Rapid Communication

First record of the non-native isopod *Paranthura japonica* Richardson, 1909 in the English Channel

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Abstract

Specimens of the Asiatic isopod *Paranthura japonica* Richardson, 1909 were retrieved for the first time in 2019 from two harbours situated along the Normandy coast in the north of France: Le Havre (295 specimens), and Cherbourg (four specimens). *Paranthura japonica* was accidently introduced for the first time in Europe in the Archachon Bay in 2013 through oyster transfer. This species, native to the Sea of Japan, may have been introduced to the English Channel through the accumulated fouling of the hulls of ships used primarily for recreational purposes.

Key words: introduced species; Le Havre harbour; non-native species; fouling; Bay of Seine; alien isopod

Introduction

The introduction of non-indigenous species (NIS) is considered as one of the main threats to biodiversity as serious as habitat destruction (Roy et al. 2019). NIS, which are also known as alien species, are those introduced to a region from outside their own natural environment by human agency (Essl et al. 2018). NIS introductions have been accelerated in recent decades by globalization and increasing human activities such as shipping, aquaculture, fisheries, and tourism (Goulletquer et al. 2002; Boudouresque and Verlaque 2005; Galil 2008; Davidson et al. 2010; Katsanevakis et al. 2014; Galil 2008; Copp et al. 2016). The major introduction pathways of NIS are the flushing of ballast water ships and the propagation of species fouling on the hulls (Carlton 1985; Hewitt et al. 2009; Galil et al. 2014; Katsanevakis et al. 2013). Other frequently cited factors include aquaculture. In their comprehensive analyses taking into account a total of 1,257 NIS for the European waters, Katsanevakis et al. (2013) concluded that more than half of the species were likely introduced by shipping. Marine and inland corridors (Suez Canal for the Mediterranean Sea) were the second most common pathway of introduction followed by aquaculture and aquarium trade. Introduction by aquaculture showed a noticeable decrease during the last decade, presumably in relation to obligatory measures implemented at a national or European level. NIS can cause changes, sometimes substantial, in the balance and functioning of the ecosystem (Larson et al. 2013; Simberloff et al. 2013; Copp et al. 2016). However, for the majority of NIS no quantitative information is yet available on the consequences of such introductions (Larson et al. 2013; Simberloff et al. 2013). Moreover, taxonomic difficulties remain with marine invertebrates and NIS, in which some of them are cryptic species (i.e. a complex of species, which cannot be distinguished morphologically). For instance, as underlined by Marchini and Cardeccia (2017), NIS amphipods offer a large spectrum of future taxonomic research between cryptogenic species, unresolved taxonomy and overlooked introductions. Molecular approaches such as those achieved by Pilgrim and Darling (2010) on two introduced biofouling amphipods (*Ampithoe valida* Smith, 1873 and *Jassa marmorata* Holmes, 1905) along the Pacific North American coast addressed identification and cryptic diversity.

Maritime traffic along the northern French coast facing the English Channel has increased markedly with the development of international ports of Le Havre, Rouen, Dunkirk, Cherbourg and Calais harbours. In this shallow sea, the volume of maritime shipping represents 15.4% of the global total traffic (Bahé 2008). In these ports, different artificial structures are present such as docks, floating pontoons, dikes and marinas. All of these provide suitable habitats for NIS and act as stepping-stones for their secondary spread (Darbyson et al. 2009; Davidson et al. 2010; Mineur et al. 2012; Airoldi et al. 2015; López-Legentil et al. 2015).

