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Decapods on Adriatic gas platforms – benthic climbers and planktonic drifters?

(Crustacea, Decapoda)

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We studied the decapod communities at pillars of gas platforms in the Northern Adriatic sorted from samples of 20 × 20 centimetre biofouling scratched at 3, 10, and 20 metres depth at seven platforms named: Ana, Ivana A, Ivana B, Ivana C, Ivana D, and Vesna. In the samples, we found nine species: *Alpheus dentipes* Guérin, 1832, *Alpheus macrocheles* (Hailstone, 1835), *Athanas nitescens* (Leach, 1814), *Galathea intermedia* Lilljeborg, 1851, *Pachygrapsus marmoratus* (Fabricius, 1787), *Pilumnus hirtellus* (Linnaeus, 1761), *Pilumnus spinifer* H. Milne Edwards, 1834, *Pisidia bluteli* (Risso, 1816), and *Pisidia longicornis* (Linnaeus, 1767). *Alpheus dentipes* was the most abundant species in our samples with 62 individuals recorded. Most of the species might have colonised the pillars from the surrounding benthic communities. The presence of the intertidal crab *Pachygrapsus marmoratus*, of one megalopa of *Pilumnus spinifer*, and numerous juvenile crabs of *Pilumnus hirtellus* and *P. spinifer* (CW < 1 cm) indicates that colonisation via planktonic drift might also occur. We discuss possible colonisation pathways and relate them to the general and wind-driven currents in the Northern Adriatic.

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Introduction

Artificial marine habitats, such as shipwrecks, jetties, sockets of wind turbines, and sea marks are prominent anthropogenic changes to the marine environment (Feary et al. 2011). They are particularly interesting in the context of colonisation studies (Bohnsack et al. 1994, Burt et al. 2009), attempts to recover destroyed benthic biocenoses (Macreadie et al. 2011) and to establish bridgeheads between distant habitats, i. e. their capacity to facilitate habitat connectivity (Henry et al. 2018). Similar ecosystem services (van Elden et al. 2019) can be provided by the offshore energy industry which is expanding its infrastructures all over the world (Parente et al. 2006), reaching more remote positions, where shallow-water and hardbottom habitats are introduced into the environments of vast soft bottom areas and/or pelagic environments. While active, such installations can offer a suitable environment for fish and macroinvertebrate populations (Gallaway et al. 1981, Scarborough & Kendall 1994, Jørgensen et al. 2002),

