Research Article

New record of the crab *Planes marinus* Rathbun, 1914 in the eastern English Channel

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Abstract

Over the last few decades, the introduction of non-indigenous species (NIS) has become a growing concern for the scientific community and international agencies. Maritime transport, in particular ballast waters and hull fouling, as well as floating marine debris, are the main vectors of these introductions. A striking example of NIS introduction occurred after the Ciaran and Domingos storms in November 2023, when a piece of wood, covered in living *Lepas anatifera* barnacles, washed up on the beach at Boulogne-sur-Mer along the French shores of the eastern English Channel. Ten crabs of the genus *Planes* were found, including three belonging to the species *Planes marinus*, which to the best of our knowledge was never reported in the north-east Atlantic and on the French coast in particular. *Planes marinus* is a species known mainly from the Pacific, but its growing presence in other oceans highlights the importance of marine debris as a dispersal vector. In this context, the present work highlights the potential impact of extreme weather events, amplified by climate change, on the distribution of NIS, as well as the need to monitor stranded debris to better understand and manage these introductions, which is crucial to the preservation of European marine ecosystems.

Key words: floating debris, brachyuran crabs, extreme weather events, morphological characteristics, non-indigenous species

Introduction

Over the last decades, studies on the introduction of non-indigenous species (NIS) have gained considerable attention in the scientific community (e.g. Hulme 2009; Massé et al. 2023) and for international governmental agencies (IPBES 2019), which enabled a better understanding of the effects these species on ecosystems and their dynamics (Diagne et al. 2021). The most significant factor responsible for the introduction of new species in any type of habitat is the transport and logistics industry (Donelan et al. 2022; European Environment Agency 2023). Although trade and transport represent a high ecological coast (Jägerbrand et al. 2019; Das et al. 2020, 2023), they are highly economically driven with an average turnover of 25 trillion US$ (UNCTAD 2024), which makes them a cornerstone of the global economic system. Multiple vectors of introduced species have emerged through maritime transport, mainly ballast waters and hull fouling (Williams et al. 2013; Zettler 2021). In addition, the aquaculture industry, the use of live feed, the trade of ornamental species, yachting, recreational fishing activities (Goulletquer 2016) and, more recently, floating debris (Póvoa et al. 2021) have all been acknowledged to contribute to the introduction of NIS. Marine debris originate from multiple sources such as land-based, ocean-based, or extreme events (NOAA 2024) and are composed of both natural and anthropogenic materials, which are often observed drifting along the coast and/or carried from the land via rivers and waterways (Galgani et al. 2015; Aragaw 2021). The bulk proportion of these floating debris are of anthropogenic origin; natural debris such as macroalgae, plants or animals, are marginal (Arnaud et al. 1976; Highsmith 1985; Edgar 1987). Amongst the anthropogenic waste, plastic is the key example of marine debris that is now ubiquitous in the world ocean, due to the lightweight nature of this material, hence its ability to float and drift (Barnes 2002; Bravo et al. 2011; Gündoğdu et al. 2017; Mghili et al. 2023; Rech et al. 2023).

Specifically, floating marine debris are now considered as one of the major vectors for transporting species (Kano et al. 2013; Gustavson et al. 2020; Mantelatto et al. 2020; Kannan et al. 2023). The biota found on these floating materials, sometimes also referred to as “floating islands” (Jokiel 1990), is typically an assemblage of many taxonomic groups and lineages, with an average of 387 taxa that can be transported over considerable distances by floating anthropogenic litter (Kiessling et al. 2015). Some organisms, such as the Crustacean Cirripeds *Lepas* sp., the so-called Goose barnacles, are well known for colonizing any type of floating debris (Boëtius 1952; Thiel and Gutow 2005) and provide shelter for several species, such as other cirripeds, bryozoans, mollusks, polychaetas or crustacean decapods (Póvoa et al. 2021).

Given its unique geographical location, France is the only European country with a coastline running along the North Sea, the English Channel, the Atlantic Ocean and the Mediterranean Sea (Noël 2002). This location, at the crossroads of Europe, implies an intense maritime traffic and diverse influx of floating objects. Notably, the eastern English Channel is one of the most important commercial and passenger transit routes globally, with nearly 500 vessels crossing the Dover Straight daily (UK Government 2024). The extent of this maritime route often entails the arrival of introduced species in the eastern English Channel through ballast waters and biofouling (Goulletquer et al. 2002; Dewarumez et al. 2011; Massé et al. 2023). Marine floating litter plays a significant role in the introduction of new species given the stranding of a wide range of debris, that are driven by currents

Figure 1. Wooden marine debris beached in Boulogne sur Mer (A) and covered with the barnacle *Lepas anatifera* (B). © Camille Hennion.

and winds, along with extreme events such as storms (Menicagli et al. 2022). The Ciaran and Domingos storms which occurred between 1st and 4th November 2023 are epitome instances of these events which typically impacted the western coast of France. This catastrophic event was considered as the 5th most devastating storm affecting the French territory, that induced numerous damages (France Assureurs 2023). In particular, this led to a large amount of debris being transported to the English Channel from rivers and the sea, which then washed up on the coast. Although the management of non-native species has become a major concern over the last few decades (Pyšek and Richardson 2010), studies on floating debris and their associated organisms are still critically scarce.

