J. Black Sea/Mediterranean Environment
Vol. 31, No. 1: 1-24 (2025)

RESEARCH ARTICLE

First documentation of rough-toothed dolphins (*Steno bredanensis*) in the Eastern Mediterranean Sea of Türkiye

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Abstract

Despite the global distribution of rough-toothed dolphins (*Steno bredanensis*), they remain an understudied species within the Mediterranean Sea, with only a handful of sighting and stranding reports within the entire basin. In the current study, an area of 3,922 km² between Fethiye Bay and the Finike Trough in the Eastern Mediterranean Sea of Türkiye was surveyed using a standard line-transect distance sampling approach. The survey was conducted over 10 days, from 12 to 21 July 2024. The survey methodology incorporated visual observations, acoustic data collection, and drone-based surveys. On 18 July 2024, an unidentified delphinid species was first acoustically detected at 04:06 in waters with a depth of 1,000 m. Later that same day, a visual detection of rough-toothed dolphins occurred at 14:40 in waters with a depth of 2,000 m. Both detections were located within the Finike Trough, off the coastal town of Kas. Post-acoustic analysis confirmed that the initial acoustic detection was also of rough-toothed dolphins. These detections are likely to represent the same encounter, given that it is likely that the short distance of 10 km can be travelled by the group within a 10-hour period. The focal group of the visual encounter consisted of 11 individuals, including two sub-adults, with multiple subgroups observed in tight formations, moving fluidly. During the encounter, the species showed no visible avoidance behaviour towards the research boat. Both non-harmonic and harmonic whistles were predominantly associated with diving and interactions with the research boat, while burst pulses were more frequent during diving activity. Upsweep whistle contours, with most energy below 10 kHz, were the most dominant whistle type, with segmented upsweep and wave shape harmonics notably prevalent in their tonal sound patterns. This study documents the first confirmed encounter with rough-toothed dolphins in Turkish waters and contributes to our understanding of the visual and acoustic behaviour of this species in the Eastern Mediterranean Sea.

Keywords: *Steno bredanensis*, Levantine Basin, distribution, vocalisation, behaviour

Received: 07.11.2024, **Accepted:** 13.03.2025

Introduction

The Mediterranean subpopulation of rough-toothed dolphins (*Steno bredanensis*) was recently identified as "near-threatened" by the IUCN Red List, with an unknown population trend (Kerem *et al.* 2021). Although distributed globally, they tend not to be present in high numbers in one of their known ranges. This has resulted in a limited and patchy collection of baseline information, both within the Mediterranean and globally (West *et al.* 2011). Up until the 1980s, rough-toothed dolphins were considered occasional visitors to the Mediterranean. However, since then there has been a notable increase in sightings, and they are now regarded as a regularly occurring species (Kerem *et al.* 2016), with the Ionian Sea and Eastern Mediterranean Sea identified as two key areas (Kerem 2020; Kerem *et al.* 2021; Foskolos *et al.* 2023). While most data suggest that rough-toothed dolphins are primarily restricted to these two basins, with the Strait of Sicily marking the boundary of their known range, an encounter from the Tyrrhenian Sea in 2011 (Santoro *et al*. 2015; Gnone *et al.* 2023) indicates that their distribution in the Mediterranean has yet to be fully delineated.

While reports of their occurrence were scarce before the 2000s (Watkins *et al.* 1987; Kerem *et al.* 2012), sightings have significantly increased since then, particularly in the Eastern Mediterranean (Boisseau *et al.* 2010; Ryan *et al.* 2014; Shoham-Frider *et al.* 2014; Kerem *et al.* 2016; Kerem 2020; Çanakçı *et al.* 2023; Foskolos *et al.* 2023), but also the Ionian Sea (Boisseau *et al.* 2010; Caruso *et al.* 2019; Foskolos *et al.* 2023), and with a recent single encounter from the Tyrrhenian Sea (Santoro *et al*. 2015; Gnone *et al.* 2023). Despite the scarcity of encounters throughout their range in the Mediterranean, previous studies on Mediterranean rough-toothed dolphins have generally been structured around sighting and stranding records, with a handful of recent studies focusing on photo-identification (Foskolos *et al.* 2023), acoustic patterns (Ryan *et al.* 2014; Kerem *et al.* 2016; Caruso *et al.* 2019; Foskolos *et al.* 2023) and threat description/analysis (Shoham-Frider *et al.* 2014; Kerem *et al.* 2016; Çanakcı *et al*. 2023; Foskolos *et al.* 2023).

Only recently, a rough abundance estimate of 1,200 mature individuals was calculated for the Mediterranean, with approximately 570 and 630 individuals residing in the Ionian and Eastern Mediterranean Seas, respectively (Kerem *et al.* 2021). In addition to the abundance estimates for the Mediterranean basin, there have also been two encounter rate estimates.

Group sizes of up to 40 individuals have been reported within the Mediterranean subpopulation (Kerem *et al.* 2016), with the majority of encounters reporting fewer than 10 individuals per group (Boisseau *et al.* 2010; Santoro *et al*. 2015; Kerem *et al.* 2016; Foskolos *et al.* 2023; Gnone *et al.* 2023). On one rare occasion in the Ionian Sea in 1985, a group of 160 individuals was documented, which represents the largest aggregation reported for the species (Watkins *et al.* 1987). In general, smaller subgroups typically form within larger aggregations of rough-toothed dolphins (Leatherwood *et al.* 1982; Watkins *et al.* 1987; Miyazaki and Perrin 1994).

