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The non-indigenous *Paranthura japonica* Richardson, 1909 in the Mediterranean Sea: travelling with shellfish?

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Abstract

An anthurid isopod, new to the Mediterranean Sea, has recently been observed in samples from three localities along the Italian coast: the Lagoon of Venice (North Adriatic Sea), La Spezia (Ligurian Sea) and Olbia (Sardinia, Tyrrhenian Sea). The specimens collected showed strong affinity to a species originally described from the NW Pacific Ocean: *Paranthura japonica* Richardson, 1909. The comparison with specimens from the Bay of Arcachon (Atlantic coast of France), where *P. japonica* had recently been reported as non-indigenous, confirmed the identity of the species. This paper reports on the most relevant morphological details of the Italian specimens, data on the current distribution of the species and a discussion on the pathways responsible for its introduction. The available data suggest that the presence of this Pacific isopod in several regions of coastal Europe might be due to a series of aquaculture-mediated introduction events that occurred during the last decades of the 1900s. Since then, established populations of *P. japonica*, probably misidentified, remained unnoticed for a long time.

Keywords: *Paranthura japonica*, isopod, non-indigenous species, Italy, Mediterranean Sea, aquaculture.

Introduction

In European seas, crustaceans account for nearly 20% of all the reported non-indigenous species (NIS), constituting the second most introduced taxon in Europe after molluscs (Zenetos *et al*., 2012). Isopods are represented by only 8 species: the parasitic cymothoids *Anilochra pilchardi* Bariche and Trilles, 2006 and *Cymothoa indica* Schioedte and Meinert, 1884 introduced in the eastern Mediterranean (Bariche & Trilles, 2006); the sphaeromatids *Paracerceis sculpta* (Holmes, 1904), *Paradella dianae* (Menzies, 1962), *Sphaeroma walkeri* Stebbing, 1905 reported from the Mediterranean (Rezig, 1978; Atta, 1991; Occhipinti-Ambrogi, 2000; Galil, 2008) and (*P. sculpta* and *P. dianae*) from Atlantic Spain (Rodriguez *et al*., 1992); the idoteid *Synidotea laticauda* Benedict, 1897 along the Atlantic coasts of Europe (Faasse, 2011); the anthurids *Mesanthura* cf. *romulea* Poore & Lew Ton, 1986 in Italy (Lorenti *et al*., 2009) and *Paranthura japonica,* Richardson 1909 on the Atlantic coasts of France (Frutos *et al*., 2011; Lavesque *et al*., 2013).

The genus *Paranthura* comprises over 50 species, common in shallow temperate and tropical waters worldwide, mainly distributed in the Indian and Pacific Oceans (Frutos *et al*., 2011). Three species are native to European waters: the coastal *P. nigropunctata* (Lucas, 1849) and *P. costana* Bate & Westwood, 1868, common in the Mediterranean and NE Atlantic (Wägele, 1982; Negoescu & Wägele, 1984; Junoy & Castelló, 2003), and the bathyal blind *P. santiparrai* Frutos, Sorbe & Junoy, 2011, recently discovered in the Southern Bay of Biscay (Frutos *et al*., 2011; Lavesque *et al*., 2013).

P. japonica was first described by Richardson (1909) from a female specimen collected at Muroran (North Japan), then redescribed from males collected near Petrov Island, Primorsky region, Eastern Russia (Nunomura, 1975) and from both males and females collected in several other Japanese localities (Nunomura, 1977). More recently, it was reported as a NIS from San Francisco Bay in 1993 (Cohen & Carlton, 1995) and Southern California in 2000 (Cohen *et al*., 2005). This species can be distinguished from its three European congeneric species because of the partial fusion of its pleonites (Frutos *et al*., 2011).

This study documents the distribution of *P. japonica* along the European coasts, providing new records from the Mediterranean Sea.

Materials and Methods

The material examined originates from three different Italian locations (Fig. 1) and was collected in the framework of two different research projects. Samples from La Spezia (Italy, Ligurian Sea) and Olbia (Sardinia, Italy, Tyrrhenian Sea) were collected in the framework of a PhD thesis project at the University of Pavia (Lodola, 2013). Samples from the Lagoon of Venice (Italy, Adriatic Sea) were collected by the team of the University of Pavia in the framework of "VECTORS", a European Commission Seventh Framework Programme project.

