instruments 6251 sound cards. The buffer boxes provided an approximately flat frequency response for the bandwidths of interest for harbour porpoises (±1 dB from 115 to 160 kHz). Audio streams from each array were sampled at 500 kHz and recorded continuously as separate 16-bit stereo wav files using Pamguard (Gillespie et al. 2009). Post survey analysis was conducted using a Pamguard click detection module configured for harbour porpoises and an analyst removed any false detections and selected detection trains. Clicks were classified as 'definite' harbour porpoise clicks if they met the following criteria: the click had a peak frequency between 100 and 160 kHz, the energy of the click was at least 8 dB above the background noise levels and less than 2 ms in duration, with a relatively flat structure (i.e. not frequency modulated) as revealed in a Wigner plot. All clicks were independently verified by a second analyst and only click trains with at least four clicks and which were listed as 'definite' were included. Click trains were considered to be a unique detection (i.e. not a detection of an animal previously sighted or a repeat detection of a previous group) if there was no corresponding sighting or click train within 6 min. This is a conservative figure which was calculated using the average speed of SOTW (6 knots), the maximum detection distance for harbour porpoises (approximately 400 m; Villadsgaard et al. 2006) and the average swimming speed of harbour porpoises (0.9 m sec $^{-1}$; Otani et al. 2006).

Water depths and distances from the coast for each sighting and detection were estimated using GEBCO 2008 bathymetry maps (British Oceanographic Data Centre; 1 min resolution). Sea-surface temperatures were automatically collected every minute from a thermometer mounted on the hull of the vessel.

Data analysis

The standard error (SE) for the detection rate n/100 km, was calculated using transects as sampling units (Buckland et al. 2001, pp78–80). The variance in the number of detections for each block (Fig. 2) was calculated as follows:

$$\hat{var}(n) = L\sum_{i=1}^{k} l_i\left(\frac{n_i}{l_i}-\frac{n}{L}\right)^2/(k-1)$$

where i is the transect number from 1 to k, l_i is the length of transect i and L is the sum of all transect lengths. The variance of the detection rate was then calculated by dividing vâr (n) by L^2 and the standard error (SE) in each block was calculated by taking the square root of the variance of the detection rate.

Strandings data

Strandings data, including novel data collated by the Pelagos Cetacean Research Institute are presented and combined with the previous 19 published stranding records in Greek and Turkish waters of the Aegean Sea and Çanakkale Strait.

Comparison of acoustic encounter rates

The acoustic encounter rates from this survey were adapted so as to be comparable with previous harbour porpoise surveys conducted from R/V *Song of the Whale* in other small, isolated populations. Only acoustic detections with seven clicks or more were included so to allow comparison with other studies methodologies (elsewhere in the results, click trains of four or more clicks have been used).

Results

Acoustic and visual harbour porpoise survey

The harbour porpoise survey of the northern Aegean Sea included 2845 km of transect which utilised at least acoustic effort, 529 km with both visual and acoustic effort and 845 km with both double platform visual effort and acoustic effort (Fig. 2). The mode sea state during this survey was two; however during many parts of the survey the sea state exceeded three and therefore only single observer visual effort was conducted during these times (see Table 2 for more information).

There were 21 distinct encounters with harbour porpoises during the survey; 12 were detected solely with acoustic techniques, five were sighted only, and four were sighted with simultaneous acoustic detection. Nine definite sightings of harbour porpoises were made on two separate days, all within Saros Bay in Turkish Aegean waters (Table 2 and Fig. 3). Six groups of porpoises were first spotted from the 'tracker' platform (with three of these subsequently re-sighted by the 'primary' observers) and three from the 'primary' platform. On 12 July 2013, four sightings of porpoises were made; one of a group of four animals, two sightings of two animals and a further sighting of a single individual. Several re-sightings were

