Marine Biodiversity (2019) 49:1587–1593
https://doi.org/10.1007/s12526-018-0926-1

SENCKENBERG

SHORT COMMUNICATION

First record of beaching events for a calycophoran siphonophore: *Abylopsis tetragona* (Otto, 1823) at the Strait of Gibraltar

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Received: 26 March 2018 / Revised: 2 August 2018 / Accepted: 8 October 2018 / Published online: 27 October 2018

Abstract

Two beaching events of the calycophoran siphonophore *Abylopsis tetragona* (Otto, 1823) were observed in two different areas of the Strait of Gibraltar during the cold season. The first was discovered on November 2014, on Getares Beach (Algeciras Bay, Mediterranean part of the Strait of Gibraltar), where more than 700 colonies were found deposited along the tideline. The second event was discovered on January 2015, on Paloma Baja Beach (Tarifa, Atlantic part of the Strait of Gibraltar) where an average density of 170 colonies m^{-2} was spread along the seashore. Both events seemed to be promoted by strong easterly winds, preceded by upwelling episodes that may have concentrated high densities of the siphonophore in superficial layers. This study represents the first report of a calycophoran siphonophore mass stranding. The records were made thanks to citizen science and jellyfish outreach at secondary schools (PERSEUS@school initiative), illustrating the importance of citizen science projects in observing natural phenomena. We consider the monitoring and recording of cnidarian stranding events especially important in highly productive and biologically active areas such as the Strait of Gibraltar.

Keywords Mass stranding · Gelatinous zooplankton · Citizen science · Outreach · Secondary schools

Introduction

Siphonophores are long pelagic colonial hydrozoans (Cnidaria) found throughout the world's oceans. They constitute a diverse and abundant group of gelatinous animals that are still poorly understood, due to their fragility and their, mostly, oceanic distribution (Pugh 1989; Haddock 2004). Nevertheless, some species are mainly coastal and neritic and they can reach very high abundances (Greve 1994; Pugh 1999; Mapstone 2014). To the suborder Calycophorae belong some of the smallest and most coastal living siphonophores, like the species *Abylopsis tetragona* (Otto, 1823). It is an abundant epipelagic siphonophore inhabitant of temperate and warm waters of the Atlantic, Pacific and Indican oceans and the Mediterranean Sea (Alvariño 1971; Mapstone 2014).

In the Strait of Gibraltar area, there are a few studies on the distribution and abundance of siphonophores, made more than 20 years ago. From them, we know that *A. tetragona* is a common and predominant species among the gelatinous zooplankters in the area (Bigelow and Sears 1937; Dallot et al. 1988; Mills et al. 1996). In the Mediterranean Sea and the Atlantic Ocean, this species is distributed mainly in the upper 50 m although it can be spread beyond 200-m depth (Pugh 1974; Gili et al. 1987a; Lučić et al. 2011) and occurs both in coastal and open waters (Bigelow and Sears 1937; Alvariño 1971; Gili et al. 1987a). According to Andersen et al. (1992), it can perform diel vertical migration of about 400 m, occurring in the upper 100 m at night. However, Buecher (1999) pointed out that in coastal waters the behaviour of *A. tetragona* must be different from offshore observations, with vertical migration being limited or negligible.

In the Mediterranean, *A. tetragona* is known to live all year around (Buecher 1999; Bouillon et al. 2004) with a main breeding period during spring (Bigelow and Sears 1937; Gili et al. 1987b). In the northwestern Mediterranean, the lowest abundances are found during the winter and the maxima

Communicated by S. Piraino

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during spring (Buecher 1999) and summer (Gili et al. 1987a). There are no studies on the feeding of this species. However, it is known that calycophoran siphonophores are voracious predators of zooplankton and they may constitute a considerable trophic impact in certain areas (Purcell 1982; Purcell and Kremer 1983; Pagès et al. 2001). In addition, they compete with the co-existing plankton, including higher trophic levels such as fish (e.g., Purcell and Arai 2001).