La Spezia harbour, situated in a natural gulf between Genoa and Leghorn, covers an area of 1500 ha and features about 5 km of wharfs. A massive seawall is located lengthwise near the mouth of the harbour, protecting the port from wave exposure. Mercantile and shipbuilding activities (both civilian and military) are centred on the old basin of the harbour, while aquaculture facilities (mussel and clam farming) are located along and near the seawall at the mouth of the harbour (Lodola *et al*., 2012). At the beginning of 2005, some small oyster beds were also set up in La Spezia Gulf (Cattaneo-Vietti *et al*., 2010). The benthic macrofauna was collected by scraping the concrete dock walls with a hand-held rigid net (sampling area: approximately 0.23 m^2), as in previous studies of artificial substrates (Marchini *et al*., 2004). Five sites, located in mooring and transit areas (identified by the codes 'P' and 'TR', respectively) were investigated in 2010 (June and September) and 2011 (June and October).

Olbia harbour is the most important port on the North-Eastern coast of Sardinia and faces the Western Tyrrhenian Sea. The harbour includes a shipbuilding area, an artificial strip designed for the mooring operations of cruise liners and commercial vessels, and docks used for the mooring of sea cruisers, recreational boats as well as small local yachts. Mussel farms (*Mytilus galloprovincialis* Lamarck, 1819) are located at the mouth of the harbour. The sampling procedure was similar to the one performed in La Spezia. The samples were collected in 2010 and 2011 (May and September).

The Lagoon of Venice is a microtidal lagoon (maximum tidal range: 2.2 m; Flindt *et al*., 1997), with an area of approximately 550 km^2, of which nearly 30% is devoted to extensive aquaculture (Bandelj *et al*., 2012). The lagoon is divided into three hydrographic basins, each of them connected to the sea by a mouth: northern basin (Lido mouth), central basin, including the town of Venice (Malamocco mouth) and Chioggia basin, including the town of Chioggia (Chioggia mouth). An extensive sampling survey of hard bottom benthic communities of this lagoon was performed in July 2012, targeting some areas assumed to be preferential for NIS introduction: shellfish farms of the Manila clam *Ruditapes philippinarum* (Adams & Reeve, 1850), commercial and tour-

