The European Zoological Journal

ISSN: (Print) 2475-0263 (Online) Journal homepage: http://www.tandfonline.com/loi/tizo21

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To cite this article: F. Betti, G. Bavestrello, M. Bo, M. Coppari, F. Enrichetti, M. Manuele & R. Cattaneo-Vietti (2017) Exceptional strandings of the purple snail Janthina pallida Thompson, 1840 (Gastropoda: Epitoniidae) and first record of an alien goose barnacle along the Ligurian coast (western Mediterranean Sea), The European Zoological Journal, 84:1, 488-495, DOI: 10.1080/24750263.2017.1379562

To link to this article: http://dx.doi.org/10.1080/24750263.2017.1379562

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Published online: 10 Oct 2017.

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The European Zoological Journal, 2017, 488–495
Vol. 84, No. 1, https://doi.org/10.1080/24750263.2017.1379562

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Exceptional strandings of the purple snail *Janthina pallida* Thompson, 1840 (Gastropoda: Epitoniidae) and first record of an alien goose barnacle along the Ligurian coast (western Mediterranean Sea)

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(Received 7 June 2017; accepted 7 September 2017)

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Abstract
During spring 2017, starting from 12 May, exceptional strandings of the purple snail *Janthina pallida* were recorded in the Ligurian Sea and along the western coast of Sardinia Island, under the effect of southern winds. The strandings continued for 3 days, until 15 May, when the winds shifted to the northern quadrant and the specimens were drifted back offshore. Such extensive strandings have never been previously reported in the scientific literature, either along the Mediterranean shores or elsewhere. Thanks to citizens' help, it was possible to create a map of the strandings and obtain a gross estimate of the number of beached gastropods. The densities of the stranded animals reached an overall average of 801 ± 215 specimens m^{-2} (with peaks of over 2000 shells and rafts m^{-2} densely packed with hydrozoan *Velella velella* sails), corresponding to an average biomass of about 1.5 kg m^{-2}. The size–frequency distribution of the shell heights showed a bi-modal trend, as is usual in the case of sequential hermaphroditism: almost all the specimens fitting the first mode (11 mm) showed a raft without eggs (males), while all the specimens belonging to the largest mode (23 mm) had rafts with settled egg cases (females). The general trend of the sea currents in the North-western Mediterranean Basin explains the spatial distribution of the strandings following 3 days of constant southern moderate breeze (up to 28 km h^{-1}). The presence of such huge *J. pallida* banks in the Ligurian Sea is stochastic, probably linked to an Atlantic population entering through the Gibraltar Strait, as evidenced by the simultaneous presence of the buoy barnacle, *Dosima fascicularis*, a circumtropical species recorded here for the second time in the Mediterranean Sea.

Keywords: *Pleuston, bloom, strandings, alien species, Mediterranean Sea*

Introduction

The genus *Janthina* Röding, 1798 comprises seven pleustonic, draft-builder gastropods, the so-called purple sea snails, distributed worldwide mainly in warm and temperate waters. They float under a raft of air bubbles enveloped in a thin, transparent sheet of glycoproteins and, being unable to swim, die if detached from their rafts (Lalli & Gilmer 1989). They prey upon pleustonic hydrozoans (Bayer 1963; Bieri 1966; Lalli & Gilmer 1989) and are often preyed upon by juvenile loggerhead turtles *Caretta caretta* (Linnaeus, 1758) (Van Nierop & Den Hartog 1984). *Janthina* species are often found floating in large groups which, under the effect of unfavourable winds, may be blown ashore (Wilson & Wilson 1956; Wilson 1958).

In the Mediterranean Sea, four valid species belonging to the genus *Janthina* are present, although records of them in the scientific literature are rare. One or a few specimens were reported stranded along the coast of the Tyrrhenian and Ionian seas (Spada & Garavelli 1969; Cachia 1981; Berdar et al. 1982) or buried in deep sediments (Di Geronimo 1974; Janssen 2012). The only strandings observed in the

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Tyrrhenian Sea were reported by Palazzi (1979), who found 280 shells of *Janthina pallida* Thompson, 1840 on a beach in North-west Sicily, and by Repetto (1989) who observed numerous specimens of *Janthina globosa* Swainson, 1822, associated with some *Velella velella* (Linnaeus, 1758) along the Tuscany coast (July 1988). In the Adriatic Sea, *Janthina* species are particularly rare, and their records were summarised by Crnčević and Cetinić (2016). During spring 2014, 2015 and 2016, numerous specimens of *J. pallida* were recorded along the coast of the Ligurian Sea contemporaneously with strandings of *V. velella* (Betti, unpublished data).