The Strait of Gibraltar (Fig. 1) is located at the southern tip of the Iberian Peninsula and connects the Gulf of Cadiz (Atlantic Ocean) with the Alboran Sea (Mediterranean Sea). Powerful local westerly and easterly winds affect the oceanography of the Strait, activating upwelling and downwelling episodes, respectively. During a westerly wind episode, Ekman transport typically drags the surface waters outwards and a deep current move towards the surface (upwelling), bringing up low-temperature waters with high nutrient concentrations. In contrast, when easterly winds dominate the surface currents flow inshore and a downwelling event can occur (Macías et al. 2008; Echevarria et al. 2009; Navarro et al. 2011). This scenario of high complex oceanography, where different water masses coexist and many frontal zones develop accumulating important phytoplankton biomasses, results in a hotspot region for marine biodiversity (e.g. Macías et al. 2006, 2009; Navarro et al. 2006).

Today, many reports of exceptional marine events and species sighting are published thanks to citizen participation in science (e.g. Boero et al. 2013; Kienberger and Prieto, 2016, 2017). More and more projects have been specifically designed to give citizens a role, some of them for the outreach and educational benefit of the volunteers, like the case of the PERSEUS project which involves scientists and secondary schools, (http://www.perseus-net.eu/site/content.php?locale=1&sel=519; Silvertown 2009). In addition, citizen science has become a request in many international project calls, like those under the European Commission's Horizon 2020 programme. Undoubtedly, the best way for the public to understand and appreciate nature and science is to participate in it (Silvertown 2009; Boero 2016). In the case of monitoring gelatinous macroplankton, citizen science has already been proved an effective tool (Boero et al. 2009; Kienberger and Prieto 2017).

This work reports on the first mass stranding events of a calycophoran siphonophore, *Abylopsis tetragona*. It occurred at the tip of the southern Iberian coast, the Strait of Gibraltar, on both the Atlantic and Mediterranean sides, during the cold season, November 2014 and January 2015. The records were made thanks to citizen science and outreach at a secondary school.

Material and methods

Study area

Algeciras Bay, on the Mediterranean side of the Strait of Gibraltar, is a semi-enclosed bay that opens into the waters of the northeastern boundary of the Strait (Fig. 1). The bay faces south-southeast and the bathymetry is characterized by a central canyon that reaches its maximum depth (about 450 m) and width at the mouth of the bay (Sammartino et al. 2014). The beach of Getares is located in the west side of the bay, just after the entrance, and faces east. On the Atlantic side, Paloma Baja Beach (Fig. 1) is situated at the most western point of the Strait of Gibraltar. It faces southwest and the continental shelf seaward is characterized by a very smooth bathymetry with depths shallower than 100 m (Luján et al. 2011).