The harbour at Le Havre was often the first site for the observation of a NIS in the English Channel (Breton and Vincent 1999; Ruellet and Breton 2012; Breton 2014, 2016). Scuba diving exploration in the harbour basin has led to the reporting of 364 animal species of which 36 were non-native (Breton 2014, 2016). Amongst the NIS list for Normandy, the crustaceans made up the most important group including the peracarids in which amphipods and isopods dominated (Pezy *unpublished data*). Currently, two native Anthuroidea species of isopod are regularly observed along the Normandy coasts of the English Channel, mainly in estuarine waters: *Cyathura carinata* (Krøyer, 1847) and *Anthura gracilis* (Montagu, 1808) (Ruellet and Dauvin 2008). Two others Anthuroidea species of isopod were reported in the Channel Islands (Guernsey, Jersey), *Paranthura costana* Bate & Westwood, 1866 and *Paranthura nigropunctata* (Lucas, 1846). The NIS Anthuroidea *Paranthura japonica* Richardson, 1909, is originated from the Asian Western Pacific (Lee II and Reusser 2012), where it is common along the northern and southern coasts of Japan (Yamada et al. 2007), the coasts of eastern Russia (Nunomura 1977) and those off eastern China (Wang et al. 2010). Recently, between 2007 and 2010, the species was recorded for the first time in Europe, in the Arcachon Bay on the eastern coast of France (Lavesque et al. 2013) and in Mediterranean Sea in

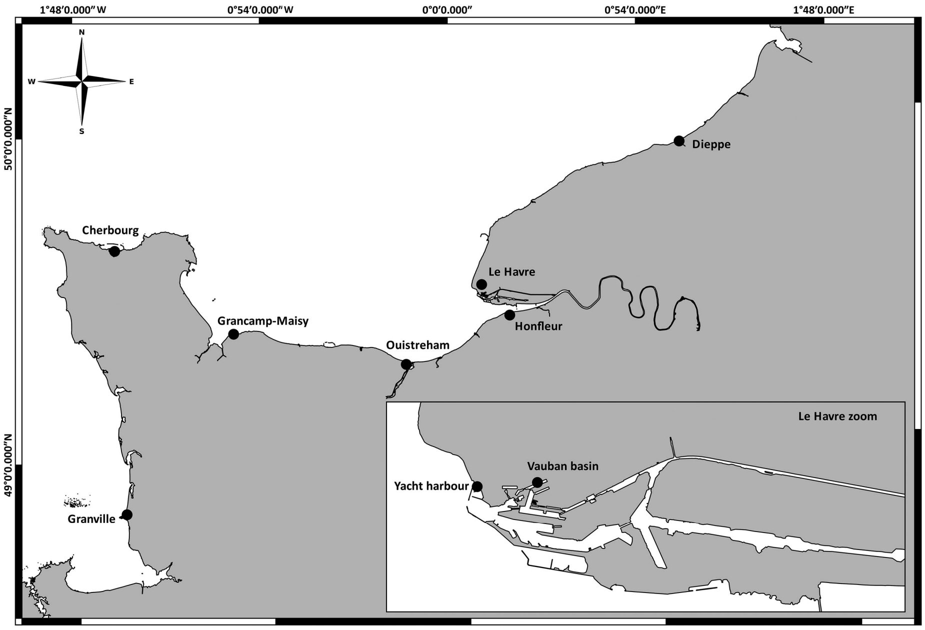

Figure 1. Map showing the locations of the eight marinas sampled in Normandy including those where *Paranthura japonica* was found: Le Havre (Vauban Basin) and Cherbourg.

2010 (Ulman et al. 2017). The species was also reported, as a NIS, in the United States on the Pacific coastline in the San Francisco Bay, in 1993 (Cohen and Carlton 1995) and in 2000 from Southern California (Cohen et al. 2005).

Under the framework of the ENBIMANOR project (ENrichissement de la BIodiversité MArine en NORmandie) in Normandy France, field surveys were organized to record NIS in coastal marinas. One of the main goals of this project was to produce an inventory of all NIS present on the hard substrata on the floating pontoons found at eight marinas along the Normandy coast running from Granville in the West to Dieppe in the East (Figure 1). The sampling was made only in leisure port excluding fishing and commercial docks. This project also offered the opportunity to discover previously unknown NIS or recently introduced in Normandy (Pezy et al. 2017a, b).

