Insights into the Crustacea Decapoda of the Adriatic Sea. Observations from four sampling locations along the Croatian coast

By Carsten H. G. Müller & Christoph D. Schubart

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Abstract. An annotated species list is provided on the basis of seven sampling surveys of decapod crustaceans carried out on various supra-, medio- and infralittoral substrates (sandy bottoms, rocky shores, seagrass beds of *Posidonia oceanica*) at four locations on the Adriatic Sea: Rovinj (in 1968), Slanik Bay (in 2001) and Pula (in 2004, 2005) on the Istrian Peninsula and the island of Šipan (in 2001, 2003, 2005) in the direct vicinity of Dubrovnik. All in all, 72 taxa were collected using shore sampling and snorkeling and scuba-diving techniques. The list of species collected is a good reflection of the spectrum of infralittoral Decapoda expected to be common along northern and southern Adriatic coastlines in the months of July and August. With a total number of 28 taxa (= 39%), the Brachyura represented the dominant group, followed by the Anomala with 20 species (= 28%) and the Caridea with (17 species = 24%). The majority of decapod crustaceans were captured on rocky substrates (51 taxa = 71%). Our present results provide an overview of typical infralittoral inhabitants within the studied areas. No Adriatic endemics and only one originally East Asian neozoan could be detected. No Lessepsian or Atlanto-tropical immigrants were encountered. Most decapod species collected have a wide distributionary range, including the whole Mediterranean Sea, or are constitutents of the Atlantic-boreal fauna in general. Besides confirming the occurrence of species reported by previous authors, we present new insights into the morphology, ecology, distribution and behaviour of some species. These are discussed in comparison to conspecific populations from other parts of the Mediterranean Sea.

Kurzfassung. Eine kommentierte Artenliste von dekapoden Crustacea wird vorgelegt, entstanden durch Besammlung verschiedener Substrate des Supra-, Meso- and Infralittorals (Sand, Fels, *Posidonia*-Wiesen) an vier Plätzen des Adriatischen Meeres: Rovinj (1968), Slanik Bay (2001) und Pula auf Istrien (2004, 2005) und der Insel Šipan bei Dubrovnik (2001, 2003, 2005). Insgesamt wurden 72 Taxa nachgewiesen. Die Artenliste gibt das zu erwartende Spektrum der infralittoralen Decapoda wieder. Mit insgesamt 28 Taxa (= 39%), sind die Brachyura die dominierende Gruppe, gefolgt von den Anomala mit 20 Arten (= 28%) and den Caridea mit 17 Arten (= 24%). Die meisten Dekapoden wurden auf Felssubstrat gefunden (51 Taxa = 71%). Die Aufsammlung bietet einen Überblick über die typischen infralitoralen Bewohner im Untersuchungsgebiet. Keine adriatischen Endemiten und nur ein ursprünglich ostasiatisches Neozoon wurden nachgewiesen. Damit werden frühere Befunde bestätigt. Neue Mitteilungen betreffen Morphologie, Ökologie, Verbreitung und Verhalten für einige der vorgestellten Arten. Sie werden im Vergleich mit mediterranem Material von anderen Fundorten diskutiert.

Key words: Crustacea, Decapoda, shallow water habitats, Adriatic Sea, zoogeography, ecology, biocoenoses

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Introduction

The Adriatic Sea is limited to the north by the lagoonary channel system around Venice and Trieste, while in the south it ends at the Strait of Otranto where the Adriatic Sea is connected to the Ionian Sea. Because of the high density of research facilities along its coastline, such as the classical marine biological institutes and museums in Venice, Rovinj and Dubrovnik, the Adriatic Sea is one of the best investigated biogeographic regions in the Mediterranean Sea. Many carcinologists have contributed to a long tradition of research, most of them especially interested in the Decapoda. The first documented insights into Adriatic decapod fauna were presented at the beginning of the 16th century by GIOVIO (syn.: JOVIUS), whose first documented observations were made in 1524. ŠTEVČIĆ (1993) defined three distinct periods of significant carcinological research activity in the Adriatic Sea: the "post-Linnean-period" (1763-1846), the "Sinonimia-moderna-period" (1847-1968), and the "current-period" (1969-present). 124 species of the approximately 240 decapod species so far reported to inhabit the Adriatic Sea (see listings by PESTA 1918, RIEDL 1968, MANNING & ŠTEVČIĆ 1985, ŠTEVČIĆ 1990, 1991, 1995, 1998, 2002; D'UDECEM D'ACOZ 1999) were recorded in the "Sinonimia-moderna-period". In the so-called "current period", 51 species have been newly recorded for the Adriatic decapod community (ŠTEVČIĆ 1991, 1995, 1998, 2002, KIRINČIĆ 2003, 2006, SCHUBART 2003). Eleven species were newly recorded in the 1990s alone which is equivalent to an average rate of one to two species descriptions every year (ŠTEVČIĆ 2002). Several species are known to be endemic to the Adriatic Sea, which may underscore the independent faunistic role of this "Randmeer" in relation to western (Atlantic-Lusitanic) or eastern (Levante Basin, Red Sea) faunal elements and its importance for biogeography (cf. TÜRKAY 1989).