Water depth also plays a significant role in their occurrence, with the majority of encounters recorded between the 1000 and 2000-metre contours (Gannier and West 2005; Baird *et al.* 2008; West *et al.* 2011; ACCOBAMS 2021). However, they are occasionally also found over the continental shelf (Lodi 1992; Kuczaj and Yeater 2007; Jefferson 2009; Boisseau *et al.* 2010; West *et al.* 2011).

Their whistles have a relatively low frequency with a small frequency range and can contain multiple individual segments (Rankin *et al.* 2015). In the Mediterranean, the frequency of their whistles is generally low, ranging from 2.4 to 10.7 kHz, with average durations of 692 ± 228 ms and 500 ± 300 ms, previously reported (Kerem *et al* 2016; Caruso *et al.* 2019). The most commonly recorded whistle type in the Mediterranean appears to be segmented upswept whistles (Ryan *et al.* 2014; Kerem *et al.* 2016).

This study compiles current knowledge on rough-toothed dolphins and presents the first documented occurrence of the species in the Turkish Eastern Mediterranean Sea. In addition, it provides further insights into their vocal behaviour, exploring potential links between observed activities and acoustic patterns. These findings contribute valuable new information to a species that remains largely understudied in many parts of the Mediterranean, helping to fill critical gaps in baseline data and enhance our understanding of their behaviour and distribution not only at a local but also at a regional level.

Materials and Methods

Survey Area

Surveys were conducted using a 13 m Beneteau Oceanis 423 sailing vessel as the research boat. The survey route was 381 km in length and ran between Fethiye Bay and the Finike Trough, covering a total survey area of 3922 km^2 (Figure 1). The survey route was followed both during the day and at night, and was conducted continuously whilst sea state conditions were favourable (Beaufort scale less than 4), with the exception of necessary breaks for refuelling, food replenishment, and other essentials. The survey was designed following a standard line-transect distance sampling approach (Buckland *et al.* 2015) and was created using Distance software (version 7.5) (Thomas *et al.* 2010). A total of 20 equally-spaced zig-zag transects were fitted across four strata. Each transect within a stratum was given a random start point and was oriented perpendicularly to the depth contour lines.

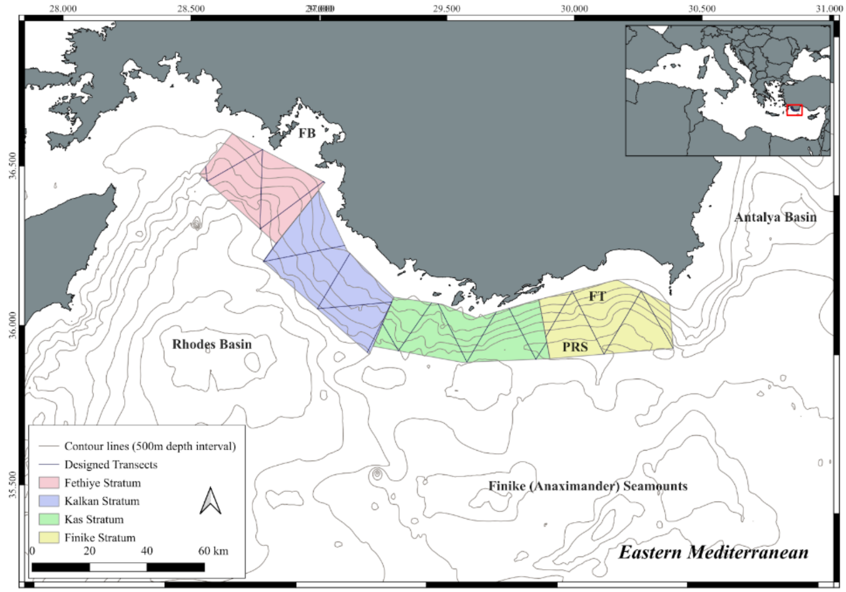

Figure 1. Survey transects in the four survey strata (FB: Fethiye Bay, FT: Finike Trough, PRS: Piri Reis Seamounts. Contour lines were drawn at 500-metre depth intervals, with the contour closest to the coast representing the 500-metre depth line.)

Data collection

Visual and acoustic data were collected when the boat was cruising at an average speed of six knots along the predetermined transects. On a typical day, sufficient light for conducting visual surveys was available between approximately 06:00 and 20:00 local time. The survey effort was recorded as "on-effort" when the research boat was within three kilometres of the transect, with any information gathered outside of this limit considered as "off-effort". In the case of an animal sighting, once the pod had passed the beam, a focal follow was initiated in order to collect photographic, behavioural and additional acoustic data. During this time the survey effort was considered as an "off-effort focal-follow". A double platform technique was used; two primary observers were placed on the bow of the boat and two secondary observers were placed on a platform (3.7 m height from the sea level), which was fixed to the front of the main mast. Each observer pair was responsible for species detection. The primary observers scanned the sea with the naked eye up to a distance of 500 m from the bow, while secondary observers scanned the sea with reticle binoculars up to the horizon. One of the secondary observers also worked as the data logger and logged the boat route, environmental parameters, and sighting information to Logger 2010 software (International Fund for Animal Welfare 2010). The data logger was responsible for recording the spatial information of the sightings, which could be dictated by either the primary or secondary observers, as well as environmental conditions (recorded on at least an hourly basis). Duplicate sightings entered by the data logger from both primary and secondary observers were later identified in the dataset and removed. The group heading, the shortest distance from the boat, group size (minimum, maximum, and best), and group composition (adult and sub-adult) were recorded for each encounter. Sub-adults were defined as any individual with a body size of less than ⅔ of a nearby adult (Ritter 2002). Reticle binoculars with an internal compass were used to determine the approximate location of each sighting. The reticles were provided by focusing to the centre of the group.