During our recent study on the recording of NIS in Normandy, numerous specimens of *Paranthura japonica* have been found in two Normandy harbours, Cherbourg and Le Havre. In this paper we report and discuss on this new NIS sighting in the English Channel.

Materials and methods

At eight sites around the Normandy coast (Figure 1, Supplementary material Table S1), samples were collected by scraping the fouling community on the floating pontoons forming actually the hard substratum with a frame of 0.25 m × 0.25 m or 0.42 m × 0.15 m depending of the pontoons structure. Five replicates were collected from each site, each replicate corresponding to a sampling surface of 0.0625 m^2. Additionally, approximately one hour was spent sampling different and distinct pontoon sections. Removed material was collected using a WP2 net (200 µm) in order to avoid any loss of marine organisms. The retrieved specimens were preserved in a 10% formaldehyde solution and taken to the laboratory for identification. Then organisms were sorted, identified and counted using a dissecting microscope and stored in alcohol.

The samples herein described originated from only two of these eight sites: Cherbourg and Le Havre. The site at Cherbourg (located on the most northern part of the Cotentin peninsular) is located in the Rade of Cherbourg (49.647668N; 1.621454W), which is a semi-enclosed artificial harbour on the French side of the English Channel (Baux et al. 2017). The harbour of Le Havre, where specifically the dock known as the Vauban Basin was targeted, is located at the north side of the mouth of the river Seine (49.490015N; 0.123776E).

At Cherbourg, the fouling community was composed of green, red and brown algae (*Saccharina latissimi* (Linnaeus) Lamouroux, 1813, *Undaria pinnatifida* (Harvey) Suringar, 1873), ascidian *Ciona* spp., *Corella* spp. and *Phallusia mammillata* (Cuvier, 1815), mussels (*Mytilus edulis* L., 1758) and amphipods *Monocorophium acherusicum* (Costa, 1853), *M. sextonae* (Crawford, 1937), *Microdeutopus gryllotalpa* Costa, 1853 and *Melita palmata* (Montagu, 1804). At Le Havre, the fouling community was composed of mussel (*M. edulis*), ascidians, the polychaete *Serpula vermicularis* L., 1767 and some vagile epifauna with important densities of the introduced caprellid amphipod *Caprella mutica* Schurin, 1935 and the ophiurid *Amphipholis squamata* (Delle Chiaje, 1828). A total of six specimens of *P. japonica* was lodged in the crustacean collection of the National Museum of Natural History at Paris under collection number MNHN-IU-2014-20754.

In both marinas, abiotic parameters were measured monthly. Seawater temperature showed a noticeable annual cycle with lower temperature in winter than in summer. Similarly, the oxygen concentration showed an annual cycle with lower values in summer than in winter, while the salinity decreased in winter only in the Vauban Basin; the turbidity was low at both sites and stable along the year (Table 1). During the survey (25 February 2019), the sea temperature at the sampling station on the Vauban Basin was 7.2 °C, with a salinity of 26.7, a turbidity of 0.8 NTU, and an oxygen concentration of 7.1 mL L^{-1}. Environmental conditions around the Cherbourg harbour were measured on March 1, 2019: the sea temperature at the sampling station was 9.2 °C, with a salinity of 33.8, a turbidity of 1.2 NTU, and an oxygen concentration of 6.5 mL L^{-1}.

Results

Amongst the isopods found, some specimens presented a dark pigmentation in the form of scattered chromatophores forming regular patches on the dorsal part of the organism. Cephalon had an anterolateral lobes extending

Table 1. Abundances of *Paranthura japonica* at Le Havre and Cherbourg (five replicates of 0.065 m² by site) and abiotic parameters (Win: winter; Sum: summer).