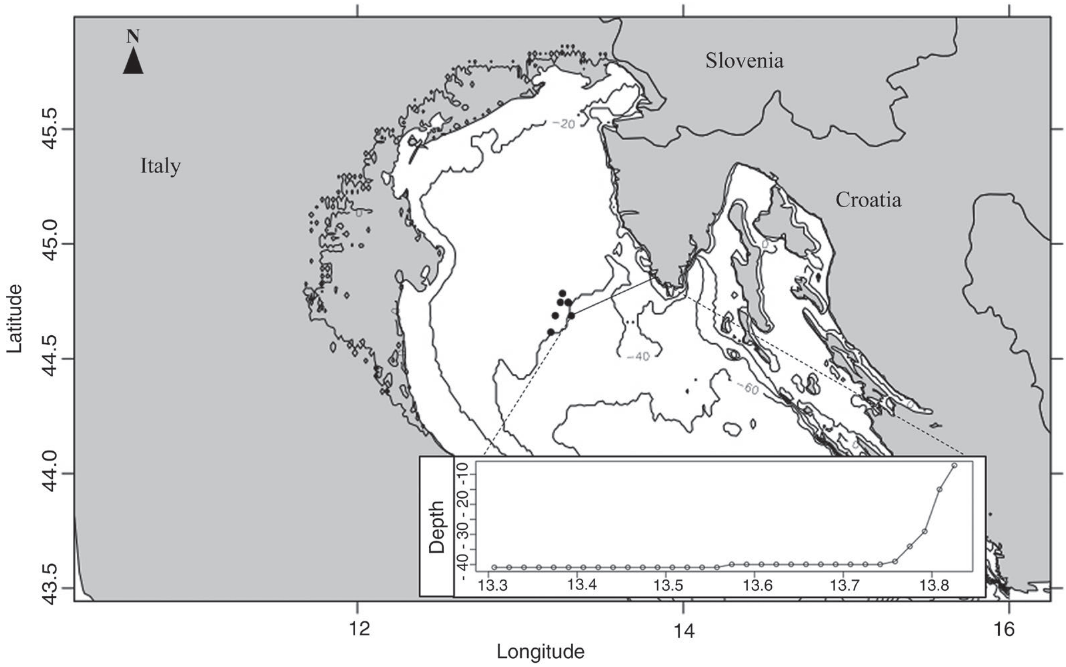

Fig. 1. Map of the Northern Adriatic Sea. The positions of the investigated platforms are shown as black dots. The black line represents a pipeline connecting the coast and the platforms. The graph shows the depth distribution along the pipeline transect across the longitude.

providing them with a hard substrate, food source, and refuge (Wolfson et al. 1979, Forteath et al. 1982, Bohnsack 1989).

Several studies so far assessed the influence of the extraction of the natural oil and gas on animal communities in the Northern Adriatic using a variety of biomarkers, such as fish or macroinvertebrates (Ponti et al. 2002, Manoukian et al. 2010, Trabucco et al. 2012). Moreover, a recent study done by Cordier et al. (2019) for the first time used eDNA metabarcoding methods to survey the impact of the Northern Adriatic platforms on the adjacent benthic and pelagic animal communities. However, detailed research has yet to be done to assess the decapod diversity on the platforms, and their colonisation patterns. Thereby, in the framework of a monitoring project at the Croatian natural gas platforms (INA) under the auspices of the Centre for Marine Research (CIM), we studied the decapod communities found at the pillars of these platforms in the Northern Adriatic Sea taken from different depths. Our aims were (i) to identify the species sampled from the pillars, (ii) analyse their depth distribution, and (iii) formulate a probable argument for colonisation pathways, namely: If the decapod species have colonised the pillars from the seafloor, or if they have arrived as larval stages with the plankton. We also research (iv) if colonisers followed the general current direction (from Italy) (Orlić et al. 1992) or another colonisation pattern.

Materials and methods

Sampling, sorting, and preservation

Samples from seven platforms were analysed. The platforms are located between 15 and 20 nautical miles from the nearest Croatian coast (Fig. 1). Thus, they reach a depth of 45 to 60 metres. Longitude and latitude of the platforms are given in Table 1. The platform pillars are clamped at the seafloor and made of iron with a thick coating layer of protective colour containing zinc. Zinc protectors are installed at all underwater structures. Sampling was performed by a scientific scuba-diving team in the period from November 2017 to the beginning of February 2018. At each platform, squares measuring 20 × 20 cm were chosen at 3, 10 and 20 metres depth from which all fouling organisms were completely removed by scratching and hammering. Afterwards, the samples were taken to the lab, preserved in 70 % Ethanol, and sorted. During sampling, we did not see any larger, vagile decapods that might have escaped from the samples. All the platforms are at their localities for more than 20 years.