In this context, following the Ciaran and Domingos storms, on November 19, 2023 a large piece of wood (ca. 6 m long and 50 cm wide) was found on the beach of Boulogne-sur-Mer ((50°43′55.2″N, 1°35′35.2″E; Figure 1A). It was entirely covered by a dense living bed of the goose barnacle *Lepas (Lepas) anatifera* Linnaeus, 1758 (Figure 1B), where 10 alive Brachyuran crabs belonging to the Grapsidae family and to the genus *Planes* were found. Here, we extensively describe the morphometrics of the 10 collected specimens and unambiguously show that some belong to the species *Planes marinus* Rathbun, 1914.

Materials and methods

Identification of Planes *species*

The 10 sampled crabs were taken back to the laboratory and stored in 70% ethanol until further analysis. Based on the morphological characteristics reported for the two species of *Planes*, i.e. *Planes minutus* (Linnaeus, 1758)

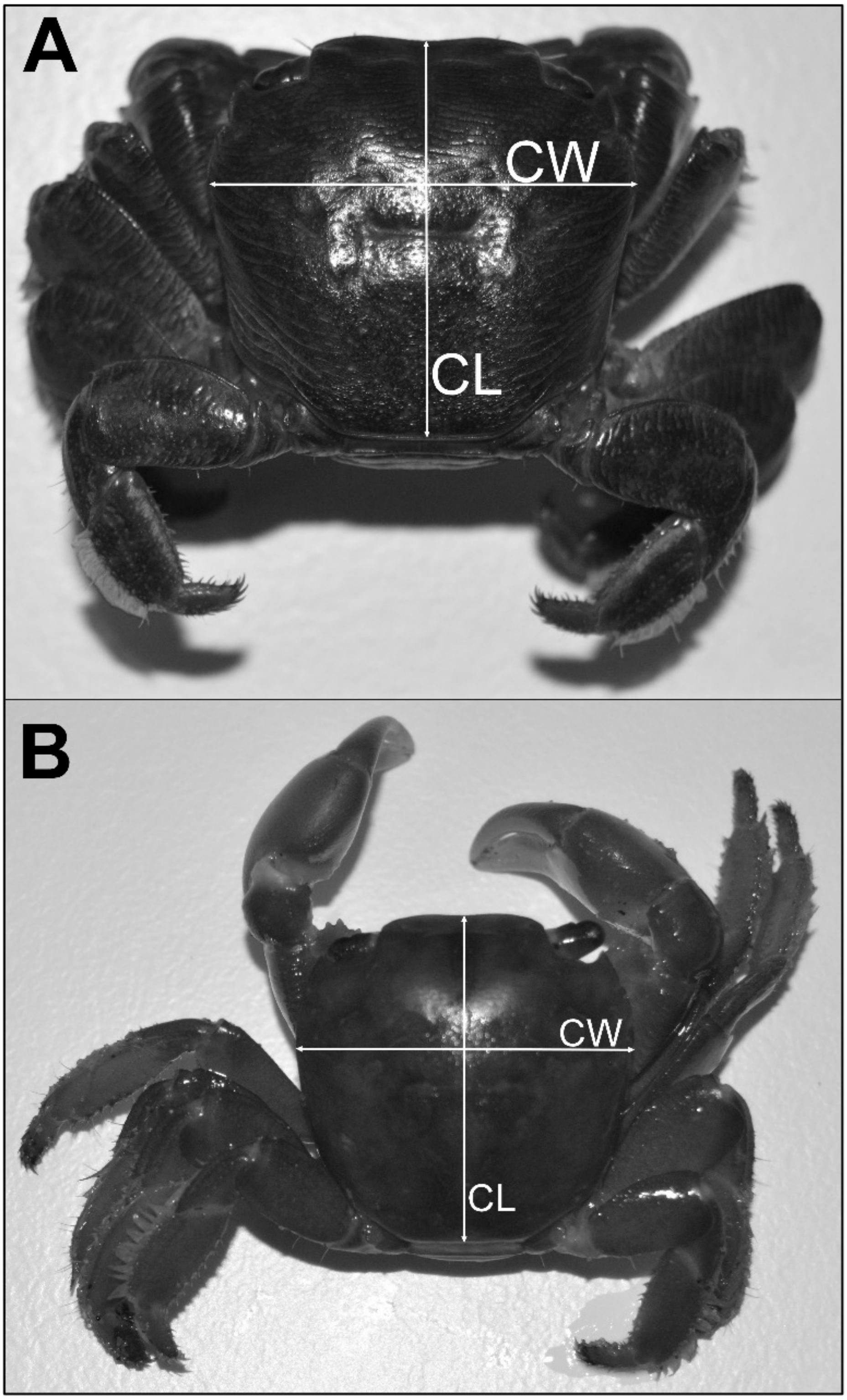

Figure 2. Carapace measurements of *Planes marinus* (A) and *Planes minutus* (B). CL: Carapace Length; CW: Carapace Width. © Camille Hennion.