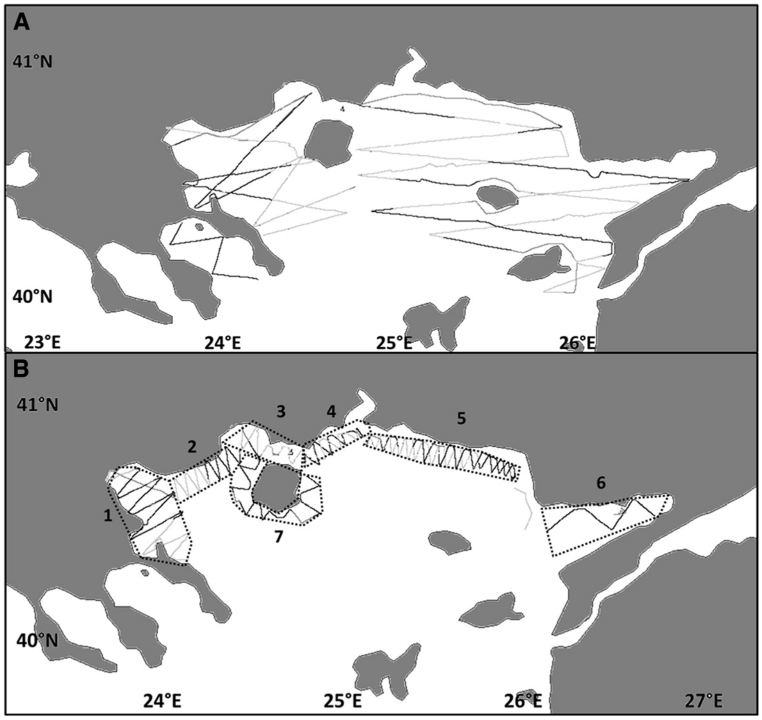


Fig. 2 Survey tracks conducted by SOTW in the northern Aegean Sea (*black lines* represent survey with visual and acoustic effort and *grey lines* represent the survey with acoustic effort only) **a** low resolution transects, **b** higher resolution coastal blocks (marked 1–7, *black dotted line*) and coastal transects

made both from the primary platform and whilst tracking the animals. After completing the remaining low resolution transects, the survey vessel returned to Saros Bay 2 weeks later, as part of the higher resolution coastal survey. On 26 July, harbour porpoises were encountered on five separate occasions, including three pairs of animals and two single individuals. One of the pairs sighted included a calf swimming in echelon position with another animal, presumably the mother. Photographs were taken during all encounters in order to confirm species identification (Fig. 4). During both days when porpoises were seen in Saros Bay, there were good sighting conditions (the sea state was between 0 and 3).

Acoustic detections of porpoises ($n = 16$, of which 14 were made 'on track' i.e. following pre-determined tracklines at the prescribed survey speed) were made in Greek and Turkish waters, four of which were accompanied by visual encounters. Eight unique acoustic detections occurred to the north of the Greek island of Thasos, three west of the Greek city of Alexandroupolis, and five in Saros Bay, off Turkey (Fig. 3). Each of the reported acoustic detections was separated by a minimum of 12 min and was therefore deemed to be an independent encounter (see Methods section for definition).

Relative 'on track' acoustic encounter rates (n/100 km surveyed) were calculated for the high resolution coastal survey (overall and per block) and for the northern Aegean (Thracian Sea) survey as a whole, including both the high and low resolution survey blocks (Table 2). The high resolution coastal transects of the Saros Bay survey block (block 6) revealed the highest acoustic encounter rate (Table 2 and Fig. 2).

During July, surface water temperatures in Saros Bay increased from 19 to 25 °C, over the 2 week period when the harbour porpoises were sighted. The 21 encounters occurred in water of varying depths (mean depth = 43 m, SD = 27 m) but all sightings and detections occurred in waters shallower than 150 m (see Fig. 1 for bathymetry). All of the encounters occurred at distances <6 nm from the coast (mean distance = 1.8 nm, SD = 0.12).

Four other cetacean species were sighted while surveying the Thracian Sea, the common bottlenose (*Tursiops truncatus*) ($n = 45$), short-beaked common (*Delphinus delphis*) ($n = 16$) and striped (*Stenella coeruleoalba*) dolphin ($n = 20$) and Risso's dolphins (*Grampus griseus*) ($n = 1$) (for more information see Ryan et al. 2014).