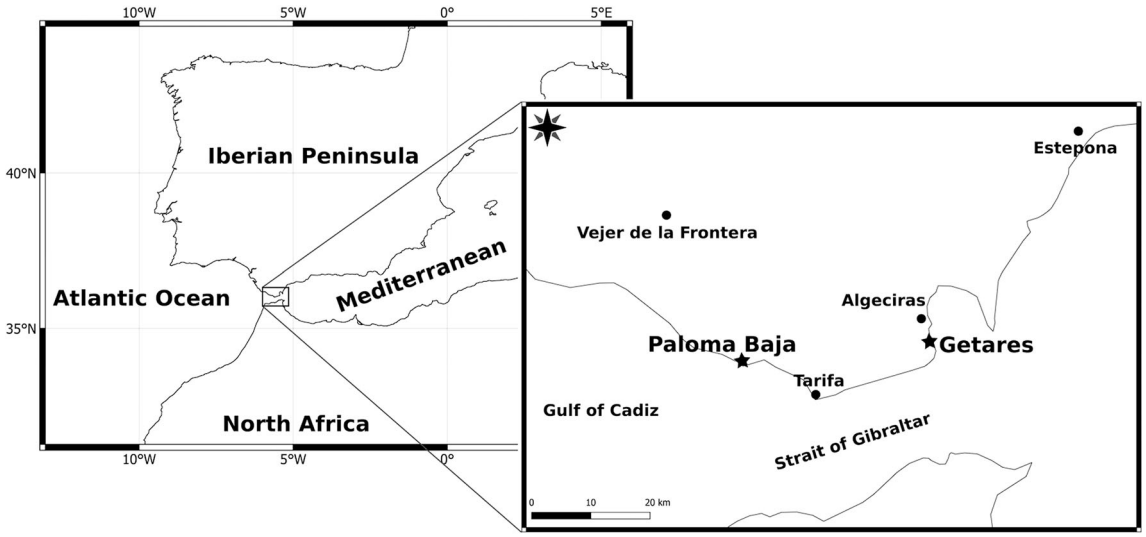

Fig. 1 Geographical location of the study area in the Strait of Gibraltar, southern tip of the Iberian Peninsula. Black stars represent the location of both beaching events, Getares Beach, Algeciras Bay, on November 21st and 22nd, 2014 and Paloma Baja Beach, Tarifa, on January 11th, 2015

Sampling

From October 2014 through February 2015, students of 1st bachelor of the high-school *María Auxiliadora* (Algeciras, Cádiz, Spain; Fig. 1) carried out daily beach surveys in order to monitor jellyfish strandings. These surveys were part of their school research project focused on gelatinous plankton, led by their biology teacher (Ana Villaescusa) and the *Instituto de Ciencias Marinas de Andalucía* (ICMAN-CSIC). This activity was inserted within the European PERSEUS@school project, an initiative working with school teachers to help and enhance marine environmental education and outreach on jellyfish in secondary schools. During these surveys, the first *A. tetragona* beaching event was recorded. The second event was discovered fortuitously by students of the same high-school during a geology field trip. Sample collecting was only possible during the first event, during which a total of 200 specimens were taken. Of these, some were preserved in 5% formalin for taxonomic identification at the Marine Science Institute (ICM-CSIC).

Meteorological and oceanographical conditions

Daily wind vector values were obtained from two meteorological stations (Junta de Andalucía), Estepona (36° 26′40″ N, 05° 12′35″ W), and Vejer de la Frontera (36° 17′06″ N, 05° 50′ 24″ W), these being the closest ones to Getares and Paloma Baja beaches, respectively. Both stations are relatively low-lying, at short distances off the coast and well exposed to the predominant winds of the Strait and the Gulf of Cadiz (http://www.juntadeandalucia.es/agriculturaypesca/ifapa/ria/servlet/FrontController?action=Init). Daily sea surface temperature satellite images were obtained to observe possible upwelling events in the studied area. The images were acquired from a 1-km advanced very high-resolution radiometer (AVHRR) Ocean Pathfinder Version 5 sea surface temperature (SST) dataset, belonging to the Physical Oceanography Distributed Active Archive Center at the NASA Jet Propulsion Laboratory (http://podaac.jpl.nasa.gov/accessed 2015 Jun 11). STT images were obtained from both previous days to the beaching and the closest possible day to each event. Additionally, daily water temperature average for the studied period was calculated from the in situ hourly sea surface temperature dataset obtained from the meteorological buoy placed in the NW part of the Strait of Gibraltar (Tarifa buoy; entity of Spanish Harbours).

Results

The siphonophore samples and pictures from both beaching events were taxonomically identified as *Abylopsis tetragona* (Figs. 2 and 3). The morphological identification of this species