and *P. marinus* (Chace 1951), four morphological features were consistently investigated on the 10 individuals (9 males and 1 female): the carapace, the chelipeds, the walking legs and the pleon. The carapace dimensions, i.e. length (CL) and width (CW; Figure 2), were precisely measured using a digital caliper (Garant 412780_150; resolution of 0.01 cm) and the ratio between these

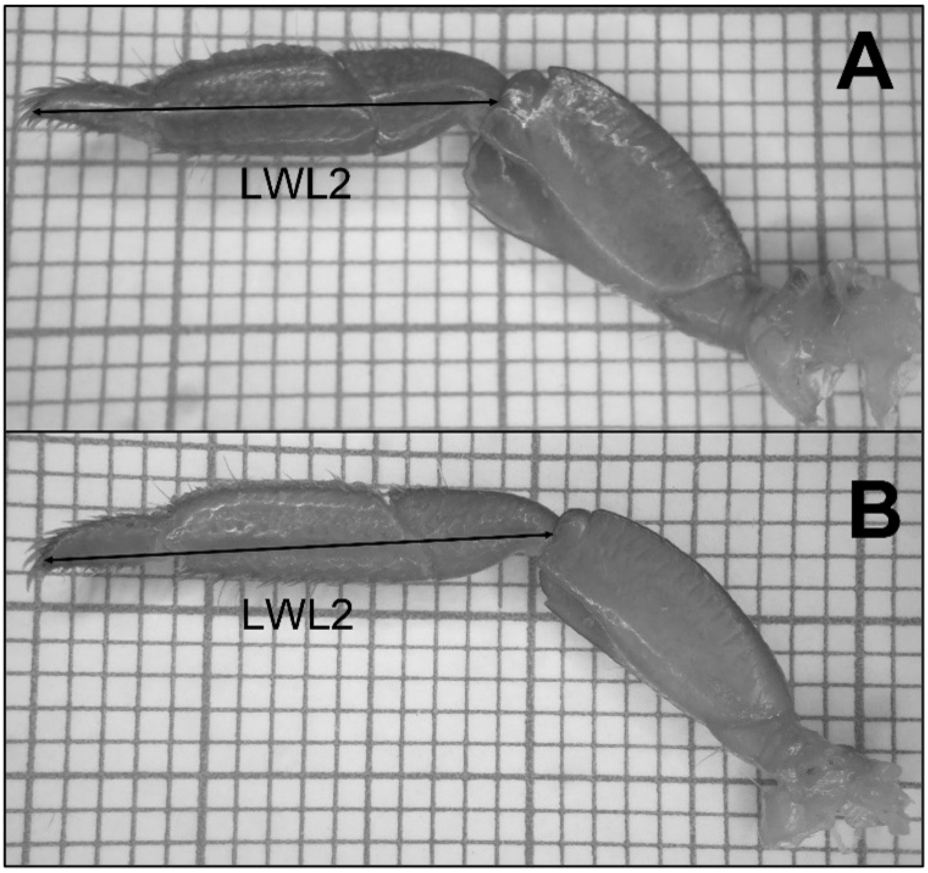

Figure 3. Three last segments of 2nd Walking Leg (LWL2) of *Planes marinus* (A) and *Planes minutus* (B). © Camille Hennion.

two values (CL/CW) was calculated. The shape of the carapace and the striated branchial region of *Planes* sp. were also carefully noted. Different shapes can be found: subquadrate (rather square shape), trapezoidal or laterally convex. The length of the three last segments of each pair of 2nd walking leg (LWL2) was measured after dissection (Figure 3) to obtain the proportion with the carapace length (LWL2/CL). All these measurements were conducted on images taken from a stereomicroscope (Olympus SZX16) and were quantified with ImageJ software (Schneider et al. 2012) with the measurements expressed in millimetres.

As firstly described by Chace (1951) and subsequently confirmed (Arnaud et al. 1972; Lemaitre 1999; Spivak and Bas 1999; Prado and de Melo 2002), the male pleon is another criteria of discrimination between the two species. Hence we investigated the ratio between the total length of the four distal pleonites (L4DP) and the width of the fourth one (W4P; Figure 4) through careful microscopic observations and accurate quantification using ImageJ software. The L4DP was taken from the middle of the pleon, representing the maximal length and the W4P was taken in the middle of the pleonite, representing the longer value following Chace (1951). Along with these measurements, the shape of the telson was also noted under the stereomicroscope. Two different shapes of telson are found in this species; narrowly triangular and laterally convex (narrowly rounded at the sides).