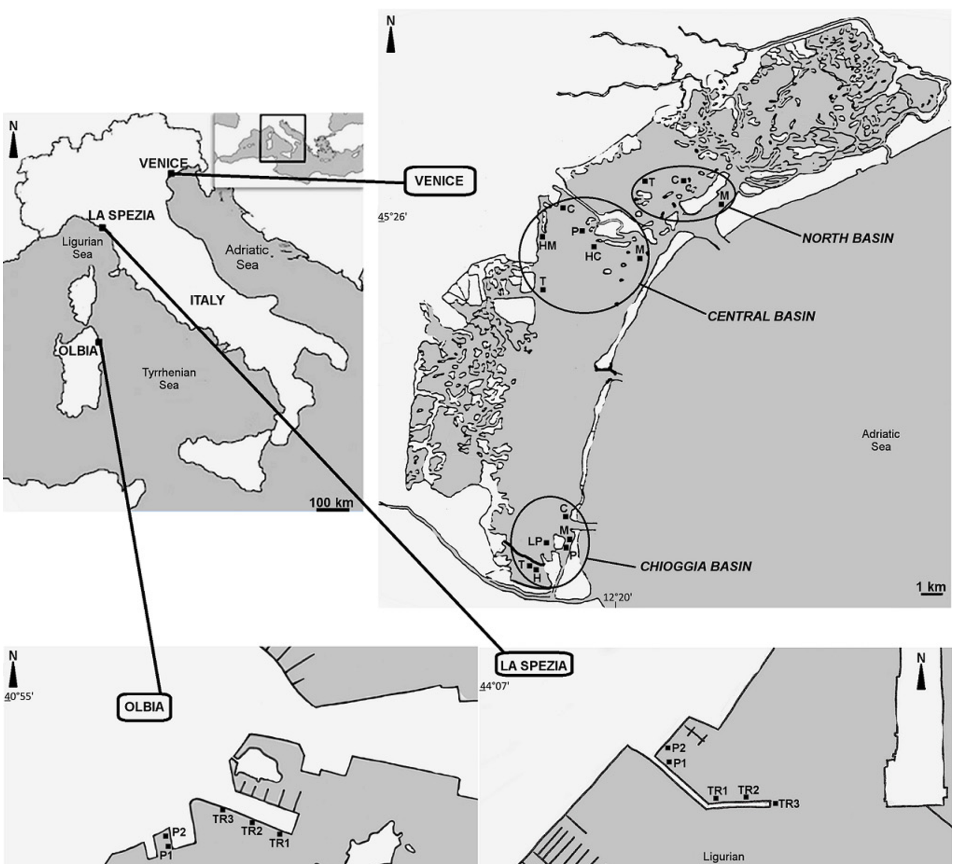

Fig. 1: Sites of collection of *Paranthura japonica*: the Lagoon of Venice and its three hydrographical basins; the harbour of La Spezia; the harbour of Olbia. Sample codes: in the Lagoon of Venice – C= control, H=harbour, LP=seafood processing site, M=marina, P= seafood trade site, T= clam farm; in Olbia and La Spezia – P= mooring areas, TR= transit areas.

ist harbours, marinas, and seafood trade and processing sites, where loading and unloading of live seafood takes place directly on docks, very close to the lagoon waters (Ferrario *et al*., 2013). Areas not in the immediate vicinity to the above anthropogenic activities were also surveyed (control sites). Samples were collected from 3 sites in the northern basin; 6 sites in the central basin and 6 sites in Chioggia. The benthic communities colonising the partially submerged wooden poles (widely disseminated along the numerous lagoon channels to indicate the navigable paths) were collected by scraping the hard substratum under the lowest tide level with a hand-held rigid net. Three replicates were collected from each site, for a total sampling area of approximately 0.68 m^2. Samples were also collected from soft bottoms (one site in each sub-basin, in Manila clam farms) using a hand-held grab sized 35 cm x 14.5 cm.

Alcohol-preserved *P. japonica* specimens were examined under a stereomicroscope and photographed with an AXIO CAM ERc5s camera, using ZEISS- AXIO VISION 4 software for image analysis. Specimens were then compared to those collected in the Bay of Arcachon (France), which in turn had been compared to Museum specimens from the native area (see Lavesque *et al.,* 2013 for details).

Ten specimens from the Lagoon of Venice were deposited in the Museum of Natural History of Venice with the code MSNVE-23075.

Results

After careful examination and comparison of material from the Atlantic and Mediterranean samples, we concluded that all specimens share the same morphology and correspond to the descriptions of *P. japonica* (Isopoda, Anthuridea, Paranthuridae) provided by Richardson (1909) and Nunomura (1975, 1977) with the following characters discriminating the species from congeneric ones:- anterolateral angles of cephalon exceeding rostral projection (Fig. 2); eyes with dark ommatidia clumping together (Fig. 2);- pereonite 6 slightly shorter than pereonite 5 (Fig. 3);- pleonites 1-5 clearly fused medially but not laterally (Fig. 3, 4, 5 - this character unequivocally excluding the three *Paranthura* species known from European waters: *P. nigropunctata, P. costana, P. santiparrai);* uropod exopods with distal concavity on mesial margin (Fig. 4, 5); pleotelson not reaching beyond tip of uropod endopods (Fig. 4, 5).

Table 1 includes data on the presence and abundance of *P. japonica* in the considered sampling sites. This paranthurid was fairly common although not abundant in the Western Mediterranean harbours of La Spezia (only 2010; no specimens were observed during the 2011 survey) and Olbia (both years 2010 and 2011). As for the Lagoon of Venice, one of the authors (AM) examined a few specimens collected in July 2005 in the Chioggia sub-basin labelled as *Anthura gracilis* (Montagu, 1808):