Extensive strandings of *Janthina* spp. seem rare along the coasts of the Mediterranean, but could have been more usual in ancient times: according to some Jewish scholars, the blue pigment of these species was used to dye prayer shawl fringes (Mienis & Spanier 1987; Cattaneo-Vietti 2015), suggesting a wider supply of these organisms.

Herein, we report data regarding exceptional strandings of this purple snail that occurred between 12 and 16 May 2017, affecting a large part of the North-western Mediterranean basin.

Materials and methods

The quantitative characterisation of the strandings of *Janthina pallida* was conducted following two working protocols.

Thanks to the involvement of about 100 persons (mainly university students, workers in Marine Protected Areas (MPAs), fishermen and other volunteers participating through social networks), operating from 12 to 16 May, data were obtained along all the beaches of the Ligurian coast as well as in other localities (Tuscany, Sardinia, Côte d'Azur) (Table I). Each volunteer was asked to send the authors images of the explored areas for the evaluation of the magnitude of the phenomenon (date, locality, presence/absence, density estimate, presence of eggs, presence of associated organisms) together with any other personal observations. These data were used to create a distribution map of the strandings with abundance information. Occasional monitoring at sea was carried out in the preceding and following periods thanks to scientific field operations as well as sightings by fishermen.

In the meantime, 11 localities of the Ligurian coast were visited (Table II) to quantify the abundance of the beached individuals, by counting the number of shells/rafts present in five standard surfaces of 50 × 50 cm for each site. All specimens present in one square from five different localities were collected and studied in the laboratory to verify the taxonomic identification, to obtain morphometric data of the shells (height × width, mm), and to obtain their wet weight (g). In addition, the rafts of all these specimens were checked to document the presence of egg cases.

All information was linked to the wind direction and intensity during the examined period; these data were obtained from the Liguria Region meteorological network (https://www.arpal.gov.it/homepage/meteo/previsioni/bollettino-liguria/riassunto.html).

Results

Dynamics of the strandings

From 30 March until 5 May, intense strandings of the hydrozoan *V. velella* were recorded in the Ligurian Sea. Mixed with them, several specimens of *Janthina* were observed too. The bubble rafts of all these specimens were lacking eggs. Taxonomic verification of the snails resulted in the identification of *J. pallida* (Figure 1(a)) as the only *Janthina* species present.

On 12 May, early in the morning, a wide bank of *J. pallida* was observed some kilometres off the eastern Ligurian coast. In the afternoon, under the effect of southern winds up to 15 kn (28 km h^{-1}), the floating rafts concentrated in-shore (Figure 1(b)) and begun to strand along the whole Ligurian Arc (Figures 1(c–e), 2, –3). The strandings continued for the following 3 days (Table I), with massive abundances, until the morning of 15 May, when high tide arose and the winds shifted to come from the northern quadrants (Figure 2). The banks were then driven back out to the open sea. In some localities, monitored continuously for the entire period, the stranded banks disappeared over one night to the next day (Table I). Finally, on 30 May, numerous rafts (without the molluscs) with dried-out egg cases were observed floating 30 mi. (56 km) off the harbour of Genoa.

It was possible to create a map of the strandings that involved the entire Ligurian Sea from Cannes (Côte d'Azur, France) to Framura, close to the harbour of La Spezia, with some exceptions such as the western side of the Portofino Promontory (Table I). The strandings involved also the Tuscany coast, up to the Baratti Gulf, and the western coast of Sardinia, from Iglesias to Alghero and inside the Asinara Gulf, but no stranded specimens were

Table I. Estimated abundance of the stranded *Janthina pallida* in several localities of the North-western Mediterranean Sea.