The enormous progress in knowledge can surely be traced back to the no less than 70 contributions published in the relatively short period of almost 40 years (see ŠTEVČIĆ 1993, 2002). One possible explanation for the considerable increase of scientific activity during the "current period" may be a continuously growing interest in zoocoenotic questions. Obviously, a further reason lies in the necessity of documenting changes in the composition of Adriatic decapod fauna. Faunal and floral communities, more precisely in our case the infralittoral macrozoobenthos, must not be seen as static units. They are exposed to dynamic changes either caused by long-term climate shifts or produced by anthropogenic impacts. The marine macrozoobenthos, for instance, is influenced by the immigration or human-mediated import of allochthonous species from other biogeographical regions. Both processes are playing an increasingly important role in ecological research projects in the Mediterranean Sea. Many neobiota, among them many Decapoda, gained entry to Mediterranean littoral habitats in previous decades and established stable populations, partly by tending to invade neighbouring regions. A current and spectacular example is the Mediterranean spreading of the atlantico-tropical flat crab *Percnon gibbesi* (H. Milne Edwards, 1853), a highly mobile member of the Plagusiidae, which was recorded almost simultaneously on various islands in the western Mediterranean in the new millenium (e.g., Pelagie Islands (Isola di Pantelleria, Linosa): RELINI ET AL. 2000, PUCCIO ET AL. 2003, 2006, Balearic Islands: GARCIA & REVIRIEGO 2000, MÜLLER 2001, Sicily: PIPITONE ET AL. 2001, Greece: THESSALOU-LEGAKI ET AL. 2006, Turkey: YOKES & GALIL 2006). In total, six neozoic decapod species - the swimming crabs *Callinectes danae* Smith, 1869, *Callinectes* *sapidus* Rathbun, 1896 and *Dyspanopeus sayi* (Smith, 1869), the brackish water-inhabiting panopeid crab *Rhithropanopeus harrisii* (Gould, 1841), the sea spider *Maja goltziana* d'Oliveira, 1888 and the penaeid shrimp *Penaeus japonicus* Bate, 1888 have been newly observed in the Adriatic Sea (D'UDECEM D'ACOZ 1999, ŠTEVČIĆ 2002). The first four of the species listed are known to stem from the northwest Atlantic, whereas *M. goltziana* comes from the tropical East Altlantic (see note of PALLAORO & DULČIĆ 2004). *P. japonicus* is originally an Indopacific species and should most probably be considered an escapee from local Adriatic aquacultures (see discussion in ŠTEVČIĆ 2002).

It should be taken into account that the frequency and intensity of investigations into macrozoobenthic organisms has become much higher in the northern part of the Adriatic Sea, but that changes are most likely to occur first in the southern Adriatic Sea. We therefore believe that it will be useful to partially fill this gap by providing new observations concerning the community of Crustacea Decapoda populating various infralittoral substrates in the coastal waters around the island of Szipan, which have hitherto remained uninvestigated despited being located in the close vicinity of Dubrovnik in southern Croatia. We compared our collection of decapod crustaceans from Šipan/Jakljan with those collections that were carried out in three localities around Istria (northern Croatia). Going on the suggestions of ŠTEVČIĆ (2002), we particularly focused on hitherto neglected microhabitats such as seagrass beds of *Posidonia oceanica*, *Cymodocea nodosa* or *Zostera* spec. and primary hard bottoms of the upper infralittoral and mediolittoral zones respectively.

Materials and methods

During seven field trips to northern and southern sites of the Croatian coast in the years 1968, 2001, 2003, 2004, and 2005, various decapod crustaceans were collected through snorkelling and diving on sandy, muddy and rocky supra-, medio- and infralittoral bottoms down to 40 metres depth, according to the ecological zoning given by PÉRÈS (1967) and MARINOPOULOS (1988). The infralittoral zones investigated included habitats such as fields of rocky boulders (with or without macroalgae coverage), steep walls, seagrass beds, sac-shaped caves and grottoes. Samples were taken both during the day and at night, either by hand or by using hand nets. Sediments were sieved underwater with hand nets of a mesh size of approximately 1 mm. Those decapods associated with macroalgae such the canopy algae of the genus *Cystoseira* or encrusting algae of the genera *Jania* and *Peyssonnelia* were obtained by cutting various algae from their rocky substrate, transferring them into small plastic tanks and carefully searching the thallous network for decapods attached to it.

Sampling in the north of the Adriatic Sea was concentrated on the Istrian Peninsula. In the framework of a field excursion of the University of Mainz to Rovinj in 1968 (organised by Prof. H. RISLER) decapod crustaceans were collected in shallow waters within the Limski-Channel (north of Rovinj) and around Dvije Sectrice, a group of small islands south of Rovinj, or dredged near Banjole on silty or muddy sediments around 35 metres depth. More recently, further sampling was carried out in Uvala Slanik, a small bay between Umag and Novigrad (13°32'26"E-45°22'54"N) in late Augst 2001 and along the coast of Pula, situated at the southwestern tip of the Istrian Peninsula (see Fig. 1) between 27th of August and 2nd of September 2004 and between 29th of August and 3rd of September 2005. In the latter, case, samples were taken along the coast of the Bay of Valsaline as well as along the western coastal line of the peninsula northwards from the campsite of Valovine. The coast is lined by belts of rocky boulders or steep, massive walls that can extend down to ten metres depth and display deep cavities (sac cave type). In the bay of Valsaline, sandy areas are present below two metres depth. These roughly sorted sandy sediments are often interrupted by fields of rocky boulders partly overgrown by various degradation stages of *Cystoseira amentacea* var. *spicata* Ercegovic, 1952. In addition, we collected decapods at Marina Veruda, an elongated shallow bay quite isolated from the open sea and characterized by dense meadows of *Zostera* spec., which grow on a muddy sediment. *Posidonia* beds were not present in any of the investigated areas.