New stranding data

Previously, 19 strandings of harbour porpoises have been reported between 1997 and 2013 in Greek and Turkish waters of the Aegean Sea and Çanakkale Strait (Güçlüsoy 2007; Frantzis 2009; Tonay & Dede 2013). There has also been ten unpublished strandings of harbour porpoises between 2007 and 2013, including

Table 2 Survey effort, detection rate, number of detections, time and date of detections, number of sightings, sea state histogram and percentage of effort surveyed in the hours of darkness for the 2013 harbour porpoise Aegean Sea survey. Acoustic effort was conducted throughout the entire survey regardless of sea state or light level

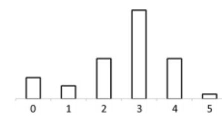
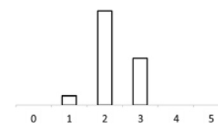
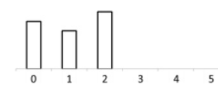
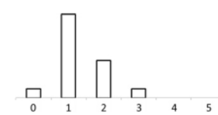
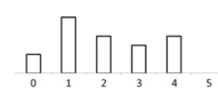
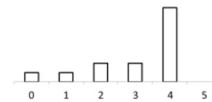
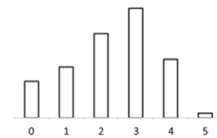
Survey/block	Acoustic effort (visual effort) km	On-track acoustic detections *n*/100 km (SE of *n*/100 km)	No of detections	Date/time of acoustic detection (UTC)	No of sightings (individuals)	Sea state histogram for daylight hours	% of the transect lines surveyed at night (acoustic only)
Low resolution survey	1690 (717)	0.24 (0.17)	4	08/07/2013 06:53:56 08/07/2013 13:18:56 08/07/2013 13:32:39 15/07/2013 12:13:32	4 (9)		48
High resolution survey	1155 (658)	0.87 (0.30)	10	n/a	5 (8)		43
Area 1	255 (150)	0 (0)	0	-	0		41
Area 2	148 (78)	0.68 (0.64)	1	18/07/2013 11:25:38	0		47
Area 3	86 (0)	2.34 (1.35)	2	21/07/2013 23:41:50 22/07/2013 00:12:27	0	N/A	100
Area 4	126 (70)	0.80 (0.80)	1	23/07/2013 17:12:52	0		45
Area 5	351 (179)	0.85 (0.46)	3	24/07/2013 07:01:07 24/07/2013 09:24:18 24/07/2013 14:53:46	0		49

Table 2 Survey effort, detection rate, number of detections, time and date of detections, number of sightings, sea state histogram and percentage of effort surveyed in the hours of darkness for the 2013 harbour porpoise Aegean Sea survey. Acoustic effort was conducted throughout the entire survey regardless of sea state or light level *(Continued)*

Area 6	54 (65)	5.61 (4.29)	3[a]	26/07/2013 08:00:05 26/07/2013 12:15:48 26/07/2013 14:09:14	5 (8)		15
Area 7	136 (115)	0 (0)	0	-	0		0
Combined high and low resolution survey results	2845 (1375)	0.49 (0.18)	14	n/a	9		46