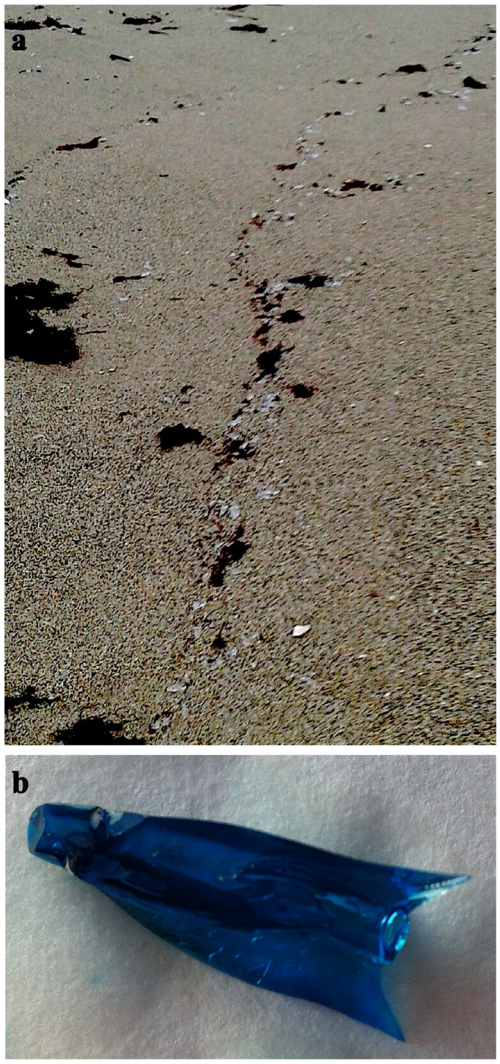

Fig. 2 Beaching event at Getares Beach, Algeciras Bay, on November 21st and 22th, 2014. **a** *Abylopsis tetragona* colonies deposited along the tideline at the sandy Getares Beach. **b** One of the colonies sampled by the students, dyed with methylene blue. Low-resolution pictures taken with a cell phone

is unmistakeable due to the characteristic shape of both the anterior and the posterior nectophores (Bigelow and Sears 1937; Mills et al. 1996). The first beaching event was found both on November 21st and 22nd, 2014 at Getares beach (36° 05′30″ N, 5° 26′37″ W; Fig. 1) in the Bay of Algeciras (Fig. 2) during an episode of stormy easterly winds with velocities up to 4.5 m s^{-1}, which lasted 3 days (Fig. 4). Here, more than 700 colonies were found deposited along the tideline for about 400 m of the beach (Fig. 2). Siphonophores were found together with the red algae *Asparagopsis armata* Harvey, 1855 (Fig. 2). This is a sandy beach, with a typical winter beach profile at the time of the stranding. During 15 days previous to this episode, continuous westerly winds with velocities up to 4.4 m s^{-1} were registered in the area (Fig. 4b). Simultaneously, the SST satellite images showed cold water in the coastal area of Algeciras Bay, supporting the concept of an upwelling event,

Fig. 3 Beaching event at Paloma Baja Beach, Tarifa, on January 11th, 2015. **a** *Abylopsis tetragona* colonies extended along the coastline of the sandy beach of Paloma Baja. **b** Detail of one of the beached colonies, with an estimated size of ca. 3 cm, in one of the students' hand (17.5 cm long). Scale bar: **b** = 1.0 cm

while during the strong easterlies warmer water was present in the area (Fig. 6).

The second beaching event was found on January 11th, 2015 at Paloma Baja Beach (36° 03′43″ N, 5° 43′28″ W; Fig. 1) in Tarifa during a windless day and just after 3 days of strong easterly winds with velocities up to 5.0 m s^{-1} (Fig. 5). Here, an estimated average density of 170 colonies m^{-2} extended for about 550 m along the coastline (Fig. 3) and no other organisms were found. This is a similar sandy beach, with a low profile at the moment of the event. In this case, no westerly winds were registered before the episode (Fig. 5b); however, cold water in the coastal area of the beach was observed in the SST satellite images, unlike the warmer water present during the easterlies (Fig. 6). Confirming this pattern, the SST data from Tarifa's buoy showed drops in water temperature during westerlies and increments during easterlies, framed in the general descent pattern due to the seasonal evolution of water temperature (Fig. 5).

In the two cases, only polygastric stages (anterior and posterior nectophores) were found but no eudoxids (sexual stage). No other gelatinous or non-gelatinous zooplankton organisms were found beached during the episodes (Figs. 2 and 3). In both cases, stranded colonies were relatively big in size (ca. 3 cm), probably all adult individuals (see Fig. 3).