Additionally, behavioural and group cohesion data were collected using a DJI Mini 4 Pro Drone, with a flight height of 5-30 m above the focal group. The flight height of the drone was maintained in this range in order to limit potential changes in behaviour that may be caused by the presence of the drone (Castro *et al.* 2021). Photo-identification data were collected using Canon 7D, Canon EOS750D and Canon EOS 5D Mark III DSLR cameras with Canon 70-200 mm, Canon 55-250 mm and Sigma 150-600 mm lenses. An attempt was made to photograph each individual's dorsal fin from both the left and right sides.

Acoustic data were collected using a towed hydrophone array and was deployed near-continuously during surveys. The hydrophone array consisted of four omnidirectional hydrophone elements for high and low-frequency monitoring, mounted within a streamlined housing and towed on a 200m strengthened cable. The two low frequency hydrophones consisted of two Benthos AQ4 elements with matching Magrec HP02 preamplifiers (nominal sensitivity of -165 dB re 1V/μPa). These have a low-cut filter in the preamplifier set to -3dB at 75Hz with a flat response to 15kHz, and reasonable sensitivity to 30kHz. The two high-frequency hydrophones consisted of HF Magrec HP03 elements with Magrec HP02 preamplifiers (nominal sensitivity -159 dB re 1 V/μPa). A low-cut filter set at 2 kHz ensured a good response between 2 and 150 kHz. The signal was amplified and conditioned using a customised hydrophone interface (Magrec HP27) and digitised using a SAIL DAQ card sampling at 250 kHz. PAMGuard software was run on a laptop, making continuous full-bandwidth recordings. The PAM operator was responsible for logging the presence of any cetacean vocalisations. In the case of acoustic detection of delphinids, the boat route was not altered unless there was a visual confirmation. A subjective five-point grading system was used in the field where zero and five indicated inaudible and extremely loud sounds, respectively.

Data analysis

The current detections, in addition to previous reports of the rough-toothed dolphins, were mapped using QGIS Desktop software (version 3.34.13). To calculate the average speed of dolphins during a visual encounter, each sighting point is mapped and later converted into a path. The total distance of this path is then divided by the time elapsed between the first and last sighting. The resulting value is multiplied by 60 minutes to estimate the average speed in kilometres per hour.

Post-analysis of the drone footage was carried out by splitting the recorded videos into one-second still image frames using the 'VideoFileClip' function in the 'moviepy.editor' package in Python (version 3.11). Behavioural activity, group structure, swim formation, breathing intervals, and the presence of defecation were recorded. Focal scan sampling per subgroup, using continuous data sampling was chosen as the sampling method. Each frame was analysed to document the behaviour; however, data logging occurred only when the behaviour changed, with the duration of each behaviour recorded for further assessment. Behavioural activities were defined as shown in Table 1 (Lusseau 2003; Christiansen *et al.* 2010; Akkaya *et al.* 2023). Swimming formation was recorded as front, line, team, leader, alone, and mixed, as shown in Table 2 (Akkaya Bas *et al.* 2018). In addition, the number of synchronised breathing events and intervals were recorded to assess the relationship with any behavioural activity of the subgroup.

Table 1. Behavioural definitions of the focal groups

Behaviour	Definition
Travelling	Dolphins move in a constant direction with a speed ranging from two to four knots.
Diving	Dolphins stay in a similar location, tails may break the surface, and heavy breathing may be heard. The time they spend submerged is longer than the time they spend on the sea surface.
Socialising	Dolphins show body contact with each other. They can engage with surface active behaviour and show frequent changes of directions.
Interacting	Dolphins approach the research boat.
Surface-feeding	Dolphins are active on the surface, they can synchronise short-duration diving. The sea surface has lots of ripples, and birds circling on top of the ripples can also be indicative. Dolphins can be observed as chasing prey.

Individual identification was conducted by examining photographs collected in the field. Good quality photographs which captured the characteristics of the fins were uploaded to the online platform, FlukeBook (https://www.flukebook.org), where individuals were identified using AI matching systems and later manually confirmed by a researcher.

The acoustic data were processed using Raven Pro 1.6 with the following spectrogram settings: a Hanning window of 1400 samples, 50% overlap between windows, and a FFT size of 2048 samples resulting in a frequency grid spacing of 122 Hz. These settings were selected to balance temporal and frequency resolution for tonal vocalisation analysis. The strength of the tonal sound was categorised as weak (the start and end of the whistle were not clear), average (the whistle was clear), or clear (the whistle was clear with a strong signal). Weak whistles were discarded from further analysis. For both non-harmonic whistles (referred to as *whistles* hereafter) and harmonic whistles, the assessed acoustic parameters included low and high frequency, peak frequency, call duration, number of segments, harmonic counts, and whistle types, all retrieved from the fundamental.

Table 2. The definition of the swim formation for dolphin subgroups.

Swim Formation	**Definition**
Front	All individuals side by side with none noticeably at the front or rear of the group.
Line	All individuals head to tail and lined up with a single individual in front and a single individual at the back of the group.
Team	Individuals are in pairs of two and side by side.
Leader	One individual in front and leading the group while the rest are clustered together.
Alone	Solitary individual.
Mixed	There is no clearly defined swim formation.

The whistle types were selected according to their contour shapes which were categorised into six main types, labelled A to F (Hickey *et al*. 2009) (Figure 2). Descriptive statistics were provided for all of the above parameters for the whistles, while only the number of segments of the fundamental whistle, harmonic counts and whistle types were considered for the harmonic whistles.