[a]2 off track detections also occurred on 26/07/2013

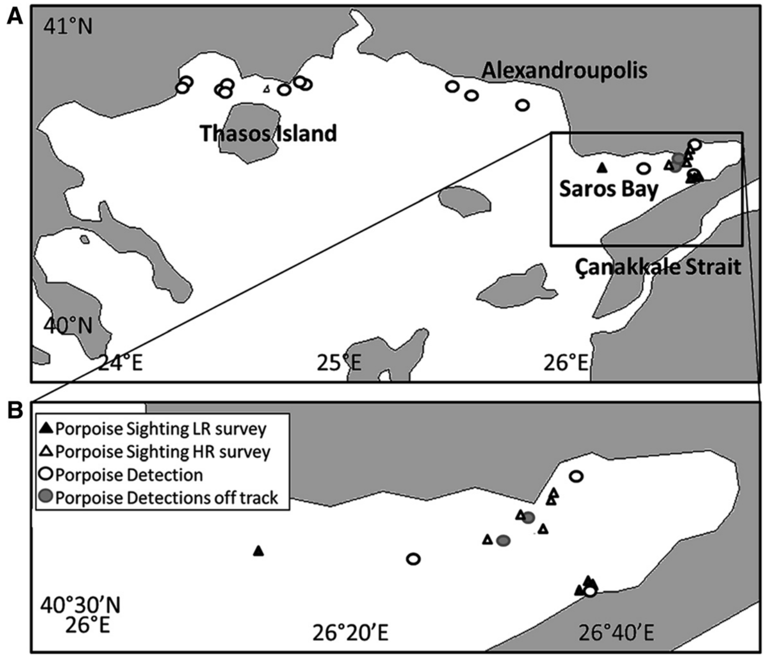


Fig. 3 a Map depicting the locations of harbour porpoise detections ($n = 16$) and sightings ($n = 9$) across the Greek and Turkish waters of the Thracian Sea. **b** an enlarged map of Saros Bay, Turkey depicting the porpoise sightings ($n = 4$) on the 12/07/2013 during the low resolution survey and sightings ($n = 5$) and detections ($n = 3$ "on track"; $n = 2$ "off track") during the high resolution coastal tracks on 26/07/2013

four in 2013 alone, in Greek coastal waters (Fig. 5) (Pelagos Cetacean Research Institute, unpublished data). The majority of the strandings were found along the northern Aegean Sea coastline, north-west of Thasos Island and close to Alexandroupolis. However, since 2006 there has been an increase in the number of strandings of harbour porpoises reported further to the south of the Aegean Sea with six strandings recorded in latitudes south of 39°N (Tonay & Dede 2013 and Pelagos Cetacean Research Institute, unpublished data). At least three of the southern stranded porpoises presented heavy infestations of an ectoparasite (*Pennella* sp.) (Danyer et al. 2014; Tonay & Dede 2013 and Pelagos Cetacean Research Institute, unpublished data) indicating that these animals may have been immunocompromised prior to stranding.

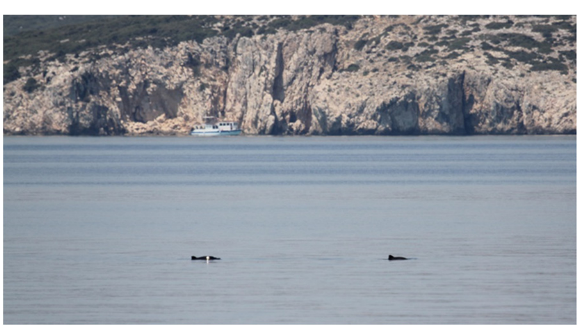


Fig. 4 A photograph of a harbour porpoise encounter with two individuals in Saros Bay, Thracian Sea (26/07/2013 10:34 UTC)

Strandings of harbour porpoises have been recorded in all months of the year with no obvious seasonal peak. Between 1997 and 2013, a maximum of five stranded harbour porpoises a year have been reported (in 2013), however there were 5 years (1998, 1999, 2001, 2002 and 2010) in which no harbour porpoise strandings were reported. Figure 6 displays all available data relating to harbour porpoise presence in the Aegean Sea collected over the last two decades including previously unpublished data from the Pelagos Cetacean Research Institute and the sightings and detections from this survey.