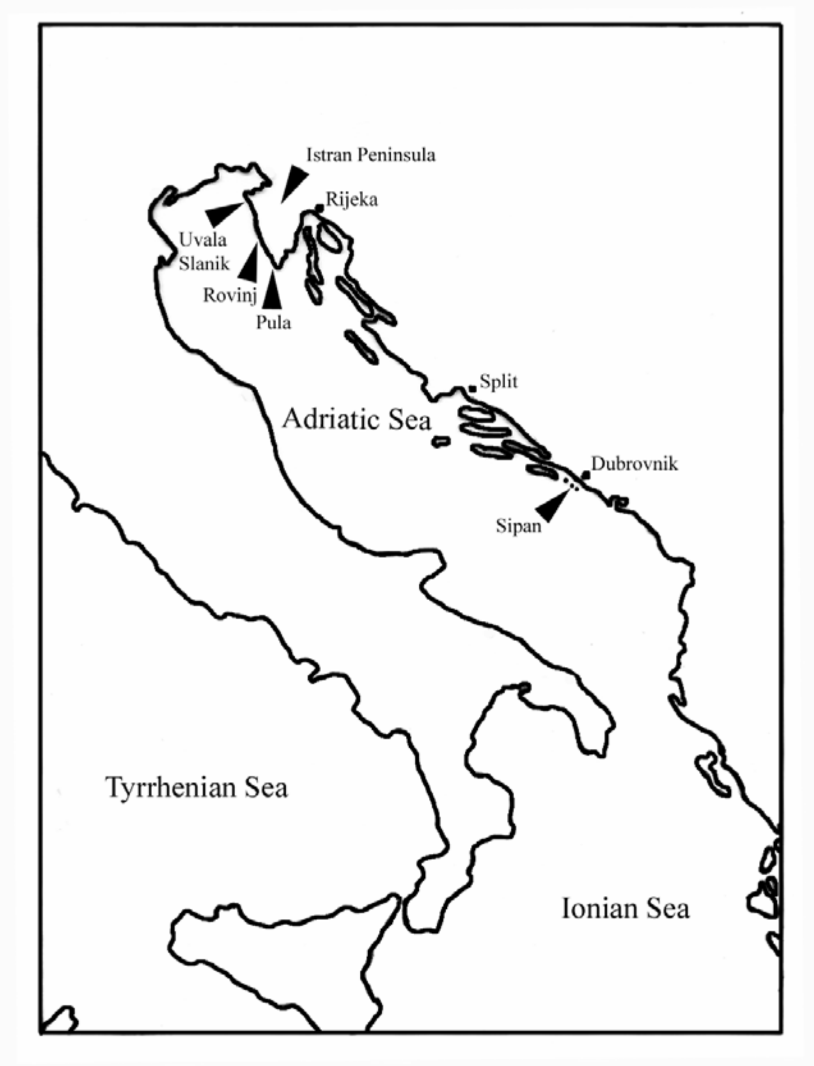

Figure 1. Map of the Adriatic Sea and surrounding Mediterranean waters showing the sampling areas at Rovinj, Uvala Slanik, Pula (all situated on the Istrian Peninsula) and the island of Šipan (Dalmatian coast). The sampling locations are marked by black arrows.

With the aim of comparing decapod communities from the northern Adriatic Sea to those from the southern Dalmatian Coast we set out on two further excursions to the islands of Šipan and Jakljan, which belong to the so-called Elaphite Islands (Fig. 1). Šipan and Jakljan are only a few hundred metres away from the Croatian mainland and several kilometres northwest of Dubrovnik. The infralittoral regions around Šipan and Jakljan display a similar diversity of habitats. During three field trips (1st-14th of

October 2001, 10th-22nd of Mai 2003, 17th-29th of September 2005) four different sampling locations were investigated, either regularly or only once: (i) the inner coastline of the Bay of Sipanska Luka (northern coast of Šipan), (ii) the outer coastline of the Bay of Sipanska Luka (northwestern tip of Šipan), (iii) the northwestern tip of Jakljan (neighbouring island to Šipan in the north), and (iv) the Bay of Sudurac (southern tip of Šipan). The first three habitats were inspected every third day only in 2001, whereas in the Bay of Sudurac decapods were caught every day during all three excursions (2001, 2003, 2005). Infralittoral habitats studied around the coasts of Šipan and Jakljan comprised rocky substrates of different vertical extensions and various degrees of exposure to sunlight and wave action (moderately sloped and steep walls, boulder fields, rough gravel sediments, artificial objects such as quay walls), submarine caves, deep crevices, secondary hard bottoms (e. g. submarine household equipment disposal sites), phytal grounds (boulders overgrown by macroalgae such as *Cystoseira* spec.), sandy or muddy sediments (muddy sediments especially observed in the highly eutrophic Bay of Sipanska Luka below eight metres depth, where anoxity was detected under a thin floccuent layer), scattered *Posidonia* and/or *Cymodocea* meadows (with leaves strongly affected by epibiontic coats, leaves not longer than 30 cm), and widely expanded detritus grounds below 25 metres depth assigned to coralligène fields of the "Nulliporen-facies" type (*sensu* HEẞ 2002).

In determining the decapod crustaceans collected we used the traditional monographs of PESTA (1918), ZARIQUIEY ALVAREZ (1968), INGLE (1980, 1993) and RIEDL (1968, 1983). Those taxa known to be difficult with respect to taxonomy were identified with the aid of specialised keys (e.g. *Hippolyte*: D'UDECEM D'ACOZ 1996, *Pilumnus*: KOUKOURAS & TÜRKAY 1996, *Periclimenes*: GRIPPA & D'UDECEM D'ACOZ 1996, *Anapagurus*: GARCÍA-GÓMEZ 1994). All collected specimens were fixed and conserved in 70% alcohol, and deposited in the Zoological Collection of the Institute for Biosciences of the University of Rostock or at the Senckenberg Museum Frankfurt (SMF).