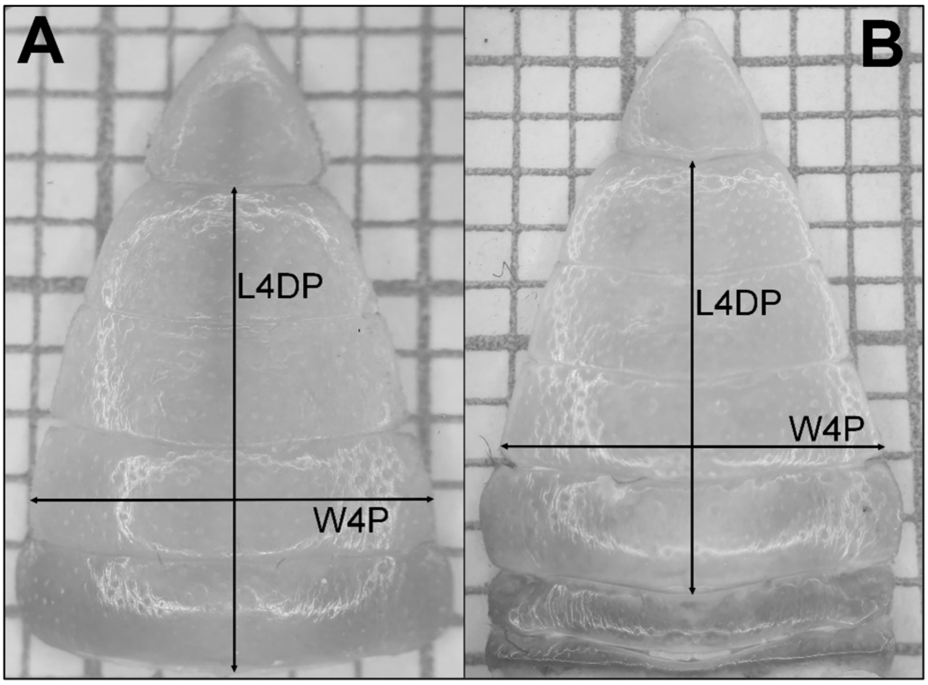

Figure 4. Pleon measurements of *Planes marinus* (A) and *Planes minutus* (B). L4DP: Length of the 4 distal pleonites; W4P: Width of the 4th pleonite. © Camille Hennion.

Statistical analyses

Due to the limited number of replicates (N = 10), non-parametric tests were used throughout this work. Specifically, differences in carapace ratio (CL/CW), second walking legs and carapace length ratio (LWL2/CL) and male pleon ratio (L4DP/W4P) were tested through a Mann-Whitney U test (Zar 2010). All statistical analyses were carried out using R-Studio (version 4.4.1).

Results

Morphological analysis

Out of the 10 sampled crabs, we identified 7 *P. minutus* (one female and six males) and 3 *P. marinus* (all males). Carapace length and width measurements were compared for males only, since only one female was collected. The CL/CW ratio showed a significant difference ($p < 0.01$) between *P. marinus* (1.03 ± 0.02; mean ± standard deviation) and *P. minutus* (1.07 ± 0.01; Table 1).

The carapace shape was laterally convex in *P. minutus*, and more subquadrate in *P. marinus* (Chace 1951; Spivak and Bas 1999) (Table 2). The analysis of this single morphological specificity is, however, not sufficient to differentiate the two species (Chace 1951). On the surface of the carapace, a clear striation was observed in *P. marinus* while the carapace of *P. minutus* was slightly striated (Spivak and Bas 1999; Table 2). More specifically, previous studies comparing the chelipeds of the two species showed a noticeable downward bending of the fixed finger only in *P. minutus* (Arnaud et al. 1972; Chace 1951; Table 2). All the crabs examined in this study exhibited a downward bending of the fixed finger (Table 2), hence this

Table 1. Morphological features measured for each crab individual. CL: Carapace Length; CW: Carapace Width. LWL2: Length of 2nd Walking Leg; L4DP: Length of 4 Distal Pleonites; W4P: Width of the 4th Pleonite.

Specimen	Sex	CL (cm)	CW (cm)	CL/CW	LWL2 (cm)	LWL2/CL	L4DP (cm)	W4P (cm)	L4DP/W4P
P. minutus-1	M	1.94	1.87	1.04	1.50	0.77	0.802	0.713	1.12
					1.54	0.79			
P. minutus-2	M	1.62	1.58	1.03	1.25	0.77	0.647	0.561	1.15
					1.23	0.76			
P. minutus-3	M	1.79	1.72	1.04	1.37	0.77	0.744	0.661	1.13
					1.39	0.78			
P. minutus-4	M	1.9	1.92	0.99	1.39	0.73	0.8	0.694	1.15
					1.48	0.78			
P. minutus-5	M	1.69	1.64	1.03	1.32	0.78	0.693	0.615	1.13
					1.25	0.74			
P. minutus-6	F	1.47	1.35	1.09	1.15	0.79	NA	NA	NA
					1.14	0.77			
P. minutus-7	M	1.87	1.81	1.03	1.55	0.83	0.708	0.59	1.20
					1.59	0.85			
P. marinus-1	M	1.99	1.86	1.07	1.40	0.70	0.746	0.689	1.08
					1.39	0.70			
P. marinus-2	M	1.96	1.85	1.06	1.38	0.71	0.724	0.669	1.08
					1.42	0.73			
P. marinus-3	M	2	1.86	1.08	1.43	0.71	0.778	0.736	1.06
					1.36	0.68			

Table 2. Morphological features of *P. minutus* and *P. marinus*, adapted and completed from Chace, 1951 with the data from this work. New or updated data are written in bold.