Date	Site	Abundance (in m²)	Temperature (°C)		Salinity		Turbidity (NTU)		Oxygen (mL.L^{-1})	
			Win	Sum	Win	Sum	Win	Sum	Win	Sum
25 February 2019	Le Havre (Vauban basin)	1,046 1,056 896 352 1,328	8.6	17.2	26.8	32.1	1.3	1.9	7.2	4.7
1 March 2019	Cherbourg harbour	16 48 0 0 0	9.6	17.8	34.0	33.8	0.8	1.2	6.4	4.5

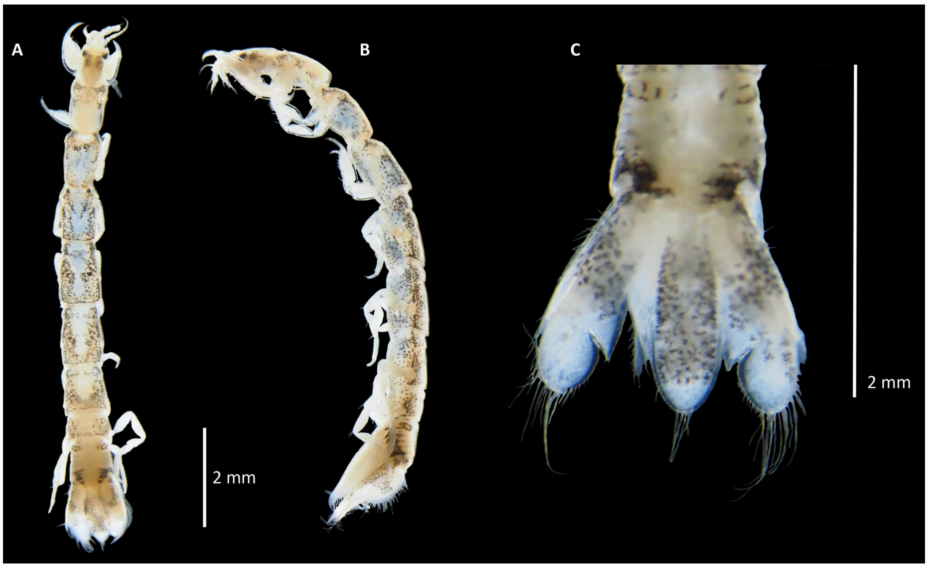

Figure 2. *Paranthura japonica* individuals, dorsal (A), profile (B) and telson (C) (MNHN-IU-2014-20754). Scale bar: 2 mm. Photo by J.P. Pezy.

beyond rostrum. The mid-dorsal fusion of the pleonites 1 to 5 permitted the distinction and identification of the European *Paranthura* species (Lavesque et al. 2013). The postero-dorsal margin of the pleonite 6 was slightly bilobed and a median slit extending about half the length of the segment. In our specimens, the pereonite 6 was shorter than pereonite 5 and the telson (Figure 2) was linguiform, basally constricted, tapering to a broadly rounded, slightly truncated apex. The uropodal peduncle with inner margin sinuous and inner distal angle produced, exopod crenulated, setose, approximately 2.3 times as long as wide, notched sub-apically; endopod ovate, setose, barely reaching to telsonic apex. The propodal palm of pereopod 2 was composed of nine stout setae in larger individuals; propodus of pereopod 7 with two stout setae in proximal half and single stout seta postero-distally. The mandibular palp 3 segmented and the second segment was the longest, with a long sub-distal seta, the third segment had a row of nine to 11 robust setae. Maxillipedal palp had an obscure terminal article and about 10 setae on the distal half. The females