Results

The present carcinological study of the infralittoral decapod fauna in the coastal waters of Rovinj, Pula and Šipan yielded the presence of 72 taxa (including 71 determined and one unidentifiable species) comprising penaeid and caridean shrimps, brachyuran crabs, hermit crabs, porcellain crabs, squat lobsters, slipper lobsters and true lobsters. The majority of these 72 taxa (71% = 51 taxa) were collected on various rocky grounds of the supra-, meso- and sublittoral, with at least 13% (nine species) preferring the epiphytic layer on compact rocky shores with steep inclinations or boulder fields. These species are referred to herein as phytal inhabitants. Usually, decapods were observed hidden under rock boulders or crammed into rocky crevices. According to our observations, there are only few troglophilic species in the infralittoral zones along/around Rovinj, Pula and Šipan (e.g. *Palaemon serratus* (Pennant, 1777)). Only four species (approx. 6% of the total number of species) were caught in seagrass beds such as those of the Neptune seagrass *Posidonia oceanica* (Linnaeus) Delile (e.g. *Dardanus calidus* (Risso, 1827)) or *Zostera* spec. (e.g. *Carcinus aestuarii* Nardo, 1847). Almost 19% (= 14 species) were found buried in or lying/moving on sandy habitats (including the sand-filled erosion crater within beds of *P. oceanica*), and of these two species were found on silty sand or muddy grounds at depth levels of one metre (*Upogebia pusilla* (Petagna, 1792, *Callianassa tyrrhena* (Petagna, 1792)) or below 20 metres (*Pagurus exacavatus* (Herbst, 1791)). Six decapod species (= 8%) were found in temporary or permanent association with other invertebrates such as sponges (e.g. *Paguristes eremita* (Linnaeus, 1767) with *Suberites domuncula* (Olivi, 1792), cnidarians (e.g. true symbiosis between *Dardanus calidus* and *Calliactis parasitica* (Couch, 1842)) and bivalves (*Pinnotheres pisum* (Linnaeus, 1767) living in the mantle cave of *Pinna nobilis* Linnaeus, 1758). The species collected either had a permanently cryptic lifestyle (e. g. representatives of the brachyuran genus *Xantho*, *Calappa granulata* (Linnaeus, 1758)), or were observed engaging in diurnal activities in the field. However, some strictly nocturnal decapod species were also recorded (e. g. *D. calidus*, *Galathea strigosa* (Linnaeus, 1761), *Herbstia condyliata* (J. C. Fabricius, 1787), *Lysmata seticaudata* (Risso, 1816). A detailed list of all taxa collected and determined with remarks on their ecology and frequency is given in Table 1.

Brachyuran crabs were the group with the highest number of 28 taxa (= 39%), followed by the Anomala with 20 species (= 28%), among which pagurid and diogenid hermit crabs (13 species) represent the dominant group. Pleocyemate shrimps, the Caridea, were another highly diverse group (17 species = 24%). Other taxa, such as the Dendrobranchiata, Palinuridea, Nephropidea, and Thalassinidea were only recorded once or twice.

Our material does not contain Lessepsian migrants or invaders from the tropical Atlantic Sea. However, it includes the first record of the varunid species *Hemigrapsus sanguineus* (de Haan, 1835) in the Mediterranean Sea (see SCHUBART 2003). This originally East Asian species had already been recorded as an invasive species along the North American and European Atlantic coastlines (summarized in SCHUBART 2003). Otherwise, the decapods collected normally occur widely in the entire Mediterranean Sea (e.g. *Pachygrapsus marmoratus* (J. C. Fabricius, 1787)) or belong to Altlantic-boreal faunal elements which are particularly abundant in the western Mediterranean Sea (e.g. *Homarus gammarus* (Linnaeus, 1758)). Specific Adriatic endemics were not recorded.

Discussion

The 72 taxa of Crustacea Decapoda collected represents 30% of the total number of 241 taxa so far recorded for the entire Adriatic Sea (ŠTEVČIĆ 1990, 1996, 2002; D'UDECEM D'ACOZ 1999). At first sight, these 72 taxa may be dismissed as a rather disappointing outcome. For instance, only 34 decapod species were found in the waters around Rovinj, whereas ŠTEVČIĆ (1971, 1985, 1991, 1995) counted almost 120 species in the same area. However, our main focus lay on those decapods inhabiting infralittoral substrates not deeper than 40 metres. Therefore, deeper substrates such as the circalittoral soft bottoms in the open northern Adriatic Sea, for instance, remained unexamined. Except at the Isle of Banjole near Rovinj in 1968, we did not have the opportunity to use heavy dredges to gather data from those decapod groups known to exclusively populate deeper sandy and muddy sediments: Processidae, Upogebiidae, Callianassidae, Thiidae, Goneplacidae and some Paguridae of the genus *Anapagurus*. We also only covered a short period of the year, even within the summer season. A more comprehensive overview of the decapod fauna would surely have required a wider sampling schedule. With these methodical limitations in mind, the present study may be considered a contribution to our knowledge of the structure of more common decapod crustacean communities living on infralittoral hard bottoms, sandy grounds and seagrass beds along the Croatian coast in late summer. It may moreover function as a useful checklist for students or colleagues exploring similar habitats and using comparable sampling methods.

In general, the lifestyle of many infralittoral decapods found along the coasts of Rovinj, Pula and Šipan coincides with that which has been reported from similar habitats on other Mediterranean coasts. Good examples in this category are common, euryoecious species such as the hermit *Clibanarius erythropus* (Latreille, 1818), the grapsid crab *Pachygrapsus marmoratus* (J. C. Fabricius, 1787) and the rockpool and shallow water shrimp *Palaemon elegans* Rathke, 1837). In contrast, we also found decapod crustaceans which differed considerably from other Mediterranean populations with regard to their frequency, habitat selection and behaviour. For example, our survey revealed a reduced diversity of the squat lobster genus *Galathea* at all sampling locations. This genus is, however, known as species-rich and abundant on various infralittoral substrates in the Mediterranean Sea (see D'UDECEM D'ACOZ 1999) and even in the Adriatic Sea (Števčić 1990).

Further surprising observations made in the areas studied concern both the species and the zoocoenotic level. Some interesting examples of these unexpected findings are discussed in the following chapters. Our comments on taxonomy and ecology are naturally not final: many conclusions need to be proven by further studies at the same sampling site or by comparison with other Adriatic regions displaying similar substrate conditions.