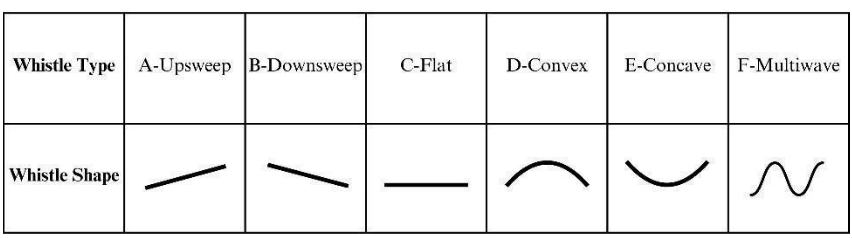

Figure 2. Visual representation of the selected whistle types

Additionally, to understand the possible relationships between the visual and acoustic behaviour of the focal group, acoustic data were compared with the visual behavioural information using corresponding timestamps. Given that the data collected only come from a single encounter, only descriptive statistics have been used to provide insights into the potential relationship between the visual and acoustic characteristics of the focal group. The preliminary assessment considers the occurrence of whistle types, burst pulses and harmonics during the observed behavioural activities.

Results

Overall, 10 days (111 hours and 15 minutes) were spent searching for cetaceans from 12 to 21 July, 2024 within the Eastern Mediterranean Sea of Türkiye, of which three delphinid species (bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), rough-toothed dolphin (*Steno bredanensis*) were detected.

An unidentified delphinid species was acoustically detected between 04:06 and 05:36 (local time) on 18 July 2024. Later that same day, a visual encounter of rough-toothed dolphins occurred between 14:40 and 16:06 (local time). Post-acoustic analysis revealed that the whistle characteristics matched those of rough-toothed dolphins, with consistent patterns observed between both encounters. The acoustic and visual encounters were separated by an estimated distance of 10 km, with a time interval of approximately 10 hours. The average speed of dolphins during the visual encounter was 1.8 km/hour based on their spatial sighting locations. Given this information, and the limited number of rough-toothed dolphins in the region, it is likely that both encounters were of the same group. The detections were between the Rhodes Basin and the Finike Trough, with the acoustic detection occurring along the 1000-metre depth contour, approximately 10 km from the nearest coast and the visual encounter taking place at a water depth of 2000 metres, about 17 km from the coast (Figure 3).

A total of 1,561 still images from drone footage were captured between 14:46 and 16:02. Eleven individuals were encountered of which two were identified as sub-adults within the close proximity of an adult. In total, 20 mins 28 secs were used to assess the behavioural activity of the focal group, where the records summed up to 35 samples. Travelling was the most prevalent activity of the focal group (6 minutes 37 seconds, 33.28%), closely followed by interacting with the boat (5 minutes 33 seconds, 27.91%), diving (4 minutes 19 seconds, 21.71%), and socialising (3 minutes 24 seconds, 17.10%). In contrast to the drone footage, on two occasions diving was recorded as resting, one occasion interacting with the boat recorded as travelling, one occasion socialising recorded as travelling from the data logger on the deck during the sighting. Besides the recorded behavioural activities, a defecation event was observed during the sighting although this event was not recorded in drone footage. The group showed no apparent avoidance behaviour to the research boat which stayed between 50 and 100 m from the focal group with the engine idling or off. During the drone footage analysis overall, 38 breathing intervals were recorded with an average duration of 15 seconds. Subgroups of three to four individuals were documented throughout the observation (Figure 4). The subgroups exhibited a fission-fusion pattern, with fluid movement occurring between them.

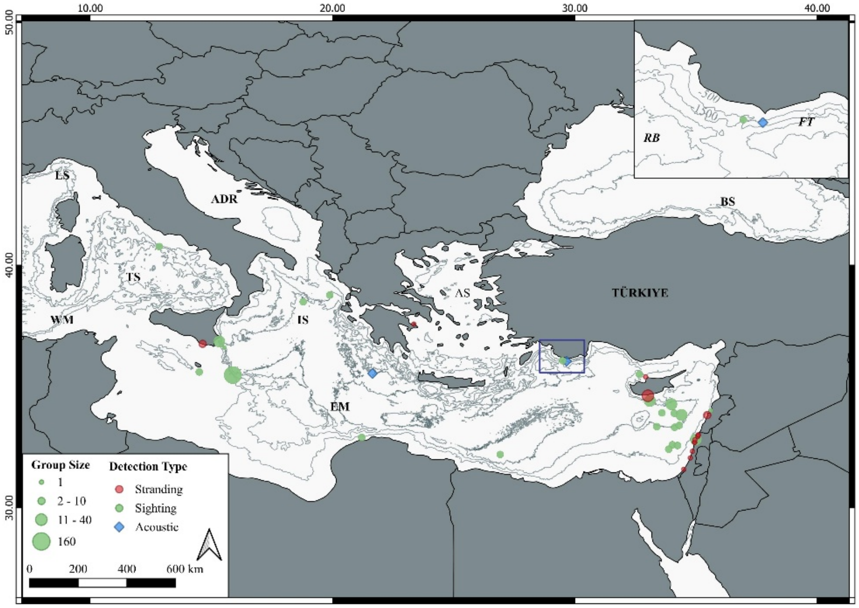

Figure 3. Spatial distribution of current and previous reports of rough-toothed dolphins in the Mediterranean Sea. Regions are abbreviated as follows: WM – West Mediterranean, LS – Ligurian Sea, TS – Tyrrhenian Sea, ADR – Adriatic Sea, IS – Ionian Sea, AS – Aegean Sea, EM – Eastern Mediterranean, BS – Black Sea, RB – Rhodos Basin, and FT – Finike Trough. Depth contours are shown at 1000 m intervals. The inset map highlights the most recent sighting and acoustic detection. Sources: ACCOBAMS (2021); Boisseau (2014); Boisseau *et al.* (2010); Caruso *et al.* (2019); Çanakçı *et al.* (2023); Eyre and Frizell (2023); Foskolos *et al.* (2023); Gnone *et al.* (2023); Gonzalvo (2009); Kerem (2020); Kerem *et al.* (2012, 2016); Ryan *et al.* (2014); Shoham-Frider *et al.* (2014); Watkins *et al.* (1987); Current paper