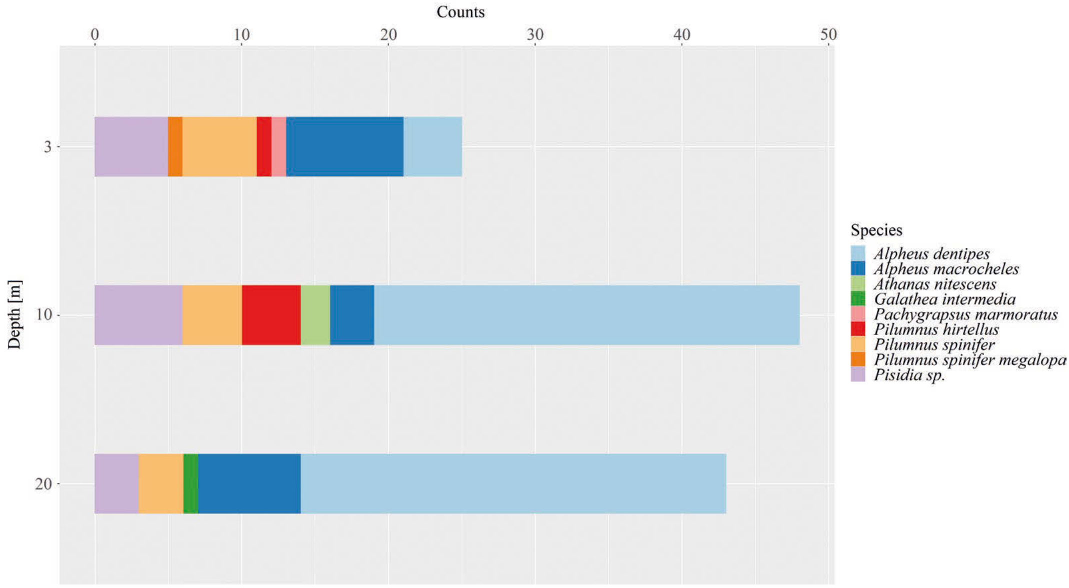

Fig. 2. Depth distribution of the individuals of species sampled from the platforms.

Identification

We used Pesta (1918), Zariquiey Alvarez (1968), Falciai & Minervini (1992), Noël (1992) and Melzer et al. (2019) for the identification of decapod representatives found in the samples down to species level, using stereomicroscopes. For species of *Pilumnus*, we used the key of Mavidis et al. (2009) and cross-checked with Oliveira-Biener et al. (2010). Sixteen out of eighteen samples of *Pisidia* spp. were missing body parts with taxonomically relevant characters (e. g. thoracal appendages) which would have allowed identification to the species level. These specimens are placed under *Pisidia* sp. (Table 1). The other two specimens were identified to species level (*P. longicornis* and *P. bluteli)*. However, in the interest of simplified graphical representation, they were as well placed under *Pisidia* sp. We used Salman (1982), Guerao et al. (2005) and Martin et al. (2014) for identification of the megalopa larval stage found in the samples using a Leitz Diaplan microscope. All collected specimens are placed in the Arthropoda varia collection at the Bavarian State Collection of Zoology, Munich (ZSM) under the numbers ZSMA2020-500−620.

The graphical representation of results was performed using the R-statistics environment 3.6.2 (R Core Team 2016), utilizing the interface RStudio (RStudio Team 2019), the "marmap" package (Pante & Simon-Bouhet 2013), and the "ggplot2" package (Wickham 2016). As we only focus on species identification and on the putative origin of the sampled decapods on the Adriatic gas platforms, we did not perform statistical analysis.

Results

General observations about the macrozooic fouling community

At the platform pillars, we observed a well-developed macrozooic fouling community composed of *Mytilus galloprovincialis* Lamarck, 1819 and *Ostrea edulis* Linnaeus, 1758 as the most prominent species in the upper (= shallower) area. They were accompanied by species that form calcium carbonate-based hard structures such as encrusting polychaetes, bivalves, and bryozoans. The resulting three-dimensional structures build a habitat for species that do not form hard skeletons themselves, like poriferans or tunicates. Encrusting macroalgae from the family *Corallinaceae* Lamouroux, 1812 (e. g. genera *Lithophyllum*, *Lithothamnion* and *Corallina)* and some filamentous algae (e. g. genera *Chaetomorpha* and *Polysiphonia*) were also present. This community composition is similar to that of exposed mediolittoral and/or uppermost infralittoral localities along the rocky coast of Croatia (Zavodnik & Kovačić 2000). However, this community composition at the pillars extends deeper than it does at the coast, down to depths of about 15 to 20 m. At a depth of around 15 m, specimens of the deep-sea oyster *Neopycnodonte cochlear* (Poli, 1795) also started occurring, increasing in abundance with increasing depth.