Sector	Locality	Coordinates	12 May 2017	13 May 2017	14 May 2017	15 May 2017	16 May 2017
LIGURIAN COASTS							
Eastern	Framura	44°12'25"N, 09°32'55"E			**		
Riviera	Riva Trigoso	44°15'26"N, 09°25'33"E	0	***	**		
	Sestri Levante	44°16'16"N, 09°23'33"E	0		**	**	
	Cavi di Lavagna	44°17'46"N, 09°21'58"E		0			
	Lavagna	44°18'19"N, 09°20'44"E	0		0	0	
	Chiavari	44°19'01"N, 09°18'51"E	0		0	0	
	Zoagli	44°20'05"N, 09°16'03"E	0				
	Rapallo	44°20'53"N, 09°13'58"E	0	***	0		0
	Rapallo, San Michele	44°20'24"N, 09°13'01"E	**	**			
	S. Margherita	44°20'09"N, 09°13'27"E	0	0			
	S. Margherita, Covo	44°19'27"N, 09°13'01"E			***		
	Paraggi	44°18 39"N, 09°12'41"E			***		
	Camogli	44°20'55"N, 09°09'08"E		0			
	Recco	44°21'35"N, 09°08'30"E		0	0		
	Sori	44°20'13"N, 09°06'04"E		0			
	Bogliasco	44°22'39"N, 09°04'06"E		*	***	0	
	Genova, Capolungo	44°22'49"N, 09°03'26"E			***		
	Genova, Nervi	44°22'59"N, 09°01'58"E		0			
	Genova, Quinto	44°23'04"N, 09°01'02"E		0	***	***	0
	Genova, Priaruggia	44°23'10"N, 09°00'11"E		0	*	0	
	Genova, Quarto	44°23'14"N, 08°59'49"E		0		0	
	Genova, Sturla	44°23'31"N, 08°59'01"E			***	***	*
	Genova, Boccadasse	44°23'22"N, 08°58'24"E			**		
	Genova, Lido	44°23 22"N, 08°58'06"E			***	0	
Western	Genova, Pegli	44°25'27"N, 08°48'48"E		***	***		
Riviera	Genova, Voltri	44°25'37"N, 08°45'10"E		***	***	***	
	Arenzano	44°24'28"N, 08°41'32"E	***	***	***	***	
	Cogoleto	44°23'20"N, 08°38'49"E				**	**
	Varazze	44°21'33"N, 08°34'54"E		*			*
	Celle Ligure	44°20'28"N, 08°32'47"E		**	**		
	Albisola	44°19'41"N, 08°30'37"E		***	***		
	Savona	44°19'06"N, 08°29'39"E		0	*		
	Bergeggi	44°14'59"N, 08°26'51"E			0		
	Bergeggi, Maiolo	44°14'21"N, 08°26'36"E			**		
	Spotorno	44°13'48"N, 08°25'26"E		0		***	
	Noli	44°12'14"N, 08°25'01"E		***	**		
	Varigotti	44°10'51"N, 08°23'31"E		**		0	
	Finale Ligure	44°10'17"N, 08°21'26"E		**	***		
	Borgio Verezzi	44°09'28"N, 08°18'43"E				***	
	Pietra Ligure	44°08'56"N, 08°17'12"E	***	***	***	***	
	Loano	44°07'30"N, 08°15'34"E	***	***	***		
	Borghetto S. Spirito	44°06'28"N, 08°14'32"E			0		
	Ceriale	44°05'41"N, 08°14'01"E			0		
	Alassio	44°00'46"N, 08°10'52"E	**	***	***		
	Riva Ligure	43°50'10"N, 07°52'30"E					***
	Ospedaletti	43°48'01"N, 07°42'59"E		***	0		
	Vallecrosia	43°46'53"N, 07°38'52"E			**		
	Ventimiglia	43°47'14"N, 07°36'28"E			*		
OTHER LOCALITIES							
	Baratti (Tuscany)	42°59'46"N, 10°30'50"E			**		
	Rosignano (Tuscany)	43°22'31"N, 10°26'16"E		**			
	Leghorn (Tuscany)	43°36'8"N, 10°17'30"E					***
	Tavolara Is. (Sardinia)	40°52'33"N, 09°39'43"E		0			
	Asinara Gulf (Sardinia)	40°49'19"N, 08°29'20"E			***		
	Alghero (Sardinia)	40°34'30"N, 08°19'43"E		**			
	Iglesias (Sardinia)	39°16'42"N, 08°25'45"E		*			
	Oristano Gulf (Sardinia)	39°54'09"N, 08°31'33"E		*			
	Mandelieu (Côte d'Azur)	43°32'28"N, 06°57'05"E		***			

0, absence of shells/rafts; *, < 200 shells/rafts m^{-2}; **, 200–1000 shells/rafts m^{-2}; ***, > 1000 shells/rafts m^{-2}.