Additionally, the predominant swim formation varied with the behavioural activity of the group. While socialising was only recorded in the mix formation, front formation was observed during 67% of the time that dolphins were interacting with the boat and team formation was recorded during 50% of the time that dolphins spent travelling. In contrast, diving behaviour was observed across various swim formations, with similar proportions of each of the observed swim formations (Table 3).

After the examination of 718 pictures taken in the field, it was found that all 11 individuals seen in the drone footage were photographed with good-quality images (Annex 1). Nine individuals with recognisable marks were added to the photo-identification catalogue in FlukeBook software, allowing for re-capture. The two sub-adults lacked distinctive individual identification cues.

Figure 4. Example of drone footage from the encounter
(The middle frame demonstrates the two sub-adults next to the adult in the front row.)

Table 3. The variation in proportion of swim formations whilst dolphins were engaged in different behavioural states.

	Swim Formation					
Behaviour	**Alone**	**Front**	**Leader**	**Line**	**Mix**	**Team**
Diving	10	20	10	20	20	20
Interaction	16.7	66.7	0	0	0	16.7
Socialising	0	0	0	0	100	0
Travelling	0	7.1	14.3	7.1	21.4	50

A total of 113 minutes and 53 seconds of acoustic recordings, where visual confirmation was also present, were processed, resulting in the identification of 330 tonal vocalisations. After removing 50 low-quality whistles, the dataset included 60 whistles and 220 harmonic whistles. Additionally, 108 burst pulses were identified and clicks were detected, primarily with a peak frequency of 38-42 kHz. For harmonic whistles, AC was the most common contour shape (n=44), closely followed by A (upsweep contour) (n=43) and F (multiwave) (n=35), with the remaining shapes showing similar frequencies of detection, with shape B (downsweep) having the lowest detection rate (n=3) (Figure 5). For whistles, the most common shapes were A (upsweep contour) (n=58), AC (upsweep with a shoulder) (n=24), and C (flat) (n=22), while other contour shapes were detected less frequently, and BC (downsweep with a shoulder) and F (multiwave) not recorded at all (Figure 6).

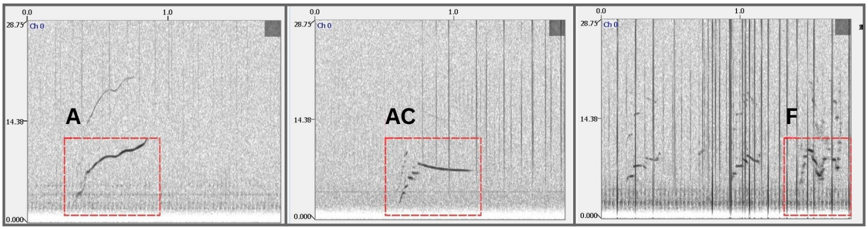

Figure 5. Example contour shapes of three harmonic whistles recorded during the encounter (the letters above the figures represent their relevant contour shapes).

Segments were evident in 76% of all detected harmonic whistles, whereas only 28% of all whistles had segments. The mean number of segments was 3.94 and 4.03 for whistles and harmonic whistles, respectively. The maximum number of segments was 16 for harmonic whistles and 11 for whistles. For harmonic whistles, the most frequently detected number of segments was three (n = 57), followed by four segments (n = 36). For whistles, two and three segments were most common, with each present in five detections.

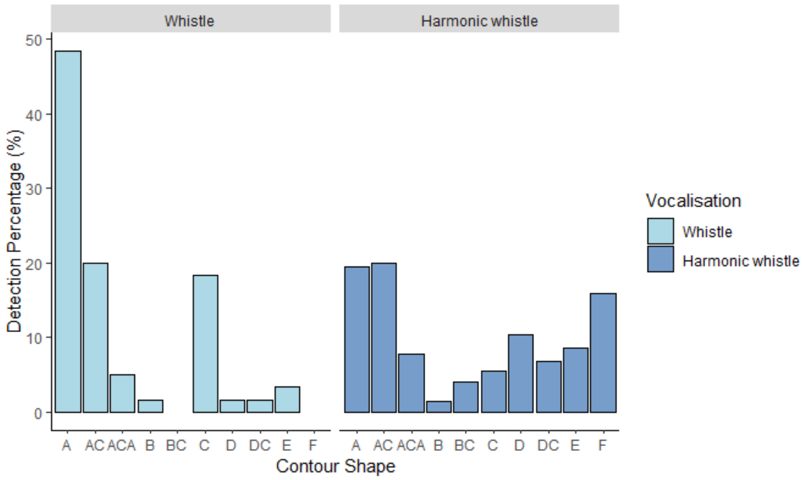

Figure 6. Frequency of detection of the contour shapes for tonal sounds

The frequency variations of the non-harmonic whistles were summarised in Table 4.