Discussion

To the best of our knowledge, these events are the first records for a calycophoran siphonophore mass stranding. Among siphonophores only the pleustonic Portuguese Man-of-War, *Physalia physalis* (Linnaeus, 1758), has been reported stranded on shore (e.g. Araya et al. 2015; Prieto et al. 2015). Mass stranding events of gelatinous zooplankton organisms along shorelines are a natural and relatively common phenomenon strongly influenced by the direction and energy of prevailing winds and surface currents (Graham et al. 2001). In both cases reported here in the South coast of Spain, *A. tetragona* was found beached during or just after the course of 3 days of strong easterly winds, which might have been one of the main drivers for the stranding of the individuals. In addition, we think that the upwelling episodes detected in the previous days in both areas could have promoted the accumulation of the existing populations of *A. tetragona* throughout the water column to the surface layers and thus facilitated a high density of individuals being washed ashore during the easterly winds. In this context, substantially increased abundance of zooplankton organisms like medusae and copepods has been reported close to the coast during upwellings in other areas (Dunstall et al. 1990; Pagès and Gili 1992).

Recent studies in the area have reported stranding of the scyphomedusan *Rhizostoma luteum* (Quoy and Gaimard,

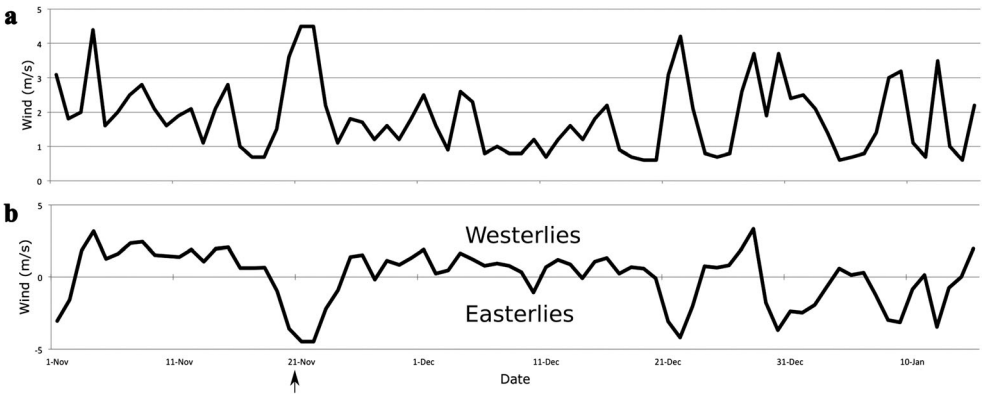

Fig. 4 Estepona time series of local winds. **a** Wind speed expressed as m/s. **b** Zonal component of the wind showing westerlies (positive values) and easterlies (negative values). Black arrow shows the date of the first beaching event

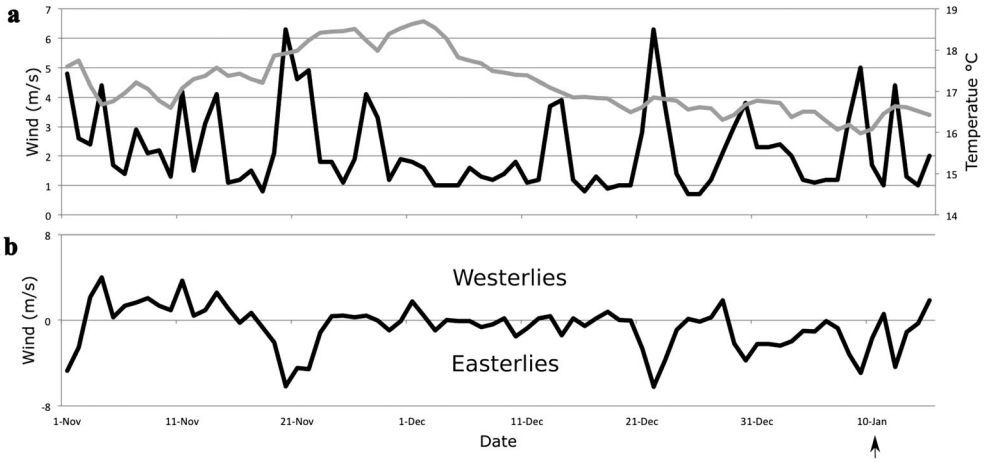

Fig. 5 Vejer de la Frontera time series of local winds. **a** Wind speed expressed as m/s (black line) and sea surface temperature (SST) recorded from the buoy offshore of Tarifa (grey line). **b** Zonal component of the wind showing westerlies (positive values) and easterlies (negative values). Black arrow shows the date of the second beaching event