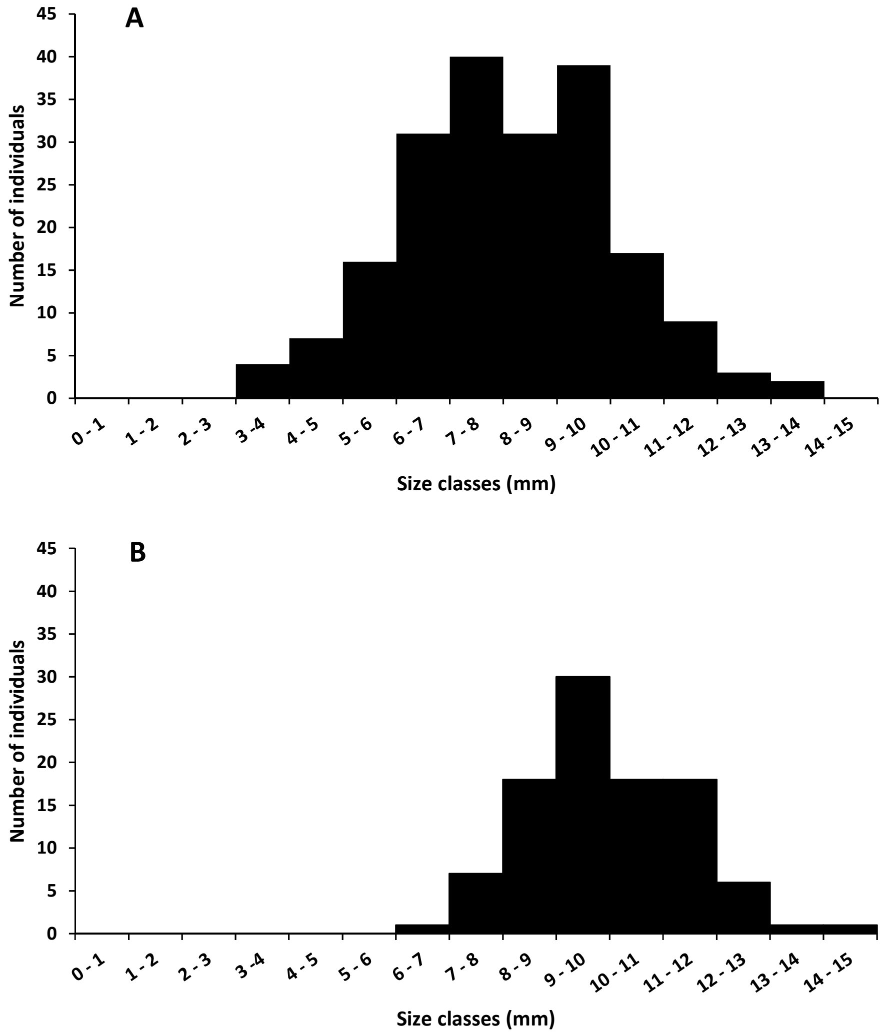

Figure 3. Size distribution of *Paranthura japonica* sampled in Normandy on 25 February at Le Havre (A) and 1 March 2019 at Cherbourg on pontoons (B); graphs for males and females.

had oostegites, whereas males had a fully developed appendix masculine and setose antennulae.

According to Lorenti et al. (2016), those morphological characters, enabled the identification of this isopod as *Paranthura japonica* Richardson, 1909 (Figure 2). On the 25th of February 2019, 295 individuals of this species were found in samples from the pontoons at Le Havre. Later, on the 1 March 2019, four more individuals were retrieved from pontoons in the harbour at Cherbourg. In both harbours, the specimens were found associated with mussel beds.

On the eight marinas prospected along the Normandy coast, *P. japonica* had been observed only at Cherbourg and Le Havre (Vauban basin) sites.

At Le Havre, the mean density of *P. japonica* was 944 ± 365 individuals per m^2 with a minimum of 352 and a maximum of 1,328 individuals per m^2.

At Cherbourg, the mean density of *P. japonica* was 13 ± 21 individuals per m^2, ranging from none to 48 individuals per m^2.

The length of the organisms collected varied between 4.0 mm and 14.3 mm (Figure 3). The sex ratio was 1.99 (100 females *versus* 199 males). The size distribution revealed that the females were larger (Figure 3)—the size ranging from 6.1 to 14.3 mm—whereas the size of the males varied between 4.0 and 13.1 mm.