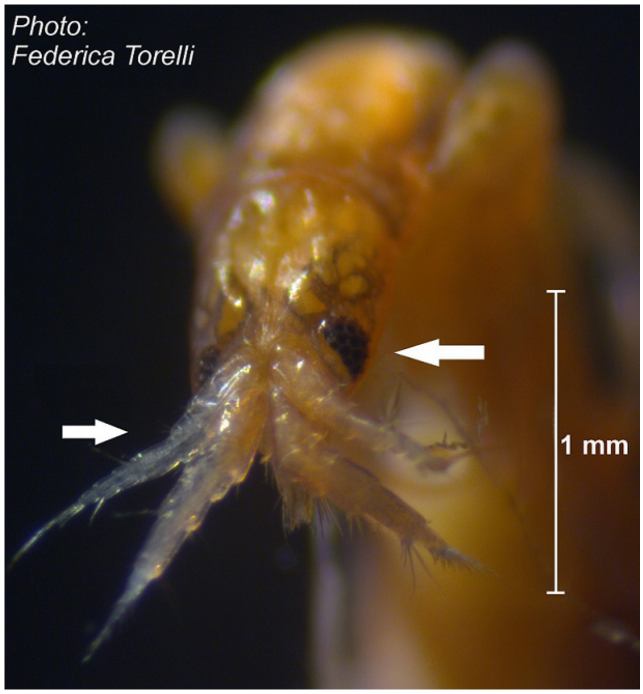

Fig. 2: *Paranthura japonica* from the Lagoon of Venice: cephalic region. Arrows highlight anterolateral angles of cephalon exceeding rostral projection; eyes with dark ommatidia clumping together.

Fig. 3: *Paranthura japonica* from the Lagoon of Venice: full female specimen. Arrows highlight pereonite 6 slightly shorter than pereonite 5; pleonites 1-5 clearly fused medially but not laterally.

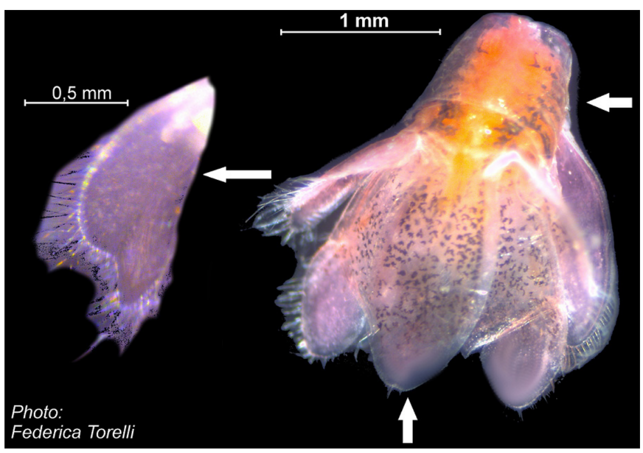

Fig. 4: *Paranthura japonica* from the Lagoon of Venice. Left arrow: uropodal exopod; right arrow: pleon; bottom arrow: telson.

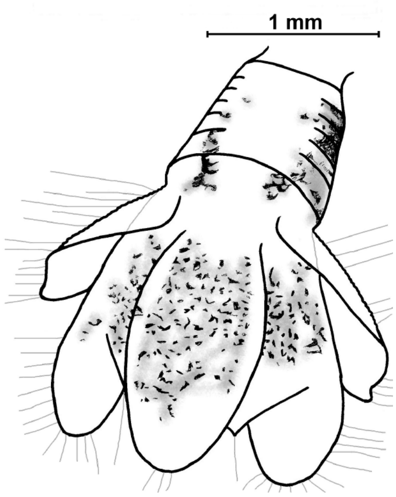

Fig. 5: Paranthura japonica: drawing of pleon, telson and uropods, highlighting distinctive characters: pleonites 1-5 fused medially but not laterally; uropod exopods with distal concavity on mesial margin.

the specimens, however, clearly belonged to *P. japonica*. This finding was not added to Table 1, because the geographical coordinates are missing. The extensive survey performed in July 2012 allowed us to confirm the successful establishment of this species in the Lagoon of Venice, where it was distributed in all three lagoon basins and all typologies of sites (harbour, marina, clam farm, control, etc.). At the time of collection, reproducing populations of *P. japonica* were observed, with many brooding females and/or juveniles, in some cases, showing notably high abundance: more than 400 individuals were counted at the "Seafood trade" site of the Chioggia basin. *P. japonica* was only observed on the artificial hard substrates (wooden poles); no specimens were observed in the soft-bottoms samples collected at three clam farming sites of the Lagoon of Venice. The only other anthuridean isopod collected in July 2012 from the Lagoon of Venice was *Cyathura carinata* (Krøyer, 1847), whereas *A. gracilis* was not observed.

Discussion

Like many peracarid crustaceans, anthuridean isopods have limited dispersion capability and are unable to extend their range over a global scale by natural means (Lorenti *et al*., 2009). The European sites where *P. japonica* has been observed are all exposed to high propagule pressure due to a variety of man-mediated pathways: harbours and marinas, shellfish farming areas, sites of live seafood trade. Records show that the species has a preference for both natural and artificial hard substrates: mussel beds, oyster reefs (French records, Lavesque *et al*., 2013), docks and wooden

Table 1. Number of individuals (#) of *Paranthura japonica* collected in La Spezia, Olbia and Lagoon of Venice in the period 2010-2012. Sampling surface in La Spezia and Olbia: 0.23 m^2; sampling surface in Venice: 0.68 m^2.