The decapods

The number of species found at the seven platforms are listed for each level of depth in Table 1. 120 individuals were identified to species level. We recorded a total of nine species: *Alpheus dentipes*, *Alpheus macrocheles*, *Athanas nitescens*, *Galathea intermedia*, *Pachygrapsus marmoratus*, *Pilumnus hirtellus*, *Pilumnus spinifer*, *Pisidia bluteli* and *Pisidia longicornis*. The most dominant species was *A. dentipes*, which was found at all examined depths, and from which 62 individuals are recorded. Of particular interest is one *P. spinifer* megalopa found at three metres depth (Fig. 2). All other individuals of *P. spinifer*, as well as the individuals of *P. hirtellus*, were juvenile crabs whose carapace width measured less than a centimetre. The only stenoecious inhabitant of the mediolittoral and uppermost infralittoral we found was *P. marmoratus.*

Discussion

We observed a rather uniform macrozooic encrusting community on the pillars down to 20 m of depth. The largest biogenic structure-building organisms were bivalves. This observation does not reflect the normal depth succession of coastal hard bottom communities. However, similar observations have been made by (Bomkamp et al. 2004). Possibly, the bivalve layer settles deeper because of the lack of competition. In addition, the presence of the bivalve larvae in the samples showed that the colonisation of the platforms can be explained by planktonic advection.

One colonisation pathway for decapods as well might be planktonic drift. Another pathway may be colonisation from the seafloor around the platforms. In the following, we will discuss both possibilities.

Zoea stage in decapods is a planktic distribution phase (Anger 2001). According to the general distribution and direction of currents in the Adriatic (Orlić et al. 1992, Supić et al. 2000) planktic colonisers from the Italian, western Adriatic coast should dominate, and the planktonic life stages of soft-bottom inhabitants should be regularly advected, especially since the ovigerous females of the species from our samples are observed in the Mediterranean almost during the whole year with emphasis from February to September (Kurian 1956, Falciai & Minervini 1992). Nevertheless, we found no genuine sand bottom inhabitants, which are dominant in the littoral zone on the Italian coast (Froglia 2010).

Table 1. Counts of individuals of decapod species found at different platforms at different depths.

Platform	Position (lati/lon)	Depth [m]	*Alpheus dentipes*	*Athanas nitescens*	*Alpheus macrocheles*	*Galathea intermedia*	*Pisidia bluteli*	*Pisidia longicornis*	*Pisidia* sp.
Ana	44.744850° N 13.293924° E	3							4
		10	5	2	3				2
		20							
Ivana A	44.744850° N 13.293924° E	3							
		10	6						1
		20						1	
Ivana B	44.687550° N 13.214581° E	3							
		10							
		20	5						4
Ivana C	44.615656° N 13.187184° E	3							
		10							
		20	3						
Ivana D	44.784073° N 13.258748° E	3	3		5				1
		10	16				1		2
		20	3		7				
Ivana E	44.745499° N 13.246267° E	3	1		3				
		10							
		20	13						2
Vesna	44.687089° N 13.313274° E	3							
		10	2						
		20	5			1			
Total			62	2	18	1	1	1	16

Conversely, all the decapod representatives we found are common primary or secondary hard bottom inhabitants of the Northern Adriatic (Števčić 1990, D'Udekem d'Acoz 1999, Melzer et al. 2016, 2019). These habitats are not commonly found along the Italian coast, but some artificial structures can provide this hard substrate (e. g. jetties). This might, for example, be a source of *P. marmoratus* from the samples. The distance of the platforms from the Italian coast is around 37 nautical miles and the typical speed of the current is 10 cm/s (Orlić et al. 1992). Although the larval development time for decapods in the wild is variable (Anger 2001), it is possible that *P. marmoratus* arrived at the platforms following general current direction.

Large extents of hard bottom and rocky shore habitats, where all the species found on the platform pillars are commonly recorded, are found along the eastern Adriatic coast or the Gulf of Trieste. These areas lay opposite to the usual current direction, but strong bora events can result in westward surface water movement which can transport larvae from the eastern Adriatic coast to the platforms. These events may be episodic but appear to sufficiently allow the colonisation of the artificial offshore structures. Because, even if the larval drift from the closest "upstream" hard substrates of the Italian coast happens, according to our results it cannot be the main source