		Features of Chace (1951)		Features of the present study	
	Characters	*Planes minutus*	*Planes marinus*	*Planes minutus*	*Planes marinus*
Carapace	Length (cm)	0.37 to 1.9	0.5 to 1.9	**1.47 to 1.94**	**1.96 to 2.00**
	Width (cm)	*NA*	*NA*	**1.35 to 1.92**	**1.85 to 1.86**
	Proportions (L/W)	0.91 to 1.12	1.07 to 1.16	**0.99 to 1.09**	**1.06 to 1.07**
	Shape (adults only)	Laterally convex	Subquadrate	Laterally convex	Subquadrate
	Surface of branchial regions	Faintly striated laterally	Distinctly striated laterally	Faintly striated laterally	Distinctly striated laterally
Chelipeds	Granulation and bending of the fixed finger	With prominent sharp granules near lower margin, bent sharply downward, especially in males	Few inconspicuous granules near lower margin, not noticeably bent downward	Granulated and slightly bent downward	**Slightly Granulated and slightly bent downward**
Walking legs	Shape	Long, slender and flattened	Rather short, stout and not noticeably flattened	Long and slender	Short and stout
	Length of 3 distal segments of 2nd walking legs pair (cm)	*NA*	*NA*	**1.47 to 1.94**	**1.36 to 1.43**
	Proportion of length of 3 distal segments of second pair to carapace length	0.83 to 1.07	0.77 to 0.99	**0.73 to 0.85**	**0.68 to 0.72**
Male Pleon	Shape of the Telson	Rather narrowly triangular	Broadly triangular	Triangular but slightly laterally convex	Triangular
	Length of the four distal pleonites (cm)	*NA*	*NA*	**0.65 to 0.80**	**0.72 to 0.78**
	Width of the fourth pleonite (cm)	*NA*	*NA*	**0.56 to 0.71**	**0.67 to 0.74**
	Proportion of length of the four distal pleonites to width of the fourth pleonite (L4DP/W4P)	1.24	1.08	**1.12 to 1.15**	**1.06 to 1.08**

feature could not be considered as discriminatory to differentiate the two species. However, the morphometry of the second pair of walking legs, i.e. the ratio between the length of the three last segments and carapace length

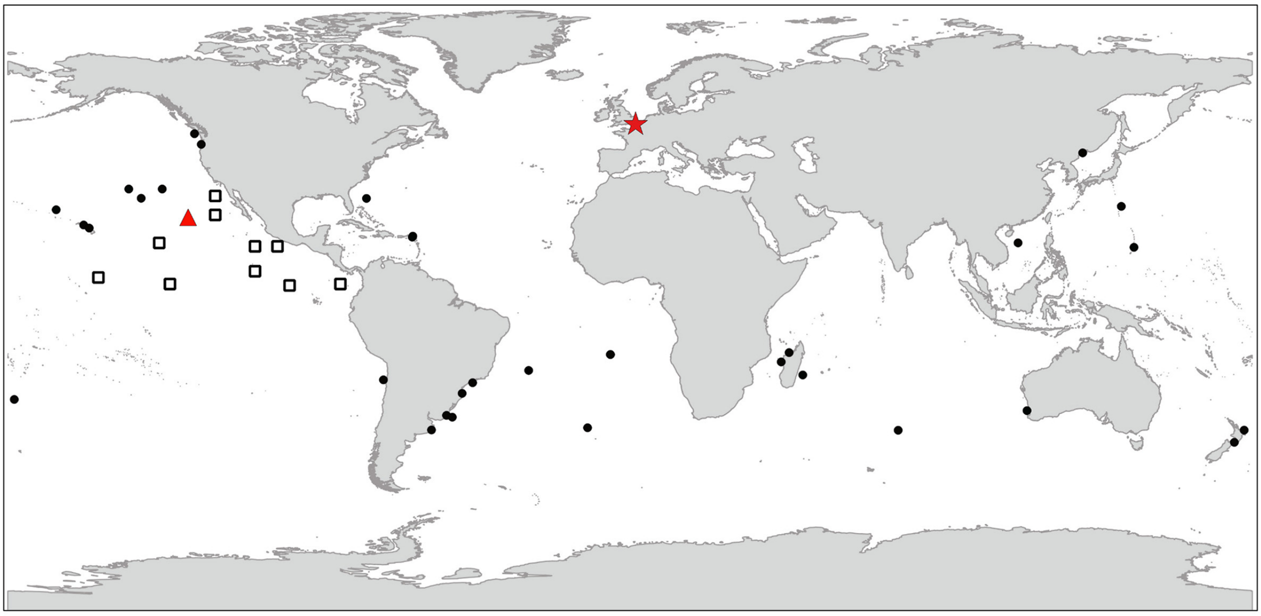

Figure 5. Locations of previous observations of *Planes marinus*. Triangle: type location; square: crabs found living on/in Sea Turtles; circle: other observations; star: this study.

(LWL2/CL), showed highly significant statistical differences ($p < 0.01$) with higher values in *P. minutus* (0.78 ± 0.03; mean ± standard deviation) than in *P. marinus* (0.70 ± 0.02). Finally, the ratio between the total length of the four distal segments and the width of the fourth one (L4DP/W4P) showed significantly higher values ($p < 0.01$) in *P. minutus* (1.15 ± 0.02) than in *P. marinus* (1.07 ± 0.01). The shape of the telson was more triangular in *P. marinus*, whereas in *P. minutus* the telson was slightly triangular and laterally convex (Table 2).