Table 4. Summary of selected whistle parameters (SE=Standard error)

Parameters	Min	Median	Mean	SE	Max
Low Frequency (Hz)	1988	4706	5081	220.71	9292
High Frequency (Hz)	5110	8954	9530	311.2	17835
Peak Frequency (Hz)	2075	7080	6984	279.75	12329
Delta Frequency (Hz)	467.7	3952.8	4449.3	379.17	14204.5
Delta Time (s)	0.0411	0.2455	0.3042	0.028	0.9344

The peak frequency of contour shapes of whistles displayed slight variations, with the median peak frequency highest for ACA (two upsweeps) at 9155 Hz, followed by A at 7934 Hz. The lowest median peak frequency was recorded for shape E (concave) at 5981 Hz. The highest variation was recorded for contour shape A, while contour shape E (concave) had the lowest variation in peak frequency (Figure 7). In terms of delta time (whistle duration), ACA exhibited the longest median duration at 0.40 s, followed closely by AC at 0.31 s. The remaining assessed whistles had similar median durations of 0.20 s. The highest variability in whistle duration was observed for contour shapes AC and A (Figure 7). Contour shapes B, D, and DC were excluded from this part of the analysis due to their limited occurrences.

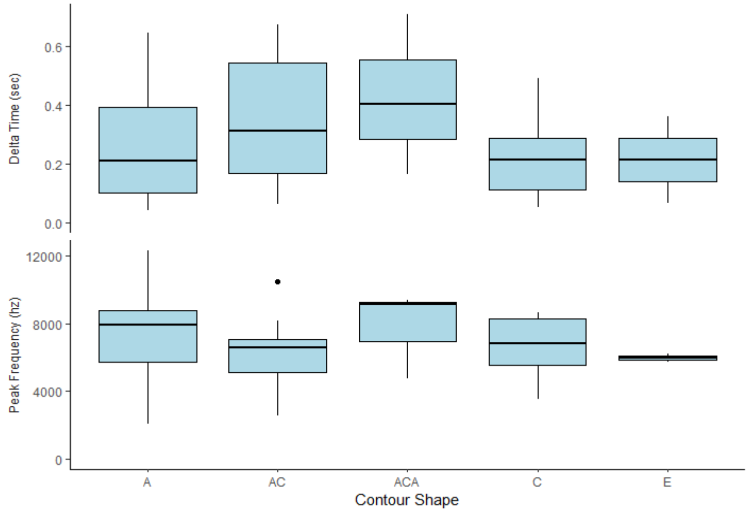

Figure 7. The variation in peak frequency and delta time for selected contour shape of whistles (While the box represents the central range of the data, the whiskers show the range excluding the outliers.)

Regarding the harmonic whistles, their duration ranged from 0.05 to 1.2 s, with a mean duration of 0.45 ± 0.02 s. The highest variation in harmonic counts was recorded for the contour shape F, with two harmonic counts predominantly recorded for most of the other whistle types. Up to ten harmonic counts including the fundamental whistle were also noted during the encounters (Figure 8).

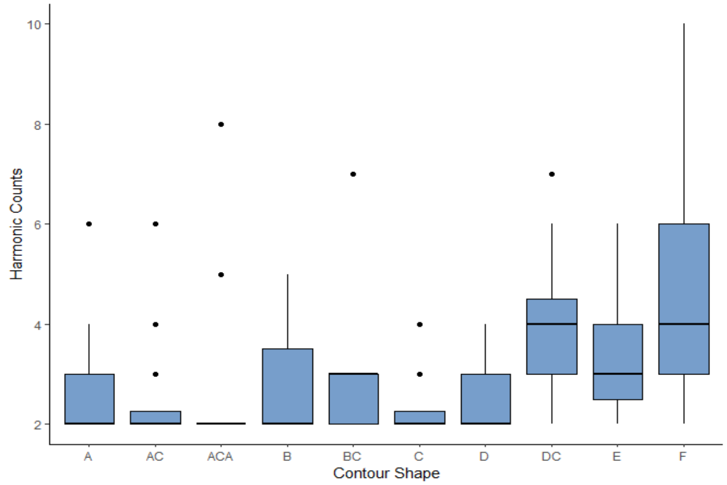

Figure 8. Number of harmonic counts for the different contour shapes of harmonic whistles

The sample size for the acoustic and visual behavioural analysis consisted of data from 50 distinct occasions where acoustic recordings coincided with visual observations from the deck. Vocalisation analysis revealed that whistles, harmonic whistles, and burst pulses were detected on 30, 20, and 22 occasions, respectively, during concurrent visual observations. Whistles were predominantly recorded during diving, followed by interactions with the boat. A similar pattern was observed for harmonic whistles, with both diving and interaction states showing an equal number of harmonics. Burst pulses were recorded most frequently during interactions, closely followed by diving behaviour. Traveling and socialising exhibited a limited number of vocalisations during the encounter, however, their frequency of occurrence with concurrent acoustic information was also the lowest during the encounter (Table 5).

Table 5. Number of vocalisations recorded across selected behavioural states (numbers in parentheses indicate the frequency of occurrence of behaviour)

	Vocalisation Type		
Behaviour	**Whistle**	**Harmonic**	**Burst Pulse**
Travelling (4)	0	1	1
Diving (32)	12	14	9
Socialising (4)	1	1	2
Interaction (29)	7	14	10

Discussion

The Eastern Mediterranean Sea has been recognised as one of the two primary habitats for rough-toothed dolphins within the Mediterranean Sea. This study marks the first confirmed sighting within Turkish waters thus extending its known range within this habitat. It also provides valuable insights into the visual and acoustic behaviour of this under-studied species. Considering that the number of authenticated encounters with this species is limited, any additional scientific data allow for improved evaluation of the population status of rough-toothed dolphins within the Mediterranean Sea.