Pilumnus spinifer megalopa	*Pilumnus spinifer*	*Pilumnus hirtellus*	*Pachygrapsus marmoratus*
	3	2	
	3	1	1
	1	2	
1			
	1		
	2		
	2		
1	12	5	1

of colonisation, due to general absence of the soft bottom inhabitants on the platforms. In accordance with this, *P. spinifer* megalopa in our samples might have found a suitable habitat to settle at the pillars from the plankton. The preference for hard bottom communities of this species suggests, that it is more likely to come from the eastern than western Adriatic coast. Another possible proof of the rarity of such strong bora events is the absence of other inhabitants of the mediolittoral and upper infralittoral such as *Porcellana platycheles* (Pennant, 1777), *Palaemon elegans* (Rathke, 1836) or *Xantho* sp. (Leach, 1814), viz. common species along the Croatian coast (Števčić 1990, 1995, 2002) and with comparable habitat preferences to the *Pilumnus* species.

Among the sampled decapods, only *P. marmoratus* is a strictly mediolittoral species, while all other species found at the pillars are found between the upper and lower infralittoral (with *P. spinifer* reaching to circalittoral). Therefore, these species could also use the second colonisation pathway, along the seafloor. Data from the literature (Števčić 1995, Froglia 2010, Melzer et al. 2019) suggest that most of the species from our samples prefer primary and secondary hard bottom substrates. Habitats surrounding the platforms are comprised of a mix of sediment grounds. Therefore, representatives of *Alpheus* spp., *Athanas* sp., *Pisidia* spp., *Galathea* sp., and *P. spinifer* might also have migrated along artificial structures connecting the coast and the platforms. This would make them candidates for colonisation of the platforms by simply climbing up from the seafloor. A possible bridge between offshore structures and the coast are supply structures (pipelines) along the seafloor that provide artificial structures at average depths of around 40 m and connect the platforms with each other and with the coast. Additionally, it can be assumed that the highly structured three-dimensional bivalve-based fouling community provides a well-suited habitat for the alpheids and representatives of *Pisidia* spp., all of them being small enough to find shelter between the bivalve shells.

Curiously, all individuals of *P. spinifer* and *P. hirtellus* from the platforms were juveniles. This occurrence can, again, be explained by the settlement of larvae that arrived via planktonic drift as ovigerous females of *P. spinifer* and *P. hirtellus* are regularly observed in the Mediterranean from March to September (Falciai & Minervini 1992). This gives enough time for zoeal stages to disperse and settle down on the platform pillars. The lack of adult representatives of *Pilumnus* spp. might be explained by the unsuitable foraging conditions on the platforms, or lack of shelter. For example, mentioned sessile macrozoobenthic community structure might offer sufficient shelter and food for juvenile crabs, but might not be enough to sustain larger sized adults of *P. spinifer* and *P. hirtellus*. Additionally, Fabi et al. (2004) showed that fish communities, sustained by offshore gas platforms in the Northern Adriatic, expressed larger levels of biomass than those from shallower waters closer to the shore. Thus, to escape this increased predatory pressure and also to find more food, adult individuals of *Pilumnus* spp. may recruit to the bottom and away from the platform pillars (Bomkamp et al. 2004) or disappear as a result of predation.

In conclusion, presence of *P. marmoratus*, a megalopa of *P. spinifer*, and small *Pilumnus* spp. juveniles indicates decapod colonisation of the pillars via plankton. However, this does not seem to happen very often because of the generally rare bora events. Conversely, for most of the species, the seafloor surrounding the pillars is a suitable habitat, and therefore, most of the specimens probably have colonised the platforms from the seafloor. This corresponds well with the fact that some of the most common Adriatic medio- or upper infralittoral inhabitants are missing in the samples. For the species reported here, artificial structures like the ones we examined may well function as bridgeheads between naturally unconnected habitats. This can increase the risk of biological invasions and the loss of population diversity. On the other hand, and as it is the case with the investigated area, the function of the artificial structures might be a connection of otherwise unconnected marine protected areas that are often too scarce and distant from each other. Moreover, one of the platforms, Ivana D is not in the use anymore, and thus it would be interesting to repeat the sampling in the near future and observe if there are any changes in the community structure.

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