Discussion

Worldwide distribution of Planes marinus

The first documentation of *P. marinus* was in California (Rathbun 1914), and the species was subsequently reported in the North-Western coast of America (Ward 1939; Chace 1951), Canada (Hart 1958) and Hawaii (Chace 1951; Edmondson 1959) (Figure 5; Table 3). This species eventually spread to the Eastern coasts of the Pacific Ocean in New Zealand and Kermadec Islands (Dell 1963, 1964; Wear 1970), the Indian Ocean with observations in Madagascar (Crosnier 1965) and in Amsterdam Island (Arnaud et al. 1972). *Planes marinus* was also reported along Southeast Asian coasts, such as in Japan and China from 1977 (Takeda and Kurata 1977; Dai and Yang 1991; Kepel et al. 2002). In the Atlantic Ocean, *P. marinus* has been reported in areas ranging from the East coasts of South America (Spivak and Bas 1999; Prado and de Melo 2002) and North America (Questel 2019), on islands in the central Atlantic Ocean (Chace 1966; Holthuis and Sivertsen 1967; Tavares and Mendonça 2022) and the Southern Atlantic Ocean (Chace 1966) in St Helena and Tristan Da Cunha Island (Holthuis and Sivertsen 1967).

Table 3. Details of previous observations of *Planes marinus*. Geo-referenced data are provided in the Supplementary material Table S1.

Geographical zone	Location	Reference	Remarks
Eastern Pacific Ocean	Low California	Rathbun 1914, 1918	Type Locality
	Off California	Ward 1939	
	Oregon, Lincoln beach	Chace 1951	Japanese mine
	Hawai, Mokapu	Chace 1951; Edmondson 1959; Pfaller et al. 2019	
	Hawai, Oahu		
	Vancouver Island, Canada	Hart 1958	Clinging to the net of a large Japanese glass float
	Northern Chile	Lemaitre 1999	found on propylene rope
	West coast of America to Hawaiian Islands	Frick et al. 2011	Sympatry with sea Turtles
	Great Pacific Garbage Patch	Pfaller et al. 2019	Flotsam
Western Pacific Ocean	New Zealand, Omaio Bay	Dell 1963	Collected from a thick layer of goose barnacles attached to a Japanese glass fishing float cast
	Kermadec Islands, Denham Bay Beach	Dell 1964	Presumably collected on the beach, with floating debris
	New Zealand, Lyall Bay, Wellington	Wear 1970	Found on a rope and barnacle-covered glass fishing float
	Japan, Ogasawara Islands	Takeda and Kurata 1977	Collected among volcanic debris
	South China Sea, Xisha Island	Dai and Yang 1991	
	Furugelm Island, Sea of Japan	Kepel et al. 2002	collected on a buoy overgrown with *Mytilus galloprovincialis*.
	Northern Mariana Islands	Pfaller et al. 2019	Flotsam
Indian Ocean	Western coast of Australia	Pfaller et al. 2019	Flotsam
	Madagascar	Crosnier 1965; Pfaller et al. 2019	
	Amsterdam Island	Arnaud et al. 1972	collected from a beached buoy covered with *Lepas sp*.
Western Atlantic Ocean	Argentina, Mar Chiquita	Spivak and Bas 1999	Collected from a piece of stranded rope
	Brasil, Sao Paulo, Alcatraze Islands	Prado and de Melo 2002	
	Brasil, Santa Catarina		
	Brasil, Rio Grande do Sul		
	Brasilian coast		
	St. Bathelemy	Questel 2019	
	Florida, USA	Pfaller et al. 2019	Flotsam/Sea Turtles
	St. Martin	Pfaller et al. 2019	Flotsam/Sea Turtles
	Trindade Island, Brasil	Tavares and Mendonça 2022	On washed log, at low tide
South Atlantic Ocean	St. Helena Island - Northeast coast	Chace 1966	collected from a drifting Kelp
	St. Helena Island – Rupert's Bay		collected from a buoy
	Tristan Da Cunha Island	Holthuis and Sivertsen 1967	
North Atlantic Ocean	France, Boulogne sur Mer	Present study	collected from a wooden debris, living on *Lepas anatifera*

In addition to the above sites, *P. marinus* was also recorded in Western Australia and Florida (Table 3 and Figure 5) in the year 2019 (Pfaller et al. 2019). In this context, our observations of *P. marinus* on a wooden debris beached along the French shores of the eastern English Channel represent the first record in the North-East Atlantic Ocean.

A short history of the classification of Planes *species*

Crabs from the *Planes* genus are also known as Colombus crabs or oceanic crabs (Lemaitre 1999), with a worldwide distribution as described above. This genus initially included two species, *Planes cyaneus* and *Planes minutus*. Later *P. marinus*, initially associated to the genus *Pachygrapsus*, was included in the genus *Planes*. In addition, according to Worms (WoRMS Editorial Board 2024), *P. cyaneus* was described as a synonym of *P. minutus*, based on their morphometric features.