Unusual habitat selection of *Pagurus prideauxi* Leach, 1815. ŠTEVČIĆ (1990) has already reported that Adriatic individuals of *Paguristes prideauxi* occur from 10 to 100 metres in depth. In comparison with our own observations on the vertical distribution of *P. prideauxi* in the western Mediterranean, e.g. in the coastal waters of Ibiza (observations on detritus grounds below 40 metres in depth), it appears that the upper limit of the vertical distribution is shifted towards much shallower bottoms in the Adriatic Sea. The finding of an adult individual of *P. prideauxi* under a boulder at one metre in depth in the coastal waters of Šipan even exceeds the bathymetric range given by ŠTEVČIĆ (1990) considerably. Also, in the coastal waters of Pula numerous individuals of *P. prideauxi* were observed above the upper depth limit proposed by ŠTEVČIĆ (1990), appearing at 7-8 metres depth. Our record of *P. prideauxi* in the very shallow waters of Šipan may be explained by an extensive migration of the macrozoobenthos (inhabiting *Posidonia* beds, sandy or hard bottom substrates) from the predominantly anoxic sediments below ten metres depth to upper infralittoral zones. The anoxia of the sediment may be caused by the particular tube-like topography of the Bay of Sipanska Luka which seems to reduce dynamics of incoming water currents and therefore prevent the necessary water exchange between overlying water columns. When pollution is also taken into account (household remains thrown into the Bay, sewage water from kitchens and toilets), it is not surprising that species from both high and deeper infralitoral facies were often observed together in high densities in the shallowest waters of Šipan. Thus it appears that these decapod zoocoenoses and the putative species richness in the uppermost infralittoral are an artificial result of strong hydrodynamic and anthropogenic influences.

The genus *Paguristes* Dana, 1851: habitat segragation useable for separation of species? Two representatives of the genus *Paguristes* were found in the areas studied, *Paguristes streaensis* Pastore, 1984 and *Paguristes eremita* (Linnaeus, 1767). While *P. eremita* is known to have established stable populations on various infralittoral substrates (but mostly sandy sediments) from 2 to 50 metres depth and to be common in the Adriatic Sea (ŠTEVČIĆ 1990) (see also chapter below), current knowledge about the presence of *P. streaensis* along the Adriatic coasts is still sketchy. Pastore (1984) described the species for the Ionian Sea; the only record from the Adriatic was provided by ABED-NAVANDI & DWORSCHAK (1998).

Individuals of *P. streaensis* observed in the shallowest waters of Sipanska Luka (a tube-like bay, 1-3 metres depth) clearly showed morphological and colouration features typical for the given species, including the apically rounded rostrum, the antennal acicle inner proximal margin with two acute processes confined to the basal part, and the specific coloration of the cephalothorax and its appendages (see INGLE 1993). However, our individuals of *P. streaensis* displayed a differing corneal and eye stalk coloration from the holotype (bright yellow instead of greenish blue) and a greater variability in terms of the arrangement of setae covering the 1st-3rd peraeopods. One explanation for phenotypical incongruencies among specimens of *P. streaensis* belonging to the population of Šipan and those specimens from La Strea (Ionian Sea) might be the existence of a hitherto undescribed species of *Paguristes* with a distribution limited to the eastern Adriatic Sea, with eyes of a whitish-yellow colour and eye peduncles which are yellow in appearance. According to previous authors, the description of new species within the genus may be necessary (INGLE 1993, PASTORE in D'UDECEM D'ACOZ 1999).

To date, the three Mediterranean species of the genus *Paguristes* (*P. eremita*, *P. streaensis*, *P. syrtensis*) are still separated on the basis of colour features, according to the description of PASTORE (1984). There are only few morphological characters to distinguish the three species from each other. The lack of solid characters have led to some authors questioning the status of *P. streaensis* as a valid species (e. g. D'UDECEM D'ACOZ 1999). We propose that in addition to morphology and phenotypes, the choice of different habitats in the uppermost and deeper infralittoral (*P. streaensis*: sandy sediments at 1-3 metres depth moderately exposed to wave action, *P. eremita*: fine sandy, muddy sediments or secondary hard bottoms (coralligène) below 30 metres depth) may provide additional support to separate the two Adriatic species. *P. eremita* and *P. streaensis* were never found together in the same habitat. If there is a significant ecological separation between the species, one could postulate that a sympatric speciation has taken place in the genus *Paguristes*.

Species previously thought to be rare:

***Gnathophyllum elegans* (Leach, 1815).** The spotted shrimp *Gnathophyllum elegans* was observed in relative high abundances inhabiting boulder fields at various depth levels around the island of Šipan. Even though it showed up at both nothern and southern sampling locations in the Adriatic Sea, *G. elegans* was considered a very rare species overall in Adriatic waters, living on detritic bottoms below 30 metres depth (HOLTHUIS 1949, ŠTEVČIĆ 1990, D'UDECEM D'ACOZ 1999). We found this species to be common in the Adriatic Sea (Tab. 1). The seemingly false impression of the real population density of *G. elegans* may be put down to local patchiness, the extraordinarily cryptic behaviour of the species, or the generally lower density of carcinological observations in the southern Adriatic sea (ŠTEVČIĆ 2002).

***Calcinus tubularis* (Linnaeus, 1767).** To date, there have been only a few records of the colourful hermit crab *Calcinus tubularis* in southern Adriatic waters (Vaso 1993, Števčić 1995). Furthermore, *C. tubularis* was considered a “very rare” species (Števčić 1995). However, we detected *C. tubularis* in remarkable abundances in the upper infralittoral zone (Tab. 1) around Šipan and would therefore agree more with the latest statement of Števčić (2002) who estimated *C. tubularis* to be “relatively common” in southern Adriatic areas.