Comparison of acoustic encounter rates

The high resolution (coastal) survey of the Thracian Sea was found to have an acoustic encounter rate of 0.43/100 km (SE = 0.33) (using only click trains with seven or more clicks to allow comparison with previous surveys). This encounter rate is comparable to the Baltic Proper, an area known to have a very low density of porpoises (0.1/100 km), however it is markedly lower than the encounter rates in the Little Belt (Denmark), which is known to have a high harbour porpoise density (16.8/100 km; Gillespie et al. 2005). It is also lower than the

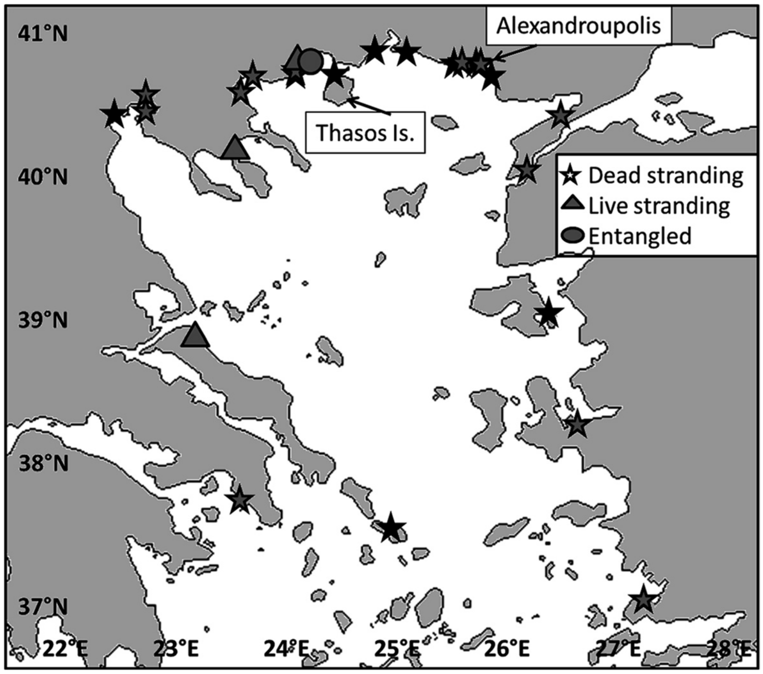


Fig. 5 Harbour porpoise strandings in the Aegean Sea and Çanakkale Strait ($n = 29$); of these, dead strandings ($n = 25$), live strandings ($n = 3$) and entangled ($n = 1$). Including previous published strandings (noted by *grey stars*, $n = 19$) as well as 10 previously unpublished strandings from the Pelagos Cetacean Research Institute (marked as *black stars*)

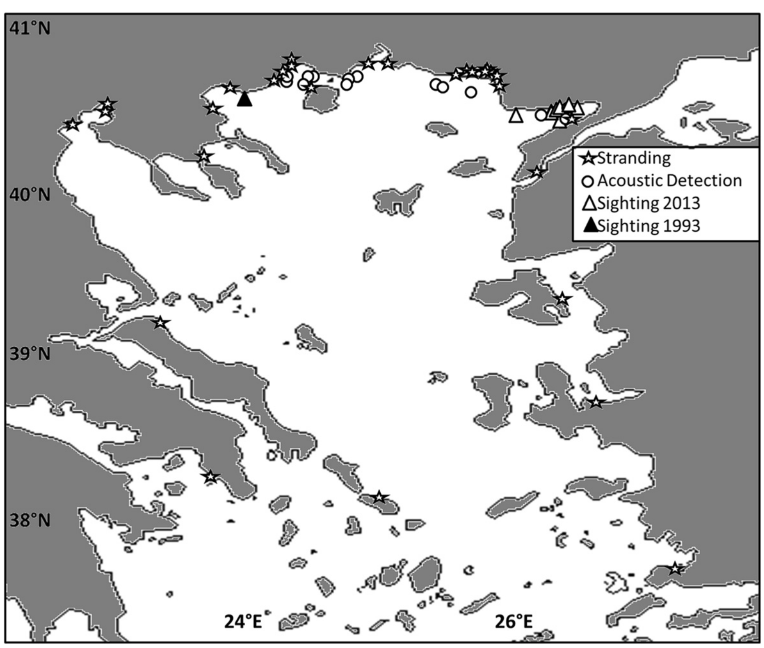


Fig. 6 All harbour porpoise sightings, strandings and acoustic detections recorded over the last two decades in the Aegean Sea and Çanakkale Strait. Strandings ($n = 29$), acoustic detections from this 2013 study ($n = 16$), sightings from this 2013 study ($n = 9$) and previous sightings ($n = 1$)

waters between Dakhla and Cape Barbas off NW Africa (6/100 km; Boisseau et al. 2007).