Planes marinus was initially described by Rathbun (1914), which was subsequently shifted to *Pachygrapsus* by Chace (1951), based on criteria such as the absence of natatory fringe of hairs on propodi of the first three pairs of walking legs. However, it was finally redefined as *Planes* spp. by Chace (1966), validating the first description of Rathbun (1914) as *Planes marinus*, based on the fact that specimens analyzed were missing the natatory fringe, a feature that was observed in other specimens (Dell 1963). These crabs are exclusively pelagic (Bouvier 1940; Edmondson 1959; Hart 1963) and occur on a range of floating object and debris (Thiel and Gutow 2005). They can be found on inorganic debris such as plastic (Dellinger et al. 1997; Lemaitre 1999), rope (Spivak and Bas 1999), buoys (Arnaud et al. 1972; Kepel et al. 2002) or wood (Crozier 1918; Tavares and Mendonça 2022), but also in association with various species of sea turtles from different regions such as *Lepidochelys olivacea* (Eschscholtz, 1829) from Chile (Miranda and Moreno 2002) and the Pacific Coast of Mexico (Díaz et al. 1992; Frick et al. 2011), *Caretta caretta* (Linnaeus, 1758) from the Southern Atlantic (Davenport 1994; Carranza et al. 2003; Frick et al. 2004), North Atlantic (*field observations*) and/or Mediterranean Sea (Gaglioti and Mazzella 2021), Northwestern Indian Ocean (Yaghmour and Al Naqbi 2020) and *Chelonia mydas* (Linnaeus, 1758) from the Eastern Pacific (Wicksten and Behrens 2000). *Planes* species were also found on floating macroalgal invasive species, e.g. *Sargassum* spp. (Rathbun 1918; Bouvier 1940; Chace 1951; Geiselman 1983).

Morphology of Planes marinus

The scientific literature abounds with morphological descriptions of *P. marinus* and its differentiation with *P. minutus* (Chace 1951; Crosnier 1965; Lemaitre 1999; Prado and de Melo 2002). The present study reports that the carapace of *P. marinus* is significantly different from that of *P. minutus*, with the latter having comparable length and width, while *P. marinus* is distinguished by a wider carapace (i.e. lower CL/CW ratio). This difference was observed by Chace (1951), who found the carapace of *P. marinus* to be 1.07–1.16 times wider, though Spivak and Bas (1999) stated that it was 1.08–1.25 times wider. It is notable, however, that the juvenile stages of *P. minutus* have a subquadrate carapace before becoming laterally convex, whereas the carapace of *P. marinus* is subquadrate at all ages (Chace 1951).

Striation is also clearly visible on the branchial surfaces of *P. marinus*, although this detail is less pronounced in *P. minutus*. The presence of the striation was also noted by Rathbun (1914) when describing the species and was later supported by other studies (Chace 1951; Crosnier 1965; Lemaitre 1999; Prado and de Melo 2002).

Another criteria to differentiate between the two *Planes* species is the chelipeds. Chace (1951) and later Dell (1963), Arnaud et al. (1972), Lemaitre

(1999) and Prado and de Melo (2002) described that *P. marinus* specimens showed a fixed finger not noticeably bent downward, compared with *P. minutus*, which has a distinct downward bending. However, in our study, we observed a downward bending in all the crabs analysed which renders this identifying feature inexact, lacking precision.

The walking legs of *P. marinus*, as described by Rathbun (1914), are short and broad. Further investigating the differences between the two species, Chace (1951) showed that the relationship between the length of the three distal segments of the second walking leg and the length of the carapace is higher in *P. minutus* than in *P. marinus*. In this study, we observed a significant difference between these ratios in the two species, in which *P. minutus* showed a ratio of 0.78 ± 0.03 and *P. minutus* a ratio of 0.70 ± 0.02. Chace (1951) also concluded that this ratio is undoubtedly the most useful detail for differentiating these two species.

Finally, previous observations of *P. marinus* males showed, a triangular pleon with a broad basal part (Chace 1951; Arnaud et al. 1972; Lemaitre 1999; Prado and de Melo 2002). Crosnier (1965) observed that the 6th segment is longer than the 5th. In this study, Chace (1951) and Spivak and Bas (1999) was followed and the ratio between the length of the 4 distal pleonites and the width of the 4th one was taken into consideration. According to Chace (1951) and Spivak and Bas (1999), this ratio is close to 1.08, which is close to the ratio found in this study (1.07 ± 0.01). Furthermore, a significant difference was noted between *P. minutus* (1.15 ± 0.02) and *P. marinus* (1.07 ± 0.01). Morphological characteristics provide a reliable and well-established method to study and distinguish new species records, particularly those closely related. Incorporating molecular techniques such as DNA barcoding can further enhance the accuracy and robustness of these identifications (Jara and Jaramillo 1979).