The ecology of *C. tubularis* is perhaps even more interesting than its apparent spreading northwards along the Dalmatian coast in past decades. In Šipan, we regularly found either solitary juvenile individuals of *C. tubularis* or larger group clusters under rocks below depths of approximately three metres. The clustering behaviour of *C. tubularis* is well studied and has been recorded in populations living in the Tyrrhenian, Aegean and Levantian Sea (Kinzelbach 1990, Gherardi 1990). In Šipan, we observed an unusual ecological separation between syntopic populations of *C. tubularis* and *Clibanarius erythropus* (Latreille, 1818), another subsocial, grazing hermit crab that prefers similar habitat structures and an almost identical variety of snail shell types (e. g. *Bittium* sp., *Cerithium* sp., *Osilinus* sp., *Stramonita* sp.). The occurrence of *C. tubularis* in the shallowest boulder fields corresponds to Kinzelbach (1990) on the ecological model which predicts that *C. tubularis* is expelled from the uppermost infralittoral (waterline/eulittoral down to three metres depth) to deeper-lying rocky grounds (below three metres depth) by its space and shell competitor *C. erythropus* in the colder western Mediterranean Sea, whereas in the warmer regions of the eastern Mediterranean Sea this process should be reversed. The distribution pattern across the rocky shores of Šipan is then characteristic for colder temperated waters, although a few hundred kilometres further south, within the Ionian Sea, the situation is different. This would once again underline the isolated role of the Adriatic Sea. Interestingly, we found no evidence of sessile individuals in studied habitats around Šipan as described by many authors (Fenizia 1933, Kinzelbach 1990, Göthel 1992). We believe that, again contradicting the ecological and ethological experiences gathered with regard to the same species in other parts of the Mediterranean Sea, the absence of sessile *C. tubularis* speaks for a locally faciliated shell supply in the rocky shores of Šipan, thus preventing the hermit crab community from suffering from the main population-limiting factor, the normally limited shell resources.

The problem of intermediates in the genus *Pilumnus* Leach, 1815. Besides the three easily determinable species *Pilumnus spinifer* H. Milne Edwards, 1843, *Pilumnus hirtellus* (Linnaeus, 1761) and *Pilumnus villosissimus* (Rafinesque, 1814), we found living individuals and exuviae which could not firmly be assigned to any of these species of *Pilumnus,* but which clearly belong to the genus. These individuals show intermediate morphological characteristics. The possession of one acute spine on the distal margin of the carpus of the pereiopods suggests they should be assigned to *P. villosissimus*, whereas the structure and density of hair coverage on carapace surface more resembles that observed in *P. spinifer*. While individuals of *P. spinifer* seem to prefer deeper secondary hard bottoms, *P. villosissimus* and the intermediates described above were observed under large boulders from grounds lying between depths of five and ten metres. Similar intermediates of *Pilumnus* were collected in the shallow waters of the Balearic Island Ibiza. In other, non-Adriatic regions of the Mediterranean Sea, including the coastal waters of the Northern Sporades (see Türkay et al. 1987), such intermediates of *Pilumnus* species were not reported, even though all species known for the Mediterranean Sea were documented in those areas investigated. However, based on the present findings, it seems necessary to revise the genus *Pilumnus* at least with respect to the Mediterranean species of the genus as postulated by D'UDECEM D'ACOZ (1999) some years ago and currently being tested using morphometric and genetic methods (SCHUBART ET AL., in prep).

The *Cystoseira amentacea*-paguroid-*Gobius* assemblage: a new facies? In the Bay of Valsaline (Pula), we observed a bizarre hard bottom community comprising an extended field of polymorphic, often contigious boulders (closely attached by sponges of the genus *Ircinia* as well as of the species *Aplysina aerophoba* (Schmidt, 1862), dispersed funnels filled with unsorted sandy sediments of high organic content, the brown algae species *Cystoseira amentacea* var*. spicata* (Ercegovic) Giaccone, appearing in a highly degenerated condition with its thallous strand heavily overgrown by (syn-)ascidians (e. g., *Phallusia mammilata* (Cuvier, 1815) and demospongial sponges (e. g., *Ircinia* sp.), the gobiid *Gobius cruentatus* (Gmelin, 1789) and masses of hermit crabs, mainly the striped hermit *Pagurus anachoretus* Risso, 1827, *Paguristes eremita*, *Anapagurus breviaculeatus* Fenizia, 1937 but occasionally also *Pagurus prideauxi* (see also chapter above). This phytal community is found below seven metres and may extend to a depth of ten metres. Even if not studied in every detail (e. g., smaller macrofauna, entire meiofauna, seasonal aspects), the species community described herein appears to be unique and has no obvious equivalent in those infralittoral benthic communities found in any other areas studied (including non-Adriatic coasts of the Mediterranean Sea), on the basis of the thorough review of HEß (2002). Furthermore, none of the species listed occurred in such high numbers in other areas investigated during the present study. The abundance of *P. anachoretus* especially was much higher than in any other habitat ever searched before by the authors. Also the presumed preference of *P. anachoretus* for large rocks with steep, shadowed margins seems to be absent when it is part of the "*Cystoseira amentacea*-paguroid-*Gobius* assemblage". We recommend further investigations into the peculiar structure of this community to verify its potential function as an independent zoocoenosis.

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Author's addresses

Carsten H. G. Müller[1,2]* & Christoph D. Schubart[3]

[1] Universität Rostock
Institut für Biowissenschaften
Allgemeine & Spezielle Zoologie
Universitätsplatz 2
18051 Rostock
Germany

[2] Max-Planck-Institut für Chemische Ökologie
Abteilung für Evolutionäre Neuroethologie
Hans-Knöll-Str. 8
07745 Jena
Germany

[3] Universität Regensburg
Fakultät für Biologie I
Institut für Zoologie
93040 Regensburg
Germany

*corresponding author; E-mail: carsten.mueller@uni-rostock.de

Tab. 1. Species list of Crustacea Decapoda collected in coastal waters of Rovinj, U. Slanik, Pula and Šipan, including details about the year and depth of sampling as well as the substrate type. Furthermore, observations on the frequency of each species are provided: 1 = rare (species spotted one to five times), 2 = common (species spotted six to 20 times), 3 = very common (species spotted more than 20 times). In some cases, details on the sampling depth for certain species caught during the Rovinj excursion of 1968 are missing due to incomplete reports (see question marks). The systematic classification of the species to the various decapod orders and families is based on the system used by d'Udecem d'Acoz (1999). Abbreviations: *ex* exuvial rest, *inl* infralittoral zone (till 20 m depth), *juv* juvenile specimen, *msl* meso(eu-) littoral zone, *Pu* Pula, *Pu** collection from lagoonary channel system of Marina Veruda, *Ro* Rovinj, *spec* specimen, *spl* supralittoral zone, *subl* lower sublittoral zone (below 20 m depth), *Sz* island of Šipan, *Uv* Uvala Slanik.