Sea	Locality	Site	Coordinates	Substrate	Date	#
Ligurian Sea	La Spezia	Harbour	44°06' N - 9°49' E	dock transit area	04/06/2010	6
		Harbour	44°06' N - 9°49' E	dock transit area	23/09/2010	18
		Harbour	44°06' N - 9°49' E	dock mooring area	04/06/2010	2
		Harbour	44°06' N - 9°49' E	dock mooring area	23/09/2010	35
Tyrrhenian Sea	Olbia	Harbour	40°55' N - 9°30' E	dock transit area	24/05/2010	37
		Harbour	40°55' N - 9°30' E	dock transit area	30/09/2010	31
		Harbour	40°55' N - 9°30' E	dock transit area	25/05/2011	8
		Harbour	40°55' N - 9°30' E	dock transit area	06/10/2011	6
		Harbour	40°55' N - 9°30' E	dock mooring area	24/05/2010	7
		Harbour	40°55' N - 9°30' E	dock mooring area	30/09/2010	10
		Harbour	40°55' N - 9°30' E	dock mooring area	25/05/2011	2
Adriatic Sea	Venice - North basin	Marina	45°26' N - 12°25' E	wooden pole	09/07/2012	55
		Clam farm	45°28' N - 12°21' E	wooden pole	09/07/2012	18
		Control	45°28' N - 12°23' E	wooden pole	09/07/2012	17
	Venice - Central basin	Marina	45°25' N - 12°21' E	wooden pole	11/07/2012	82
		Clam farm	45°23' N - 12°16' E	wooden pole	11/07/2012	31
		Seafood trade	45°26' N - 12°18' E	wooden pole	11/07/2012	218
		Harbour (cruise lines)	45°26' N - 12°18' E	wooden pole	11/07/2012	28
	Venice - Chioggia basin	Marina	45°13' N - 12°17' E	wooden pole	10/07/2012	118
		Clam farm	45°13' N - 12°15' E	wooden pole	10/07/2012	123
		Seafood trade	45°13' N - 12°17' E	wooden pole	10/07/2012	420
		Seafood processing	45°13' N - 12°16' E	wooden pole	11/07/2012	276
		Harbour	45°12' N - 12°15' E	wooden pole	10/07/2012	81
		Control	45°14' N - 12°17' E	wooden pole	10/07/2012	48

poles (present work), whereas it was not observed on soft bottoms. Due to the absence of statocysts, paranthurids have little orientation capability and tend to climb on hard substrates such as rocks, calcareous algae, macroalgae, polychaete tubes, bryozoans and sponges, rather than burrowing into sediments (mud, sand) as other anthurids do (Negoescu & Wägele, 1984). This habitat preference suggests that *P. japonica* is likely to be co-transported with the fouling communities on ship hulls, rather than in ballast waters or in ballast tank sediments. Therefore, maritime transport as biofouling is a possible vector of introduction and spread of *P. japonica*. However, since all European findings of *P. japonica* are from intensive bivalve culture sites (oysters, mussels, clams), aquaculture appears to be the most likely pathway of introduction for this paranthurid in European waters. In particular, the fouling hypothesis cannot be retained in the case of the Bay of Arcachon because it only harbours a small local fishing port.

On the basis of the available data on distribution, abundance and dates of record of *P. japonica* in European Atlantic and Mediterranean waters, combined with information on transfers of cultured bivalves, we suggest a step-by-step route of *P. japonica* invasion: a first introduction from Japan to the Bay of Arcachon, France; a second step, from France to Venice, Italy, followed by a third step, from Venice to the Western Mediterranean (Olbia and La Spezia, Italy).