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Table II. Estimated abundance of the stranded *Janthina pallida* in several localities of the Ligurian coast.

Locality	Coordinates	Date	Average density (N m^{-2})	Notes
Rapallo, San Michele	44°20'24"N, 09°13'27"E	12 May 2017	164.0 ± 58.5	Mixed with *V. velella*
Bogliasco	44°22'39"N, 09°04'06"E	13 May 2017	12.8 ± 2.3	Mixed with *V. velella*
Bogliasco	44°22'39"N, 09°04'06"E	14 May 2017	2408.0 ± 482.9	Mixed with *V. velella*
Genova, Sturla	44°23'31"N, 08°59'01"E	13 May 2017	1,14.4 ± 287.2	
Arenzano	44°24'28"N, 08°41'32"E	12 May 2017	1044.0 ± 122.5	
Cogoleto	44°23'20"N, 08°38'49"E	16 May 2017	608.0 ± 72.8	
Celle Ligure	44°20'28"N, 08°32'47"E	13 May 2017	340.8 ± 59.3	
Albisola	44°19'41"N, 08°30'37"E	13 May 2017	1079.2 ± 142.6	
Noli	44°12'14"N, 08°25'01"E	13 May 2017	158.4 ± 30.0	
Varigotti	44°10'51"N, 08°23'31"E	13 May 2017	512.8 ± 51.1	Mixed with *V. velella*
Finale Ligure	44°10'17"N, 08°21'26"E	13 May 2017	1175.2 ± 214.8	
Finale, Capo S. Donato	44°09'43"N, 08°20'10"E	13 May 2017	397.6 ± 99.6	

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recorded in the Tavolara MPA, on the North-eastern Sardinia coast (Figure 3).

Quantitative characterisation of the strandings

A semi-quantitative estimation of the density of the strandings, from a chronological point of view, was obtained from the images sent by the volunteers (Table I), while a quantitative characterisation was carried out in the sampling sites (Table II).

From a geographical point of view, the most conspicuous strandings (> 1000 shells/rafts m^{-2}) occurred along the western Ligurian Riviera (Figure 3). The quantitative evaluation of the beached *Janthina* specimens at the 11 stations indicated an average of 801 ± 215 shells m^{-2} (maximum average 2408.0 ± 482.9, minimum average 12.8 ± 2.3) (Table II) which, considering a wet weight of 1.88 ± 0.99 g per specimen, resulted in an average biomass of about 1.5 kg m^{-2}. In the majority of the sites, the stranded banks were composed only of shells and rafts, while in four localities they were mixed with dead *V. velella* (Table II).

The size–frequency distribution of the shells' heights showed a bi-modal trend, with a first mode in the 11-mm size class and a second mode at 23 mm (Figure 4(a)). A similar distribution was found in the analysis of shell width (Figure 4(b)). Almost all the specimens falling in, or near, the first mode had a raft without eggs, while all the specimens of the larger mode showed rafts with settled egg cases, particularly evident due to their pink colour (Figure 1(a,b,e)). The smallest specimens with eggs had a shell 11 mm tall.

Within the strandings, a dozen specimens of the cosmopolitan buoy barnacle *Dosima fascicularis* (Ellis & Solander, 1786) was collected on the beaches stretching between the city of Genoa and the nearby town of Bogliasco. This species is characterised by a thin exoskeleton and a peculiar lifestyle: as an adult, it can detach from floating objects, producing a raft to float on its own (Figure 1(f–g)).

Discussion

The extensive strandings of *J. pallida* on the Ligurian shores on May 2017 were absolutely unique, regarding both quantitative and biological aspects. First of all, the present data allow a gross estimate of the total biomass of stranded gastropods along the Ligurian coast of about 150 tons, by considering an overall extension of 100 km of the Ligurian beaches (Ferretti et al. 2003). This amount, which must be considered only a part of the whole Ligurian population, gives a picture of the magnitude of the demographic explosion of this species.