Discussion

This study represents the first dedicated survey for harbour porpoises conducted in the Mediterranean Sea. It confirms the presence of free-swimming harbour porpoises in Greek and Turkish waters of the northern Aegean Sea in summer 2013. The inconspicuous nature of harbour porpoises severely reduces the probability of seeing individuals in sea conditions above sea state two (Teilmann 2003) and reduces significantly above sea state three (Palka 1996). Due to these challenges, harbour porpoises are not easy to observe in anything but perfect sea conditions. Although the mode sea state during this survey was two, during many parts of the survey the sea state exceeded three, thus compromising sighting conditions and highlighting the value of passive acoustic detection techniques in surveys for inconspicuous, vocally-active species. It is worth noting that all harbour porpoise sightings in this study were made when the sea-state was between zero and one and porpoises were never visually detected in higher sea states, even in blocks where several acoustic detections were made.

There were a total of 21 distinct acoustic or visual detections of harbour porpoises throughout the survey (visual $n = 5$, acoustic $n = 12$ and combined $n = 4$) grouped in three discrete blocks: north of the Greek Island of Thasos; southwest of Alexandroupolis; and Saros Bay, Turkey where the highest encounter rate (acoustic and/or visual) was recorded. Similar to porpoise populations in the Atlantic (Hammond et al. 2008) and Black Sea (Birkun & Frantzis 2008), the harbour porpoises were all encountered in shallow (<150 m) coastal habitat (within <6 nm of land). The sea-surface temperature in Saros Bay, where the highest density of porpoises occurred, was up to 25 °C, above the previously postulated "limiting thermocline" for the species (Tolley & Rosel 2006) and to the authors' knowledge, may be the warmest sea surface temperatures in which harbour porpoises have been observed. Although no previous systematic survey for harbour porpoises had been conducted in the Thracian Sea, parts of this area had previously been surveyed for cetaceans. During spring and summer visual surveys of the Turkish waters of the Aegean Sea between 2005 and 2008, including Saros Bay, no harbour porpoises were observed (Dede & Öztürk 2007; Öztürk et al. 2009; Altuğ et al. 2011); possibly due to poor sea state or disturbance from the motor research vessel. Previous strandings data indicated the presence of porpoises in the Aegean Sea was largely confined to the northern Thracian Sea coast with several strandings northwest of Thasos Island and close to Alexandroupolis (Birkun & Frantzis 2008). The results of this survey are consistent with the distribution of strandings in the region. However, this study highlights Saros Bay as an additional potentially significant area for porpoises, with the highest relative acoustic encounter rate in a location with just one previously reported stranding (Tonay et al. 2009; Tonay et al. 2012). This demonstrates the importance of using both strandings and systematic surveys to inform our understanding of harbour porpoise distribution. The recent increase in the number of strandings in the more southerly latitudes of the Aegean Sea suggest a possible increase in the range of harbour porpoise in this area; however the presence of high parasite loads in three of the six southerly strandings (Tonay & Dede 2013 and Pelagos Cetacean Research Institute unpublished data) may indicate difficulties in survival for porpoises in these southerly latitudes. The multiple sightings, and the presence of a calf in one of the groups, indicate that porpoises in the northern Aegean may be breeding there. That a pregnant porpoise was found stranded north-west of Thasos Island further supports this hypothesis. With the Black Sea population of harbour porpoises estimated from genetic analysis to be just 10 % of its former size (Fontaine et al. 2010), and considering the unknown status of harbour porpoises in the Mediterranean Sea, signs of a possible breeding group of porpoises in the Aegean Sea are highly significant. Considering that porpoises occur in the northern Aegean Sea in low relative abundances, occasionally with calves and exhibit an apparent preference for coastal waters, management measures towards their protection are warranted. The porpoises within the Black and Aegean Seas face many anthropogenic threats including pollution, climate change, fisheries bycatch and habitat degradation (Notarbartolo di Sciara 2002). As an example, a fisheries survey in the 1990s revealed 996 licensed fishing vessels with 964 set nets and longlines, 29 purse seines, two trawls, and one beach seine operating in Turkish waters of the northern Aegean Sea alone (Kara & Gurbet 1999). Since this study was published the number of registered fishing vessels has increased, Ayaz et al. (2008) reported that there were about 250 fishermen using gillnets and trammel nets in Saros Bay. One of the animals listed as stranded in this study demonstrated evidence of entanglement in fishing gear (Fig. 5). As information on the levels of harbour porpoise bycatch in fisheries within the Mediterranean Sea is currently lacking, efforts are needed to quantify and reduce bycatch in all fisheries, especially in the Thracian Sea. Additionally, more information on the distribution of harbour porpoises in the Aegean Sea is required, especially seasonally and through the Turkish Straits System.