Step 1: From Japan to Arcachon, France - The Bay of Arcachon is an area with extensive oyster farming. The Pacific cupped oyster *Crassostrea gigas* (Thunberg, 1793) was massively introduced to this bay between 1971 and 1975 to sustain the oyster industry, as the local *C. angulata* (in fact a *C. gigas* strain of Taiwanese origin) was decimated by a viral disease (Goulletquer *et al*., 2002). Spat was imported from Sendai Bay (NE Honshu Island, Japan), up to 638 tons in 1971, fixed on *Crassostrea*/*Pecten* shell collectors and transported by plane (Gruet *et al*., 1976). Adult oysters were also imported from British Columbia (Canada), about 138 tons during 1971-73 (Grizel & Héral, 1991) and probably from other unrecorded shipments. Many NIS were introduced to Arcachon Bay as a result of these oyster transfers, such as the macroalgae *Antithamnionella spirographidis* (Schiffner) E.M. Wollaston, *Neosiphonia harveyi* (J. Bailey) M.-S. Kim, H.-G. Choi, Guiry and G.W. Saunders, or the mollusc *Urosalpinx cinerea* (Say) (Goulletquer *et al*., 2002; Verlaque *et al*., 2008).

This information suggests that *P. japonica* could have been unintentionally introduced to the Bay of Arcachon during the oyster spat transfers from eastern Japan in the 1970s, then forming established populations that have persisted but remained unnoticed until recent records (2007-2010), either because it was too rare or because it was misidentified. Lavesque *et al*. (2013) also suggest that it could have alternatively been introduced along with an undeclared oyster transfer from Japan or from another area where this anthurid has not been identified so far.

Step 2: From France to Venice - The Lagoon of Venice is the hotspot of introduction in Italy, i.e. the Italian location with the highest number of introduced NIS (Occhipinti-Ambrogi, 2000; Occhipinti-Ambrogi *et al*., 2011). This lagoon is particularly prone to invasions since it hosts most of the anthropogenic activities responsible of NIS introductions: recreational and commercial harbours, marinas, sites of live seafood trade, and a flourishing mariculture activity (Occhipinti-Ambrogi, 2000). The NIS introduced into the Lagoon of Venice include a number of macroalgae and invertebrates of Western Pacific origin, accidentally introduced *via* shellfish farming activities. Some examples are the macroalgae *Heterosiphonia japonica* Yendo, *Polysiphonia morrowii* Harvey, *Sargassum muticum* (Yendo) Fensholt, *Undaria pinnatifida* (Harvey) Suringar (Sfriso & Curiel, 2007), and the bivalves *Arcuatula senhousia* (Benson in Cantor, 1842) (A. Marchini, personal observations) and *Xenostrobus securis* (Lamarck, 1819) (Sabelli & Speranza, 1993). Some of them may have been directly introduced from their native range, whereas others may have resulted from secondary introductions *via* shellfish trade from other European localities, where they had been introduced first.

The isopod *P. japonica* might have followed a similar pathway towards Venice, and originate either directly from the NW Pacific, with imports of the Pacific oyster *Crassostrea gigas*, or with stocks of the Manila clam *Ruditapes philippinarum* (Flassch & Leborgne, 1992), perhaps directly from Arcachon. The history of shellfish imports in Venice supports the latter hypothesis. The first deliberate introductions of the Pacific cupped oyster *Crassostrea gigas* occurred in the Northern Adriatic (Po river delta and Lagoon of Venice) in 1964-66 (Matta, 1969). The Manila clam *Ruditapes philippinarum* was imported during the 1970's in the Atlantic coasts of Europe (Arcachon being one of the preferred sites), and subsequently exported from the Atlantic to certain Mediterranean countries (Goulletquer, 1997). In Italy, it was first introduced in 1983 in the Lagoon of Venice (Cesari & Pellizzato, 1985), where it is still successfully exploited, providing 50% of the entire Italian production, which is the second largest in the world (Boscolo Brusà *et al*., 2011). If *P. japonica* had been introduced in the 1960s with *Crassostrea gigas*, it would probably have had time to establish and spread into the lagoon before the 1980s and, therefore, would have been observed during the extensive surveys of peracarid communities performed in the 1980s and 1990s in the Lagoon of Venice (Sconfietti, 1989; Sconfietti & Danesi, 1996; Sacchi *et al*., 1998). However, this is not the case; *P. japonica*, which is currently common in the entire Venice lagoon and locally abundant, probably appeared in Venice samples starting from 2000, when it might have been misidentified as *Anthura gracilis* (Montagu, 1808). Therefore, a plausible explanation for the high numbers observed in 2012 is an introduction in the 1980s with *Ruditapes philippinarum*, a 'lag-phase' (Hummel & Wijnhoven, 2014) in the late 1980s and early 1990s, and then the beginning of the exponential phase in the late 1990s, peaking with the high numbers observed in 2012.