There have been 38 reports of rough-toothed dolphins since 1985 (Figure 3). While the only record in the Aegean Sea originates from a stranding event, the species has been recorded during three separate sightings in the Ionian Sea. The remaining 34 reports come from the Eastern Mediterranean, including 19 live sightings, one acoustic recording, and the remaining cases reported as bycatch victims and strandings.

Although the current study documented two encounters, with the first being exclusively acoustic, it is probable that these represent the same group of rough-toothed dolphins. The encounters were separated by a distance of 10 km over a time interval of 10 hours. Delphinids are reported to travel at speeds ranging from

5 to 10 km/hour (Ritter 2002; Wells *et al*. 2008; Wiggins *et al*. 2013), and in this study, estimated speed was almost 2 km/hour (visual encounter). Even at the lower estimate of 2 km/hour, the group could have traversed the 10 km distance in approximately 5 hours. This suggests that the two encounters likely represent a single group. However, the possibility of independent encounters cannot be completely excluded.

Additionally, the habitat preference of rough-toothed dolphins in the current encounter aligns with previous findings both within the Mediterranean Sea and the wider global oceans (West 2002; Baird *et al*. 2008; Jefferson 2009; Foskolos *et al*. 2023), as the encounters reported in the current study occurred between 10 and 17 km from the coast in water depths of 1000 to 2000 metres, respectively. Ritter (2002) and Kerem (2020) highlighted the importance of sea surface temperature in determining the spatial preferences of rough-toothed dolphins, with a preference for waters above 20°C (Jefferson 2009). Off Kaş, the temperature typically fluctuates between 27 and 30°C, and on the day of the encounter, modelling based on sea surface temperature satellite data estimated the temperature at 29.95°C (Clementi *et al*. 2025). This suggests the conditions were potentially favourable for the species. However, further dedicated study is needed to thoroughly assess how environmental variables influence their regional habitat preferences.

The visual encounter was made with 11 individuals, including two sub-adults. The dolphins formed tight subgroups of three to four individuals, demonstrating a fluid composition where individuals frequently moved between different subgroups. The presence of tight subgroups throughout their global distribution range appears to be a characteristic feature of the species (Ritter 2002; West 2002; Götz *et al*. 2006; Baird *et al*. 2008; Jefferson 2009), although they have also been recorded as solitary individuals (Kucjaz and Yeater 2007). Conversely, tight subgroups formation might be caused by drone presence in the field (Castro *et al*. 2021). Previous studies documented the formation of tight subgroups when resting, both on the surface and when submerged (Ritter 2002; Götz *et al*. 2006; Jefferson 2009). The species also shows limited avoidance behaviour towards boats when in close proximity (Ritter 2002). The current study also found that travelling and interaction with the boat were the main behavioural activities observed during the encounter. As marine traffic in deep waters increases, rough-toothed dolphins in the Mediterranean may face a heightened risk of collisions or disturbances, especially if they do not actively avoid vessels (David 2002; Weilgart 2007; Awbery *et al.* 2022).

The vocal behaviour of rough-toothed dolphins in the Mediterranean remains largely unexplored, with only a handful of studies addressing the acoustic characteristics of the species in the Mediterranean Sea (Ryan *et al.* 2014; Kerem *et al.* 2016; Caruso *et al.* 2019; Foskolos *et al.* 2023). During the current encounter, harmonic whistles formed 80% of the total tonal sounds, of which 76%

were segmented. Both non-harmonic and harmonic whistles were predominantly recorded during interactions with the boat and diving behaviour, while burst pulses were recorded in most cases during diving. Although the number of dolphin interactions with the boat recorded with concurrent visual and acoustic sampling was too limited to draw any meaningful conclusions, it provides a foundation for future studies.

Despite limited knowledge on the potential role of harmonics in dolphin communication (Lammers and Au 2003), it has been proposed that they are likely to aid in group cohesion and have been documented to alter under different levels of ambient noise (Marley *et al*. 2017; Fouda *et al*. 2018). Further, it is believed that they may contain information that allows the listener to infer the position and movement direction of the vocalising animal (Lammers and Au 2003; Lammers and Oswald 2015; La Manna *et al*. 2019). It is important to note that the directionality of the focal group during the acoustic recording can considerably influence the number of harmonics detected. Specifically, recordings of the harmonic calls increase markedly when the group is both in close proximity to and facing in the direction of the array (Lammers and Au 2003; Rasmussen *et al*. 2006; Branstetter *et al*. 2013; La Manna *et al*. 2019). During the current study, the research boat was drifting without the engine in gear, and the focal group remained in close proximity to the boat. While the high number of harmonics recorded could be attributed to the dolphins' proximity to the array, it is equally plausible that the non-harmonic whistles were emitted independently of this proximity. The stationary position of the boat eliminates the confounding factor of engine noise or movement, suggesting that the likelihood of recording harmonics versus non-harmonics may not solely depend on the dolphins' proximity but also on the natural variation in their vocal behaviour (Lammers *et al.* 2003). As with the current study, upswept-segmented contour shapes have previously been identified as the main whistle recorded in rough-toothed dolphin encounters in the Ionian and Aegean Seas (Watkins *et al*. 1987; Kerem *et al*. 2016; Caruso *et al.* 2019; Foskolos *et al.* 2023). Segmented whistles appear to be a distinguishing feature of rough-toothed dolphin vocalisations globally. This characteristic could be used to enhance the ability of classifiers for species identification from acoustic recordings (Ryan *et al.* 2014; Kerem *et al.* 2016).