The bimodal distribution of the shells' size reflects the proterandrous strategy of this sequential hermaphroditic species (Laursen 1953; Graham 1954): the specimens of the smaller mode, accounting for about 20% of the population, were mainly males, while the remaining 80% is completely composed of females with eggs.

The ecological role of this huge presence of *J. pallida* in the Ligurian Sea may be extremely relevant. Purcell et al. (2015) pointed out the influence of *V. velella* blooms on fish recruitment and, more generally, on the macro-planktonic assemblages; it is evident that corresponding blooms of *J. pallida*, which in the Mediterranean Sea feeds only on *V. velella*, could mitigate this impact.

The spatial distribution of the strandings is consistent with the general trend of the currents in the North-western Mediterranean Sea (Millot 1987, 1999; Astraldi et al. 1994) (Figure 3, inset). The

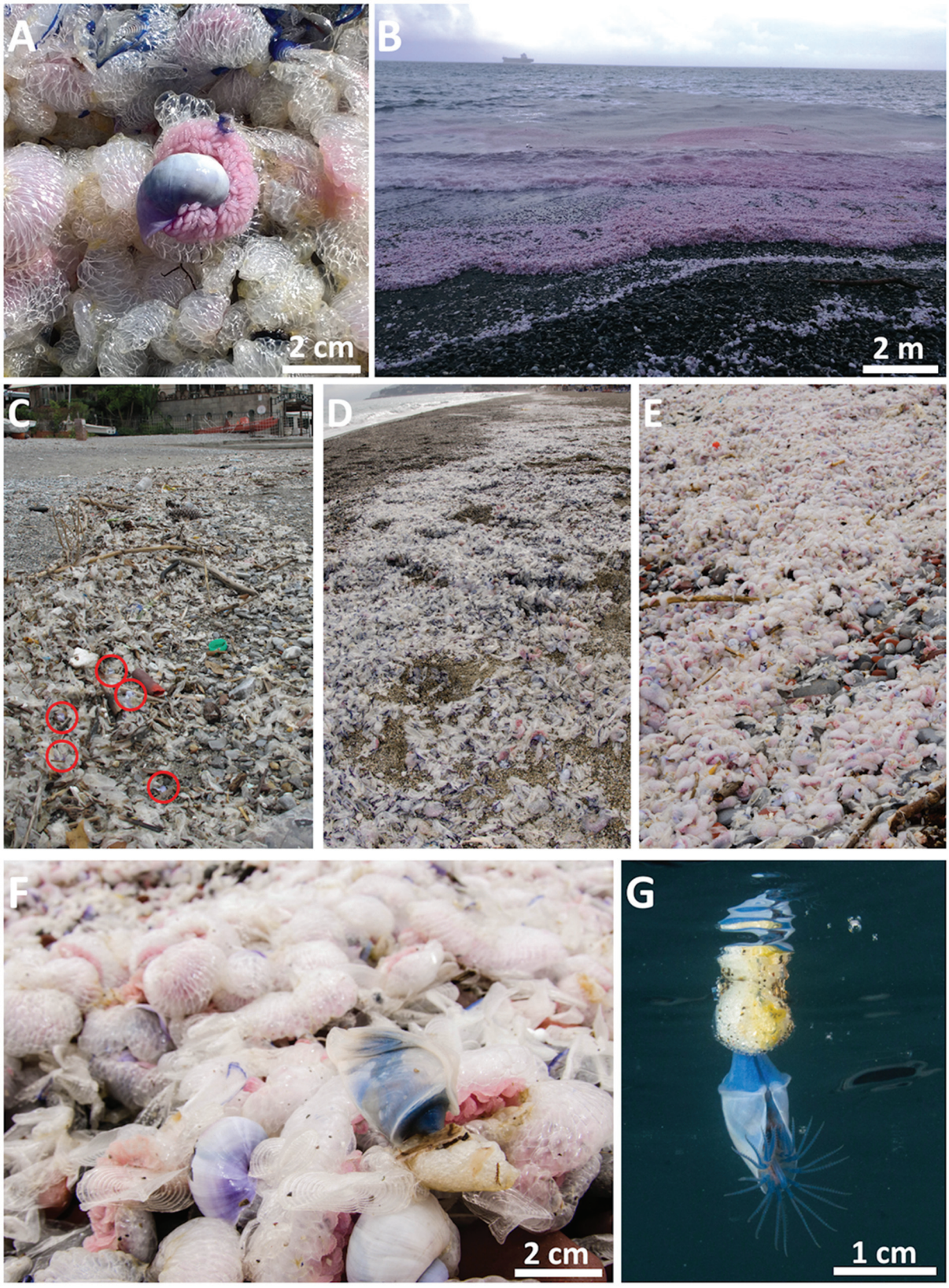

Figure 1. *Janthina pallida* and *Dosima fascicularis*. (a) specimens of *J. pallida*; (b) a bank of *J. pallida* in the backwash close to the beach; (c–e) small (c), medium (d) and massive (e) strandings of *J. pallida* along the Ligurian coast. (f, g) a stranded (f) and a floating (g) specimen of *D. fascicularis*.

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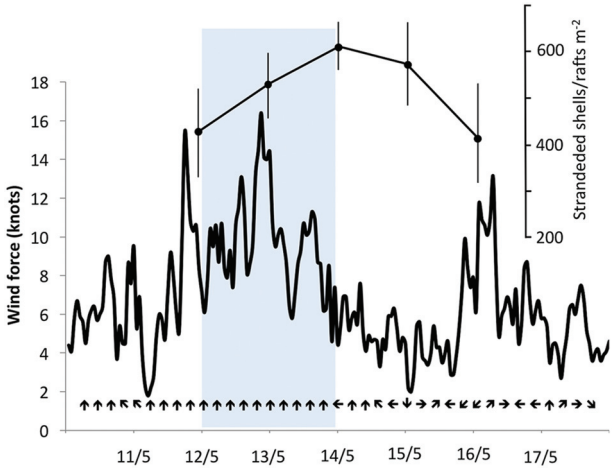

Figure 2. Intensity (line) and direction (arrows) of the wind from 10 to 18 May 2017 in the Ligurian Sea. The shaded area represents the period of the main stranding of *Janthina pallida*. The graph in the upper part (average ± standard error, SE) shows the trend of the number of stranded shells. Data are obtained from the images sent by the volunteers (see Table I).