Step 3: From the Lagoon of Venice to La Spezia and Olbia harbours – The third step of the European tour of *P. japonica* is the most puzzling one, although there are clues that it may have started from Venice towards the Western Mediterranean. Venice, being a hotspot of introductions (Occhipinti-Ambrogi *et al*., 2011), represents both an important sink and source of NIS in the Mediterranean Sea**.**

Two factors suggest aquaculture as a very likely pathway supporting the hypothesis of Venetian origin of the La Spezia and Olbia populations of *P. japonica*: (i) both harbours host cultures of commercial bivalves (clams, oysters, mussels) (Cannas *et al*., 2009; Cattaneo-Vietti *et al*., 2010; Doneddu, 2011; Lodola *et al*., 2012) and over the years some material could have been imported from Venice. Interviews with local mussel farmers in Olbia confirmed that the majority of mussel seeds were imported from the northern Adriatic lagoons (Lodola *et al*., 2012). (ii) Both La Spezia and Olbia display a set of NIS in common with Venice, whose occurrence had been justified with aquaculture-mediated introductions: in La Spezia harbour, the peracarids *Caprella scaura* Templeton, 1836 and *Paracerceis sculpta* (Holmes, 1904) and the bryozoan *Tricellaria inopinata* d'Hondt and Occhipinti Ambrogi, 1985 (Lodola *et al*., 2012; Lodola, 2013); in Olbia harbour, the molluscs *Arcuatula senhousia* (Benson in Cantor, 1842), *Rapana venosa* (Valenciennes, 1846), *Ruditapes philippinarum* (Flassch & Leborgne, 1992), *Xenostrobus securis* (Lamarck, 1819), the peracarids *Caprella scaura* and *Paracerceis sculpta* and the bryozoan *Tricellaria inopinata* (Campani *et al*., 2004; Cannas *et al*., 2009; Doneddu, 2011; Lodola *et al*., 2012; Lodola, 2013). *P. japonica* might have followed the same "caravan" of marine NIS introduced along with commercial bivalves.

Making inferences on the temporal sequence and route of the introduction events of *P. japonic*a in the Western Mediterranean is challenging. There are at least four possible options: either (1) transport from Venice to La Spezia and from Venice to Olbia (two independent introductions via mussel transfers); or (2) from Venice to Olbia via mussel trade and then a secondary spread from Olbia to La Spezia; or, conversely, (3) from Venice to La Spezia and then a secondary spread from La Spezia to Olbia; or, finally, (4) from Arcachon (or Venice) to other localities in the Mediterranean and then secondary spread to Olbia and La Spezia. Live bivalves are in fact farmed at several other Mediterranean sites, which in the past have traded shellfish with Arcachon and Venice and now share a similar NIS set, for example, Sacca di Goro (Italy, Northern Adriatic Sea), Mar Piccolo di Taranto (Italy, Ionian Sea), Thau Lagoon (France, Western Mediterranean) (e.g. see Cecere *et al.,* 2000; Verlaque, 2001; Mistri, 2002; Sjøtun *et al*., 2008). Therefore, we cannot exclude that the species is already present elsewhere in Europe and that the history of its dispersal has followed a more complicated pathway. The time of introduction of *P. japonica* to La Spezia and Olbia is also unknown; it could have happened anytime during the 1990-2010 period.

In addition to aquaculture, shipping is an alternative credible pathway to explain movements of the Asian isopod between Olbia and La Spezia. Commercial vessels travel regularly from Sardinia to the Ligurian Sea and *vice versa*. Furthermore, both localities are situated in areas with extremely high tourist traffic, and display highly frequented marinas and moorings for recreational boats and fast ferries (Lodola, 2013). Recreational boating has been recently acknowledged as a relevant vector of secondary spread of peracarid species (Ros *et al.,* 2013) and the very same *P. japonica* was found outside of its native range in California marinas (Cohen *et al*., 2005). However, in our 2010 and 2011 surveys *P. japonica* was not collected in marinas located near Olbia and La Spezia (Lodola, 2013), thus weakening the hypothesis of transport via recreational boats. Future surveys of marinas in the same areas will improve the understanding of the secondary spread of *P. japonica* throughout the Mediterranean.

The hypothesis of transport as floatsam may also be taken into account. Transport of fouling as rafting material in the Tyrrhenian and Ligurian Seas has already been demonstrated by Aliani & Molcard (2003), who developed a numerical model showing that 45% of floating objects could reach the Ligurian coast from Corsica (about 75 km) in 50 days.