Occurrence of Non-Indigenous Species through floating debris

The introduction of Non-Indigenous Species (NIS), relying on single and/or multi introduction vectors (Carlton and Ruiz 2015), is a source of ever-increasing concern and is partially controlled through massive regulations and managements. Ballast waters, considered as the main introduction vector for marine NIS, is nowadays strictly controlled at the international level, following the International Maritime Organizations' Ballast Water Management Convention (International Maritime Organization 2004). The use of alien species in aquaculture in EU is managed since 11th June 2007 through the Barring Council Regulation Act (EC) No 708/2007 (Council of the European Union 2007), but concerning hull biofouling, there is currently no regulation in place (Massé et al. 2023). Marine debris, considered as an emerging vector, remain poorly assessed (Carlton and Ruiz 2015), despite the fact that the number of debris, most of which is plastic (i.e. 75%; Napper and Thompson 2020), has been increasing since the 1970s (Jambeck et al. 2015). The release of debris into the seas and oceans can sometimes be very significant, particularly during extreme events, such as the tsunami caused by the earthquake that hit Japan in 2011 which released millions of diverse fragments of floating objects into the Pacific Ocean (JTMD: Japan Tsunami Marine Debris) (Shimada 2016; Carlton et al. 2017). Carlton et al. (2017) state that 289 species of living animals were observed for the first time on the West American coast following this Tsunami, on the JTMD. Other processes, such as waves and currents have also been acknowledged as major drivers of beaching marine debris, especially in the North-East Atlantic Ocean, which is considered as an important area for beaching, given the influence of the North-Atlantic drift (Bosi et al. 2021). Recent studies have modelled the potential path of floating debris and showed that it may cross the Atlantic Ocean before washing up in UK's waters (Barry et al. 2023). Even if the identification of the wood debris washed up after the successive passage of the Ciaran and Domingos storms (which is the subject of this article) remains speculative, it seems very likely that this debris originated from the North-West or South-West Atlantic. The NOAA recently provided a program that allows to track drifting buoys, using Argos positioning system, developed by Elipot et al. (2016) (https://www.aoml.noaa.gov/phod/gdp/index.php). Monitoring the drift of some buoys deployed as part of this program supports our hypothesis that the wooden debris, considered in this study, presumably have drifted from the western Atlantic coast.

Barry et al. (2023) developed a model using the daily growth rates of the Capitellum (Evans 1958) and Scutum (Green et al. 1994) of *Lepas anatifera* on a floating object, making it possible to obtain an estimate of the floating time of the debris, as *L. anatifera* can only develop when attached to a single substrate (Barry et al. 2023). The calculation of floating duration (days) is equal to the relation of total length of the barnacle plate (mm) multiplied with the relevant growth rate (mm day^{-1}). Using a typical growth rate of the Capitellum as 0.44 mm day^{-1} (Evans 1958) and the maximal length of the Capitellum found in our barnacles (i.e. 37 mm), we estimated the maximal floating duration of the wooden debris to be approximately 85 days (almost 3 months). This is consistent with the floating duration for a debris originating from the western Atlantic coast to reach the eastern coast.

On the relation with global change

Since the 1950's, global change has been affecting both terrestrial and marine biodiversity. It's becoming a well-documented topic in the scientific community and many predictions are available, depending on the compartment, research topic or regarding to the IPCC scenario.

Global change can have a number of effects on marine communities, leading to the appearance of NIS. This study shows that extreme events, such as the storms that swept along the European coast in November 2023 resulted in the transportation of *P. marinus*. Although similar extreme events have occurred in recent years, future predictions of the impact of global change on mid-latitude winds and storms can only be speculative, as reliability is low (IPCC 2014). However, it is acceptable that the main cause of transport of this marine debris are currents and winds on the European coast (Van Sebille et al. 2020). Pinto et al. (2009) and Brown et al. (2010) suggest that all the predictable changes could be responsible for an increase in the occurrence of storms and cyclones in the north-east Atlantic (Feser et al. 2015). It is therefore more likely that the synergy or the compounding effect of the change in environmental factors on a global scale, often termed as a global change could correspond to an increase in the occurrence of NIS on European waters.

In this study, we highlight the consequences of an extreme event that resulted in the transport of a non-native species to the European coastline (González-Ortegón et al. 2024). However, this poses no significant risk of invasion under the current conditions, as *Planes* species primarily inhabit floating debris and currently show no tendency to colonize tidal flats (Yaghmour and Al Naqbi 2020). On contrary, it is also an important indication which denotes that global environmental changes can possibly increase the advent of NIS which is conducive to higher number of invasive species. Such circumstances are alarming for the balance of community structure and the symmetry of ecosystem dynamics. Hence, this study tangentially highlights the continual need for monitoring beached floating substances in order to record the NIS, not merely through ballast waters, but also after extreme meteorological events like the Ciaran and Domingos storm in 2023.

Authors' contribution

Camille Hennion – research conceptualization; sample design and methodology; investigation and data collection; data analysis and interpretation; writing – original draft; writing – review and editing. Jean-Luc Bourgain – investigation and data collection; writing – review and editing. Shagnika Das – sample design and methodology; data analysis and interpretation; writing – original draft; writing – review and editing. Nicolas Spilmont – research conceptualization; sample design and methodology; data analysis and interpretation; writing – review and editing. Emilie Moisez – investigation and data collection. Laurent Seuront – research conceptualization; sample design and methodology; data analysis and interpretation; writing – original draft; writing – review and editing.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Geo-referenced records of *Planes marinus* previous observations, references and remarks associated.

This material is available as part of online article from:
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