Taxa	**Location**	**Year**	**Habitat preferences**	**Depth (m)**	**Frequency**
Dendrobranchiata					
Sicyoniidae					
Sicyonia carinata (Brünnich, 1768)	Ro	1968	inl	?	?
Caridea					
Gnathophyllidae					
Gnathophyllum elegans (Risso, 1816)	Sz	2001	inl, under rocks	2 to 15	2
Paleamonidae					
Palaemon elegans Rathke, 1837	Ro, Sz	1968, 2001	inl, spl, rock pools, phytal	0 to 1	3
Palaemon serratus (Pennant, 1777)	Sz, Pu	2001-05	msl, inl, caves	1 to 3	2
Palaemon adspersus Rathke, 1837	Ro	1968	phytal	?	?
Periclimenes amesthysteus (Risso, 1827)	Sz	2001	inl, between rocks, associated	2	1
			with *Anemonia sulcata*		
Periclimenes aegylios Grippa & d'Udecem d'Acoz, 1996	Pu	2004	inl, between rocks, associated	3 to 15	1
			with *Anemonia sulcata*		
Typton spongicola O.G. Costa, 1844	Ro	1968	inl	?	?

Alpheidae					
Alpheus dentipes Guérin, 1832	Ro, Pu	1968, 2004, 2005	inl, under rocks	5 to 20	2
Alpheus macrocheles (Hailstone, 1835)	Sz	2001	inl, under rocks	3 to 20	2
Athanas nitescens (Leach, 1814)	Ro, Sz, Pu	1968 and	inl, subl, under rocks,	2 to 30	3
		2001-2005	sandy sediment		
Hippolytidae					
Hippolyte inermis Leach, 1814	Ro, Sz, Pu	1968, 2001-2005	inl, in *Posidonia*-beds	3 to 25	1 to 2
Hippolyte sapphica d'Udecem d'Acoz, 1993	Pu	2004, 2005	inl, phytal (*Cystoseira*, *Posidonia*)	2 to 5	2
Hippolyte prideauxiana Leach, 1817	Ro	1968	inl, phytal	below 5	?
Hippolyte cf. *garciarasoi* d'Udecem d'Acoz, 1996	Sz	2004	inl, phytal (*Cystoseira*)	0 to 2	3
Lysmata seticaudata (Risso, 1816)	Sz, Pu	2001-2005	msl, inl, under rocks,	0 to 15	2
			in caves and crevices		
Spirontocaris cranchi Leach, 1816	Ro	1968	inl	below 10	?
Crangonidae					
Philocheras bispinosus (Hailstone, 1835)	Sz	2001	subl, sandy bottom	35	2
Palinuridea					
Palinuridae					
Palinurus elephas (J.C. Fabricius, 1787)	Sz	2001	subl, cave entry	35	1
Scyllaridae					
Scyllarus arctus (Linnaeus, 1758)	Sz, Pu	2001-2005	inl, subl, rocky ground, caves	15 to 35	1 to 2
Nephropidea					
Nephropidae					
Homarus gammarus (Linnaeus, 1758)	Sz	2001	subl, coralligène	35	1 (ex)

Nephrops norvegicus (Linnaeus, 1758)	Ro	1968	inl	below 30?	?
Thalassinidea					
Upogebiidae					
Upogebia pusilla (Petagna, 1792)	Pu*	2004, 2005	msl, muddy ground	0 to 1	3
Callianassidae					
Callianassa tyrrhena (Petagna, 1792)	Pu*	2004	msl, muddy ground	0 to 1	3
Anomala					
Galatheidae					
Galathea squamifera Leach, 1814	Ro, Sz, Pu	1968, 2001-2005	inl, between and under rocks	3 to 15	3
Galathea strigosa (Linnaeus, 1761)	Pu	2004-2005	inl, rocky grounds	10 to 15	2
Galathea intermedia Lilljeborg, 1851	Ro, Sz	1968, 2001	inl, subl, under rocks	10 to 40	1
Porcellanidae					
Porcellana platycheles (Pennant, 1777)	Ro, Sz, Pu	1968, 2001-2005	msl, inl, under rocks	1 to 10	2 to 3
Pisidia bluteli (Risso, 1816)	Sz, Pu	2001-2005	msl, inl, under rocks	1 to 20	3
Pisidia longicornis (Linnaeus, 1767)	Ro	1968	inl, under rocks	below 1	?
Pisidia longimana (Risso, 1816)	Ro	1968	inl, under rocks	below 1	?
Diogenidae					
Calcinus tubularis (Linnaeus, 1767)	Sz	2001	inl, rocky grounds, phytal	3 to 20	2
Clibanarius erythropus (Latreille, 1818)	Ro, Sz, Pu	1968, 2001-2005	spl, msl, rocky grounds, rock pools	0 to 2	3
Dardanus calidus (Risso, 1827)	Sz, Pu	2001, 2005	inl, rocky grounds, *Posidonia*-beds	3 to 20	2
Diogenes pugilator (P. Roux, 1829)	Ro, Sz, Pu	1968, 2001-2005	inl, sandy bottoms	2 to 10	3
Paguristes eremita (Linnaeus, 1767)	Ro, Sz, Pu	1968, 2001-2005	inl, subl, sandy bottoms	10 to 40	2
			sometimes with *Suberites domuncula*		