banks were driven by the ascending Atlantic water (AW, surface water of Atlantic origin), which, bordering the western coast of Sardinia, enters the Ligurian Sea. Along the Ligurian coast, the purple snails were distributed, under southern breezes, following the main current running from east to west, as demonstrated by the absence of strandings on the western side of the main promontories.

The marine meteorological conditions (3 days of constant moderate southern breeze, Figure 2) that favoured the massive strandings are not exceptional in spring in the Ligurian Sea. This suggests that the occurrence of *J. pallida* banks in the Ligurian Sea has to be considered stochastic, probably linked to a population coming from the Atlantic Ocean, and related to an unpredictable, peculiar concomitance of environmental and biological factors (Boero 1994, 1996). The Atlantic origin of the population is also supported by the simultaneous record of the buoy barnacle *Dosima fascicularis*, a circumtropical species, found so far only once, washed ashore at Malta in 2004 (Mifsud 2005). Sciberras and Schembri (2007) pointed out that, this species being common in the Atlantic Ocean, it might accidentally enter the Mediterranean Sea through the Straits of Gibraltar. *Janthina pallida*, forming wide populations in Atlantic waters (Bayer 1963), could have followed the same path. Recent changes in the Mediterranean surface water temperature, related to global warming, are affecting the water circulation (Theocharis et al. 1999) and may be linked to new ingressions of floating organisms from the Atlantic Ocean, and their stranding episodes.