1827) and the pleustonic siphonophore *P. physalis* on both sides of the Strait of Gibraltar (Prieto et al. 2013; Prieto et al. 2015). These two studies concluded that strong westerly winds were responsible for the stranding events in contrast to the easterly winds found to be responsible in the present study. We think the difference between these results could be for two reasons: firstly, the natural habitat of the stranded animals and secondly, the associated upwelling events previous to the beachings. For the first reason, *A. tetragona* is an epipelagic species presenting coastal populations (Bigelow and Sears 1937; Gili et al. 1987a) thus most probably inhabiting the nearby waters of the beaches where stranded. However, the stranded *P. physalis* and *R. luteum* found in the Strait of Gibraltar area come from the more open-ocean North Atlantic waters pushed by both the dominant currents, towards the Mediterranean, and the westerly winds, towards the southern Iberian coast (Prieto et al. 2013; Prieto et al. 2015). Nevertheless, other jellyfish species like the scyphomedusan *Pelagia noctiluca* (Forsskål, 1775), when occurring in waters of Algeciras Bay, had also presented stranding events during strong easterly winds episodes on a regular basis (Kienberger, per. obs.). Regarding the second reason, the existence of a high abundance of animals in the surrounding waters at the moment of the stranding is the primordial factor for observing these natural events (Graham et al. 2001; Houghton et al. 2007). In this context, the occurrence of upwelling events in

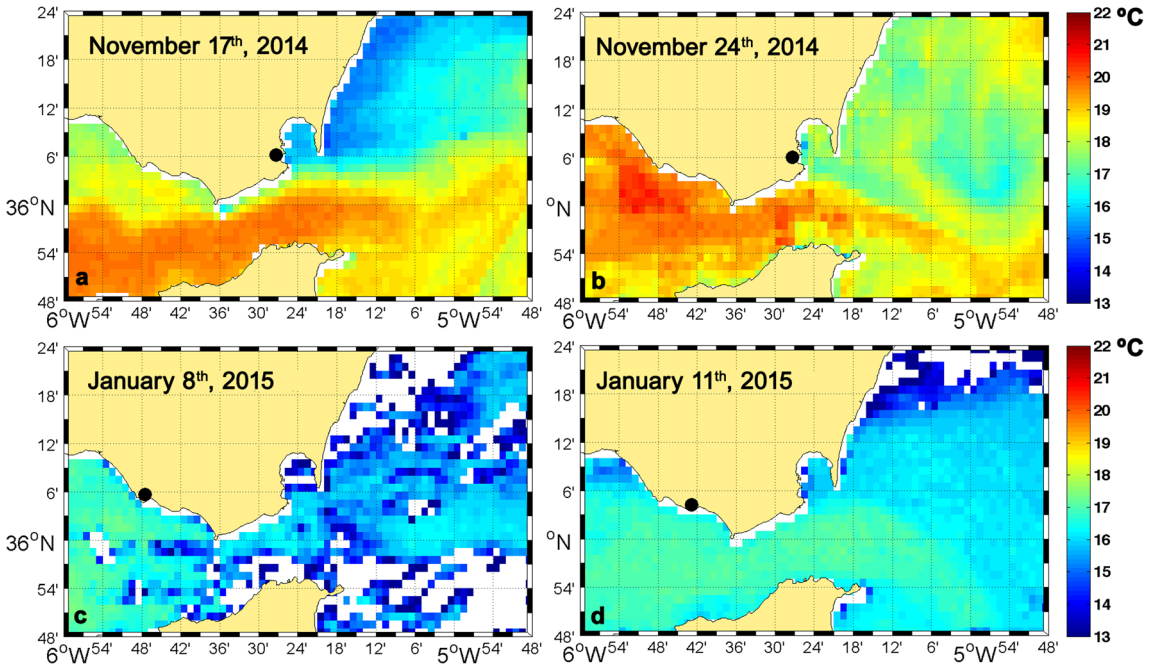

Fig. 6 Sea surface temperature (°C) satellite images (AVHRR sensor, 1 km^2 spatial resolution). **a** 4 days before the first beaching, in Getares Beach (black dot), while continuous westerly winds, showing cold water in the area. **b** 3 days after the first beaching, showing warmer SST after the intense easterly wind. **c** 3 days before the second beaching event, in Paloma Baja Beach (black dot), showing cold water in the area. **d** The same day of the second beaching, showing warmer SST after the intense easterly wind