If the proposed hypotheses regarding *P. japonica* routes of introduction to the European coastline are valid, a question arises, namely, how has *P. japonica* been able to travel through Europe without being noticed for so long? As a matter of fact, isopods and other groups of mobile fauna are generally disregarded in surveys of hard bottoms, which in many cases focus on sessile macroinvertebrates or macroalgae (e.g. Piola & Johnston, 2008; Canning-Clode *et al*., 2013). Anthurids, in particular, are poorly known in the Mediterranean, for several reasons: (i) they are usually not very abundant in benthic communities, and therefore they might simply not be present in many samples; (ii) Even when present, they may have gone unnoticed by scientists who were not particularly attentive to this group; (iii) A comprehensive guide to the identification of isopods in the Mediterranean is completely missing and the published texts to support identification of Mediterranean isopods in general, and anthurids in particular, are scattered among many (old) publications that are not easily accessible. As regards the genus *Paranthura*, the only contribution to the Mediterranean species (including a key for identification) is the work by Wägele (1982), published in German, and therefore not easily exploitable by Mediterranean scientists; (iv) Anthurids are not easy to identify. All species belonging to the genus *Paranthura* are very similar and present only subtle differences in the shape and proportion of pereopods, uropods and telson (Wetzer & Brusca, 1997).

Lavesque *et al*. (2013) suggest that in the Bay of Arcachon *P. japonica* could have been misidentified in the past as the cosmopolitan *Cyathura carinata* (Krøyer, 1847). In the lagoon of Venice it was most probably misidentified as the Atlanto-Mediterranean *Anthura gracilis* (Montagu, 1808), which also displays partially fused pleon segments. Literature records from the 1980s and 1990s report *A. gracilis* as a rare species in the Lagoon of Venice (Sconfietti, 1989; Sconfietti & Danesi, 1996). Thereafter, in a Master's thesis defended at the University of Pavia (Paolucci, 2003) regarding samples collected in 2000-01, it was indicated as quite common in the Chioggia basin. All those *A. gracilis* records might have been misidentifications of *P. japonica*, but we do not have access to those samples and, therefore, we cannot verify the actual identity of the species. In our most recent survey of peracarids in the Lagoon of Venice, we observed specimens of *C. carinata*, especially in the soft bottom samples, but never saw any *A. gracilis*. It is possible that the few anthurids collected in the Lagoon of Venice over the past years were *P. japonica*, either being wrongly identified as *A. gracilis*, or that *A. gracilis* was actually present there as a rare species that subsequently regressed after the invasion of *P. japonica*. Unfortunately, we lack the evidence to establish which hypothesis is the more realistic one.

The impact due to the presence of *P. japonica* on native communities in European coastal habitats is unknown. However, predator-prey and competitive interactions can be expected. All anthurid isopods are predators, feeding on polychates and other invertebrates with soft teguments. The family Paranthuridae has evolved stinging mouthparts, able to pierce hard teguments. The observation of live paranthurids showed that they principally feed on amphipods (Negoescu & Wägele, 1984). The native species that could be affected mainly by competitive interactions with *P. japonica* are the congeneric *P. nigropunctata* and *P. costana* (Wägele, 1982). However, knowledge on the biology and ecology of these small crustaceans is insufficient to assess the quantitative effects of their interactions.

Conclusions

This work reports on the first records of *P. japonica* in the Mediterranean Sea, and increases the number of European localities at which the species is currently known to exist to four (France: Bay of Arcachon in France; Italy: Lagoon of Venice, La Spezia and Olbia). The Lagoon of Venice is the European location hosting the most abundant population of *P. japonica*, probably representing both a sink and source for this species in the Mediterranean. Although the species was first identified from samples collected in 2012, it was very likely present back in 2005, and possibly even earlier, having been misidentified during previous surveys.

Due to the intensive trade of shellfish stocks that occurred in the past few decades to and from Venice and other Mediterranean aquaculture sites (e.g. Sacca di Goro, Italy - North Adriatic Sea; Mar Piccolo di Taranto, Italy - Ionian Sea; Thau lagoon, France - Tyrrhenian Sea), combined with the scarcity of studies on the isopods from these sites, it is possible that *P. japonica* has spread even further and that its current distribution is much wider. Surveys at aquaculture sites, harbours and marinas should be encouraged in order to provide new insights into the invasive history of this paranthurid species in coastal European waters.

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