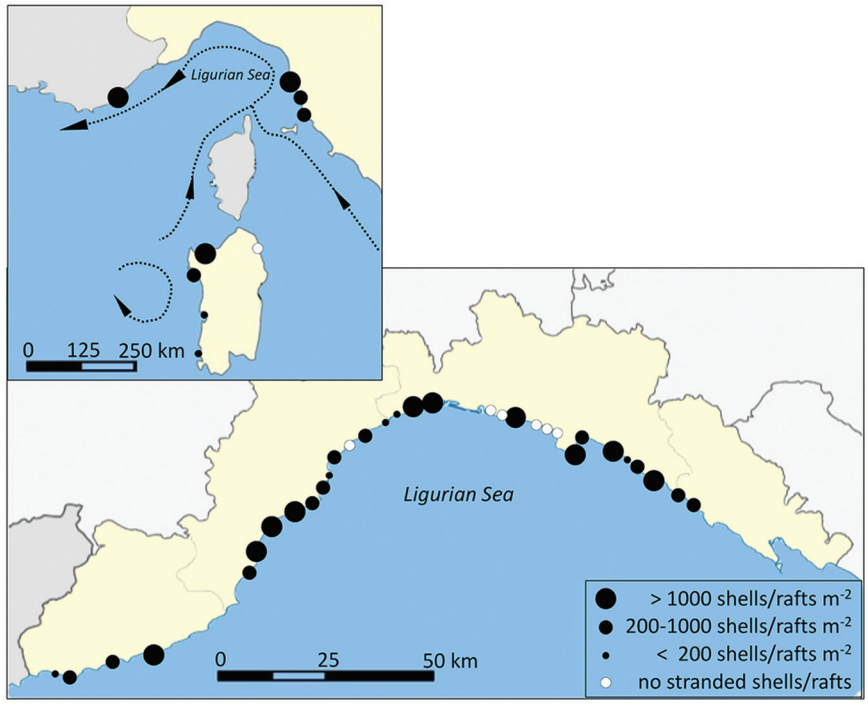

Figure 3. Pattern of stranding of *Janthina pallida* in the North-western Mediterranean basin. The dotted lines are the main superficial currents of the studied area.

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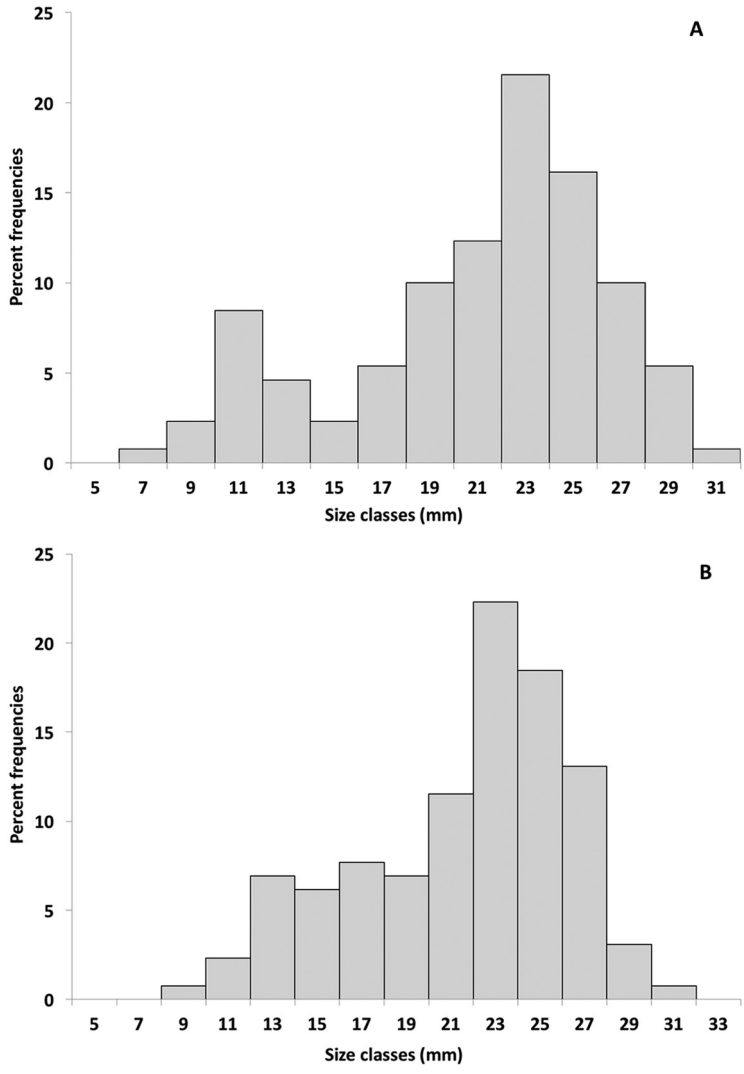

Figure 4. Size frequency distributions of (a) heights and (b) widths of the stranded shells.

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Acknowledgements

The authors are indebted to all of the volunteers who supplied observations.

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