both areas prior to strong easterly winds may be of importance in observing plankton strandlines (Davenport 1995).

Whether these calycophoran beaching events are usual or not in the area of the Strait of Gibraltar and whether they are seasonal episodes we cannot know from the information recorded here. Nevertheless, the observations made by Buecher (1999) in the Bay of Villefranche who found *A. tetragona* essentially in a mixed and cold water column and becoming less numerous in the surface layer when the seasonal thermocline develops, support the fact that the reported events occurred during the winter season, when the water column is homogeneous. Also, the higher frequency of strong and stormy winds during the cold season makes these events potentially seasonal as observed for other gelatinous zooplankton (Graham et al. 2001).

The fact that only polygastric stages (asexual) specimens of *A. tetragona* were found stranded on both beaches is an interesting result that could indicate the composition of overwintering populations of this group of siphonophores in the area (Houghton et al. 2007). Coincident with this result, Dallot et al. (1988) found basically polygastric stages on the Atlantic side of and in the Strait of Gibraltar itself during the months of October and November. Furthermore, the main breeding period for this species has been described as occurring during spring in the Mediterranean Sea (Bigelow and Sears 1937; Gili et al. 1987b).

We consider monitoring and recording of cnidarian stranding events of importance, since they may give information on life cycles, seasonality, spatial distributions, and historical occurrence (Houghton et al. 2007; Kienberger and Prieto 2017), especially in highly productive and biologically important areas such as the Strait of Gibraltar (Gómez et al. 2004; Navarro et al. 2011) where zooplanktivorous siphonophores may have a considerable trophic role (Purcell 1982; Pagès et al. 2001). Furthermore, some authors have pointed out the usefulness of documenting mass strandings as an index of future global changes (Flux 2009).

This work highlights the importance of marine and jellyfish scientific knowledge outreach in schools, the existence of projects promoting outreach and also the interaction between researchers, school teachers and students. This promotion of citizen science to increase the ocean literacy of people living near the sea is essential, as well as our sense of responsibility for the ecosystems that sustain us (Boero 2016).

In summary, this study represents the first report of a calycophoran siphonophore mass stranding event. The individual events seemed to be promoted by strong easterly winds, preceded by upwelling episodes that may have concentrated high densities of the siphonophore in superficial layers. This is a good example of the importance of citizen science projects, with cooperation between scientists and society and schools to improve knowledge of regular or exceptional natural phenomena.

Acknowledgments Special thanks to the students of first bachelor of the school María Auxiliadora (Algeciras): Beatriz Escobar, Irene Tirado, Paola Cuellar, Mario Mena, Quique Laza, Víctor Hernández, Daniel Jaén, Eduardo Conde and Pedro Martínez, and the students of 4° high-school of the same school: Cristina Martínez Pérez, Aurelio Sánchez Alfonso, Alejandro Pérez Romero and Manuel Jiménez González who informed about the second event. The students involved in the project won two first national prizes in two different young researchers competitions (April and June, 2015) and were finalists in the international Science on Stage competition (Hungary, July 2017) for their developed jellyfish research project. Thanks to Dr. G. Mapstone for encouraging this work and her valuable comments on the manuscript.

Funding KK, LP and GN were funded by PERSEUS European Project (FP7-287600). KK was also funded by the Rotary Club Genève Lac, Switzerland.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain studies with live animals performed by any of the authors.

Sampling and field studies All necessary permits for sampling and observational field studies have been obtained by the authors from the competent authorities and are mentioned in the acknowledgements, if applicable. The study is compliant with CBD and Nagoya protocols.

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