Discussion

Paranthura japonica is a species that could be easily confused with the cosmopolitan *Cyathura carinata* (Kroyer, 1847), an Anthuridae present along the European coasts (Lavesque et al. 2013). *Cyathura carinata* was reportedly found on the 14th of March 2001 in the Vauban dock at Le Havre (Breton et al. 2005); however, it is possible that it was at that time confused with *P. japonica* (Breton et al. 2005). Thus, *P. japonica* may have been present at Le Havre since early 2000's.

Possible mode of introduction

The harbour of Le Havre could be considered as a major source of introduction of NIS into the English Channel noting the large number already detected (Breton 2014, 2016). Furthermore, both-harbours of Le Havre and Cherbourg are also predisposed to biological invasions since they exhibit several major anthropogenic activities that can be responsible for NIS introductions such as those relating to recreational and commercial shipping.

At a larger spatial scale, for Ulman et al. (2017), new *P. japonica* observations in Spain and Malta increased the known distribution of *P. japonica*, revealing it as one of the most widespread NIS in the Mediterranean Sea. While the initial findings of *P. japonica* had suggested an association with aquaculture transfers, these new records showed that it most likely is a polyvectic species, which complicates the possibility of reconstructing its invasion trajectory (Ulman et al. 2017).

According to Lavesque et al. (2013), *P. japonica* was accidently introduced in the Arcachon Bay in 2013 through oyster transfer. However, the absence of aquaculture near Le Havre, (especially oyster production), was not a plausible vector, as suggested by Lavesque et al. (2013). In addition, dispersion by currents from the Arcachon Bay is excluded, because this species is unable to swim over long distances and to drift by currents. Moreover, as commented by Lorenti et al. (2009), anthuridean isopods have a limited spreading capacity and are unable to extend their range over a global scale purely by natural means. Flushing of ballast water has been suggested as a possible pathway for the introduction of *P. japonica* along the Pacific coast of North America (Cohen and Carlton 1995; Cohen et al. 2005). However, another invasive peracarid amphipod species present in the Vauban dock at Le Havre was the Caprellidae *Caprella mutica* Schurin, 1935, another epibenthic species. The absence of both of these two NIS (*C. mutica* and *P. japonica*) from the entrance to the port at Le Havre, suggests their direct introduction in the Vauban dock by fouling.

Paranthura japonica was observed only at Cherbourg and Le Havre marinas, localities where leisure marinas, fishing and commercial harbours shared the same port area. As a polyvectic species, its introduction may also be attributed to import seafood processing in fish markets (Marchini et al. 2014).

Recreational vessels arriving at the Vauban basin are often covered by several colonizing organisms, and a possible transfer of species from the Arcachon Bay to Le Havre harbour is possible by such pleasure boats. Minchin (2007) noted that some recreational boats are used to travel long distances, and their relatively low speeds make them ideal vectors for those species that attach to their hulls. Species transfer by hull fouling is the most likely factor for the introduction of *Paranthura japonica.* The same conclusion holds true for other isopods such as *Mesanthura* sp. in Italian harbours (Lorenti et al. 2009) and *Synidotea laevidorsalis* (Miers, 1881) (Chapman and Carlton 1994).

Potential consequences

In the Western Pacific, particularly along the Japan coasts, *P. japonica* is an isopod known to feed on *Sargassum* spp. (Nunomura 1977) and on subtidal *Zostera* spp. meadows (Nakaoka et al. 2001). In Normandy, and along the English Channel, these two species (*Zostera marina* meadows and *Sargassum muticum*) are also present. It is likely that *P. japonica* could have expanded its area of distribution since these first observations in Le Havre, where the population was already well established and in Cherbourg where relatively few specimens were collected. Further attention will be needed to the identification of other Anthuroidea isopods in hard natural and artificial substratum including macrophyte habitats bordering the English Channel and around other parts of the North-eastern Atlantic coasts including the Mediterranean Sea.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Geographic coordinates of sampling sites.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2020/Supplements/BIR_2020_Pezy_etal_Table_S1.xlsx