Paguristes streaensis Pastore, 1984	Sz, Sl?	2001, 2004	inl, fine sandy funnels, muddy grounds	1 to 5	2
Paguridae					
Pagurus prideauxi Leach, 1815	Sz, Pu	2001-2005	msl, inl, subl, under rocks,	1 to 40	1 to 2
			sandy bottoms, with *Adamsia palliata*		
Pagurus cuanensis Bell, 1845	Sz	2001	inl, rocky grounds, phytal	5 to 20	1
Pagurus anachoretus Risso, 1827	Ro, Sz, Pu	1968, 2001-2005	msl, inl, subl, rocky grounds,	1 to 30	2 to 3
			sandy bottoms		
Pagurus chevreuxi (Bouvier, 1896)	Sz, Pu	2001-2005	inl, under rocks	3 to 10	2
Cestopagurus timidus (P. Roux, 1830)	Sz, Pu	2001-2005	inl, under rocks, *Posidonia*-beds	2 to 20	2
Anapagurus breviaculeatus Fenizia, 1937	Pu	2004, 2005	inl, sandy bottoms at the margins	10 to 25	3
			of *Posidonia*-beds		
Pagurus exacavatus (Herbst, 1791)	Ro	1968	inl, sandy and muddy bottoms	below 20	?
Brachyura					
Dromiidae					
Dromia personata (Linnaeus, 1758)	Ro, Sz, Pu	1968, 2001-2005	inl, under and between rocks,	2 to 10	1
			carries *Suberites domuncula*		
Majoidea					
Majidae					
Eurynome aspera (Pennant, 1777)	Ro	1968	inl	?	?
Macropodia rostrata (Linnaeus, 1761)	Sz	2001	inl, phytal, attached to algous thalli	10	1 (juv)
Inachus phalangium (J. C. Fabricius, 1775)	Pu	2004, 2005	inl, rocky grounds, associated	5 to 15	2
			with *Anemonia sulcata*		
Inachus thoracicus P. Roux, 1830	Ro, Sz	1968, 2001	subl, transition zone between	20 to 40	1
			sandy and rocky substrate		
Acanthonyx lunulatus (Risso, 1816)	Ro, Sz, Pu	1968, 2001-2005	msl, phytal, attached to algous thalli	0 to 2	3
Pisa tetraodon (Pennant, 1777)	Sz	2001	inl, phytal, rocky grounds	10 to 20	2

Pisa nodipes (Leach, 1815)	Ro	1968	inl, rocky grounds	?	?
Herbstia condyliata (J. C. Fabricius, 1787)	Sz, Pu	2001, 2005	inl, under and between rocks	1 to 10	1
Maja crispata Risso, 1827	Ro, Sz, Pu, Sl	1968, 2001-2005	msl, inl, subl, phytal, primary and	1 to 30	2
			secondary hard substrates		
Maja squinado (Herbst, 1788)	Ro	1968	inl, rocky grounds	?	?
Dorripoidea					
Dorripidae					
Ethusa mascarone (Herbst, 1785)	Ro, Sz	1968, 2001	inl, phytal, attached to algous thalli	5 to 20	1
Leucosioidea					
Leucosiidae					
Ebalia cranchii Leach, 1817	Sz	2001	subl, under rocks	35	1
Ilia nucleus (Linnaeus, 1758)	Pu	2005	inl, mixed sandy and rocky bottoms	5 to 15	2
Calappoidea					
Calappidae					
Calappa granulata (Linnaeus, 1758)	Sz	2001	subl, sandy ground	30	1 (ex)
Portunoidea					
Portunidae					
Carcinus aestuarii Nardo, 1847	Ro, Pu*, Sl	1968, 2004, 2005	msl, muddy sand, *Zostera*-beds	0 to 2	3
Parthenopoidea					
Parthenopidae					
Parthenope massena (P. Roux, 1830)	Ro, Sz	1968, 2001	inl, subl, sandy ground	10 to 35	1
Xanthoidea					
Xanthidae					
Xantho poressa (Olivi, 1792)	Sz, Pu, Sl	2001-2005	msl, inl, under rocks	1 to 20	1 to 3

Xantho hydrophilus (Herbst, 1790)	Ro, Sz, Pu	1968, 2001-2005	msl, inl, under rocks	1 to 15	2
Xantho pilipes A. Milne-Edwards, 1867	Pu	2004, 2005	inl	10 to 20	1
Eriphiidae					
Eriphia verrucosa (Forskal, 1775)	Ro, Sz, Pu, Sl	1968, 2001-2005	msl, rocky crevices and small holes	0 to 2	2
Pilumnidae					
Pilumnus spinifer (H. Milne-Edwards, 1843)	Sz, Pu	2001, 2004	inl, subl, rocky ground	5 to 35	1 to 2
Pilumnus villosissimus (Rafinesque, 1814)	Sz, Pu	2001-2005	inl, rocky grounds, sometimes	5 to 10	2
			associated with *Anemonia sulcata*		
Pilumnus hirtellus (Linnaeus, 1761)	Ro, Pu	1968, 2004, 2005	inl, rocky ground	10 to 20	1
Pilumnus sp.	Sz	2001	inl, rocky grund	5 to 10	1 (1 indiv.)
Grapsoidea					
Grapsidae					
Pachygrapsus marmoratus (J. C. Fabricius, 1787)	Ro, Sz, Pu, Sl	1968, 2001-2005	spl, msl, rocky substrates, rock pools,	0 to 1	3
			phytal (under macrophytes)		
Varunidae					
Hemigrapsus sanguineus (de Haan, 1835)	Sl	2001	spl, rocky littoral	0	1
Pinnotheroidea					
Pinnotheridae					
Pinnotheres pisum (Linnaeus, 1767)	Ro	1968	inl, in various Bivalvia	?	?