The peak frequency of the whistles was recorded at an average of 7 kHz, with mean low and high frequencies of 5 kHz and 9.5 kHz, respectively. The mean whistle duration of 0.3 s is shorter than previously reported, although harmonic whistles had a slightly longer mean duration of 0.45 s. Caruso *et al*. (2019) documented a whistle duration of 0.7 s based on seven whistles produced by a solitary individual in the Ionian Sea in July 2017; they also analysed the data from Watkins *et al*. (1987), gathered from the largest recorded aggregation of the species, which were reported to have a mean duration of 0.6 s. Kerem *et al*. (2016) reported a mean duration of 0.5 s. The variations observed between different regions of the Mediterranean Sea are likely due to the limited number of acoustic reports available and it is currently challenging to draw conclusions about regional differences in whistle characteristics for Mediterranean rough-toothed dolphins.

While the present study addresses a significant gap in our understanding of the spatial distribution and behavioural patterns of rough-toothed dolphins in the Mediterranean Sea, expanding the dataset with more comprehensive visual and acoustic recordings from multiple encounters is crucial. Such data will be essential not only for assessing the population's status but also for understanding acoustic characteristics and evaluating potential geographic variation. This study emphasises the importance of long-term, dedicated research, particularly in understudied regions such as the easternmost Mediterranean (Mannocci *et al.* 2018), to enhance our knowledge at both local and regional scales.

Acknowledgements

We would like to express our sincere gratitude to the Ministry of Agriculture and Forestry General Directorate of Nature Conservation and National Parks of the Republic of Türkiye. We extend our gratitude to the Turkish Coast Guard Antalya Group Command, Southern Aegean Group Command, and Eastern Mediterranean Group Command for ensuring the safety of our surveys. We are also grateful to the Ambassade de France en Turquie for providing us with the necessary funding to complete this research. Additionally, we appreciate those who provided logistical support including Setur Kaş Marina and Setur Finike Marina for welcoming our research boat and crew. We are grateful to WWF-Türkiye for their endless support of our work. Lastly, we want to thank Leyla Israpilova and Uğraş Metin for their contributions to data collection in the field.

Competing Interest: No potential conflict of interest was reported by the authors.
Ethics committee approval: There is no necessity for ethical approval for this research.
Financial disclosure: This research received fundings from Ambassade de France en Turquie.
Author Contributions: AA planning the surveys. AA, AD, CO, PL collection of the data. AA and TA behaviour, group composition and drone footage analysis. AA, AD, CO, PL acoustic data analysis. CO photo-identification analysis. PL acoustic consultant. AA wrote the initial manuscript draft with input from all the authors. All authors contributed to the article and approved the submitted version.

Türkiye'nin Doğu Akdeniz sularında kaba dişli yunuslar (*Steno bredanensis*) üzerine ilk bilimsel kayıt

Öz

Kaba dişli yunuslar, küresel dağılımlarına rağmen Akdeniz'de az çalışılmış türler arasında yer almaktadır ve tüm havza içinde yalnızca sınırlı sayıda gözlem ve karaya vurma raporu kaydedilmiştir. Türkiye'nin Doğu Akdeniz sularında gerçekleştirilen bu çalışmada, Fethiye Körfezi ile Finike Çukuru arasında 3.922 km²'lik bir alanı kapsayarak, standart hat-transekt mesafe örnekleme yöntemi izlenmiştir. 12 - 21 Temmuz 2024 tarihleri arasında toplam 10 gün gözlemler yapılmıştır. Araştırmada görsel kayıtlar, akustik veriler ve drone tabanlı analizleri içeren metodoloji kullanılmıştır. 18 Temmuz'da, tanımlanamayan bir yunus türü ilk kez 1.000 metre derinliklerde saat 04:06'da akustik olarak kaydedilmiş, ardından aynı gün içerisinde 2.000 metre derinliklerde saat 14:40'da kaba dişli yunuslar, görsel olarak kayıt altına alınmıştır. Her iki gözlem de Kaş ilçesi açıklarındaki Finike Çukurunda gerçekleşmiştir. Araştırma sonrasında yapılan analizler, gerçekleştirilen ilk akustik kaydın da kaba dişli yunus türüne ait olduğunu doğrulamaktadır. Kaba dişli yunus grubunun 10 km'lik mesafeyi 10 saatlik bir süre içinde kat etmesi muhtemel olduğu göz önüne alındığında, bu iki kaydın aynı grup olması olasıdır. İki genç birey de dahil olmak üzere 11 bireyden oluşan grupta, bireylerin sıkı formasyonlarda ve akışkan yapı içinde olduğu birkaç alt grup oluşturduğu gözlenmiştir. Karşılaşma boyunca hayvanlar, araştırma teknesine karşı, gözle görülür bir kaçınma veya uzaklaşma davranışı göstermemiştir. Harmonik ve harmonik olmayan ıslıklar, ağırlıklı olarak dalma davranışı ve araştırma teknesiyle etkileşim davranışlarıyla ilişkilendirilmiştir. En yaygın ıslık tipi, çoğunlukla 10 kHz'in altında olan ve yükselen kontur şekline sahipken, segmentli yükselen ve dalgalı harmonik özellikleri taşıyan tonal sesler oldukça yaygın olarak gözlenmiştir. Bu çalışma, kaba dişli yunuslarla Türkiye sularında teyit edilen ilk karşılaşmayı belgeleme ve bu türün Doğu Akdeniz'deki görsel ve akustik davranışlarını anlamamıza katkıda bulunmayı amaçlamaktadır.

Anahtar kelimeler: *Steno bredanensis*, Levantin havzası, dağılım, vokalizasyon, davranış

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Annex 1. Photographs of the right-hand side of each individual photographed