In small discrete porpoise populations, such as that in the northern Aegean Sea, monitoring trends in abundance is essential to maintaining their conservation status. The Baltic Sea and north west African coastal waters are both areas considered to have discrete harbour porpoise subpopulations (Huggenberger et al. 2002; Tolley & Rosel 2006) with the Baltic Proper population being critically endangered due to its low density (Hammond et al. 2008). The results from this first dedicated northern Aegean Sea survey reveal acoustic encounter rates which are comparable to that of the Baltic Proper. Scientists studying small populations of phocoenids, such as harbour porpoises in the Baltic Sea and vaquita in the Gulf of California, have, following initial vessel and aerial surveys, established large arrays of autonomous acoustic recording devices to facilitate longer term monitoring of certain areas (Rojas-Bracho et al. 2010; Benke et al. 2014). Now that harbour porpoise presence has been confirmed in the Aegean Sea from this study, and certain areas noted as potentially significant, fixed acoustic devices have the potential to be used here to monitor presence and detect changes in abundance of porpoises more rapidly and over extended periods of time. As such it is recommended that relevant agencies, such as ACCOBAMS and the Turkish and Greek governments, consider these methods to monitor this small population in order to target further protection and assess the efficacy of conservation measures to reduce anthropogenic threats. Zones for marine protected area (MPA) designation have already been suggested in the high seas of the Aegean Sea (Öztürk 2009). In certain areas, such as the coastline off Alexandroupolis, and north of Thasos Island, the need for designation of MPAs has been noted; the information presented here supports the case for the creation of marine Natura 2000 sites with harbour porpoises as a qualifying interest (PCRI 2009). In recognition of the high biodiversity in Saros Bay, the Bay was declared an MPA in January 2011 and limitations have been set on the large-scale trawling, purse-seining and bivalve dredging fisheries in the area. This is a positive development in terms of conservation but, at present there are no limitations on gillnet fisheries, which have been described as "the single most important threat to porpoises" in other areas (Jefferson & Curry 1994) and their prevalence in the region is of serious concern. In light of new evidence presented here on the presence and distribution of harbour porpoises in the northern Aegean Sea in both Greek and Turkish waters, a sharp focus on the protection of this small, coastal and possible breeding group is urgently required.

Abbreviations

ACCOBAMS, the agreement on the conservation of Cetaceans in the Black Sea, Mediterranean Sea, and contiguous Atlantic area; IUCN, International Union for Conservation of Nature; MPA, marine protected area; SD, standard deviation; SE, standard error; SOTW, song of the Whale (the survey research vessel).

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Authors' contributions

ACC participated in the survey planning, leading the survey team, data analysis and drafting of the manuscript. AF, OB and AM conceived of the study, and participated in its design and coordination. OB, MR, CR, AO, AT and AP all participated in the survey, OB and MR supervised the data analysis and additionally AO, AF and AT provided historic unpublished datasets to the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Data sharing

The data will not be shared publically through this forum. The raw data are audio files and databases which were then analysed further. If organisations, students or the public would like to use the data for further studies, please get in touch at MCRinfo@mr-team.org.

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