ANNALES

Anali za istrske in mediteranske študije
Annali di Studi istriani e mediterranei
Annals for Istrian and Mediterranean Studies
Series Historia Naturalis, 29, 2019, 1

UDK 5 Annales, Ser. hist. nat., 29, 2019, 1, pp. 1-158, Koper 2019 ISSN1408-533X

UDK 5

ISSN 1408-533X (Print)
ISSN 2591-1783 (Online)

ANNALES

Anali za istrske in mediteranske študije
Annali di Studi istriani e mediterranei
Annals for Istrian and Mediterranean Studies

Series Historia Naturalis, 29, 2019, 1

KOPER 2019

ISSN 1408-533X (Tiskana izd.)
ISSN 2591-1783 (Spletna izd.)

UDK 5

Letnik 29, leto 2019, številka 1

Izdajatelja/*Editori/Published by:*

Zgodovinsko društvo za južno Primorsko - Koper / *Società storica del Litorale - Capodistria*©
Inštitut IRRIS za raziskave, razvoj in strategije družbe, kulture in okolja / *Institute IRRIS for Research, Development and Strategies of Society, Culture and Environment / Istituto IRRIS di ricerca, sviluppo e strategie della societa, cultura e ambiente*©

Sedež uredništva/*Sede della redazione/*
Address of Editorial Board:

Nacionalni inštitut za biologijo, Morska biološka postaja Piran / *Istituto nazionale di biologia, Stazione di biologia marina di Pirano / National Institute of Biology, Marine Biology Station Piran*
SI-6330 Piran /*Pirano*, Fornače/*Fornace* 41, tel.: +386 5 671 2900, fax 671 2901;
e-mail: annales@mbss.org, ***internet:*** www.zdjp.si

Redakcija te številke je bila zaključena 21. 6. 2019.

Sofinancirajo/*Supporto finanziario/*
Financially supported by: Javna agencija za raziskovalno dejavnost Republike Slovenije (ARRS), Luka Koper in Mestna občina Koper

Annales - Series Historia Naturalis izhaja dvakrat letno.

Naklada/*Tiratura/Circulation:* 300 izvodov/copie/copies

Revija Annales, Series Historia Naturalis je vključena v naslednje podatkovne baze / *La rivista Annales, series Historia Naturalis è inserita nei seguenti data base / Articles appearing in this journal are abstracted and indexed in*: BIOSIS-Zoological Record (UK); Aquatic Sciences and Fisheries Abstracts (ASFA); Elsevier B.V.: SCOPUS (NL).

Vsi članki so v barvni verziji prosto dostopni na spletni strani: http://zdjp.si/p/annalesshn/
All articles are freely available in color via website: http://zdjp.si/en/p/annalesshn/

ANNALES · Ser. hist. nat. · 29 · 2019 · 1

Anali za istrske in mediteranske študije - Annali di Studi istriani e mediterranei - Annals for Istrian and Mediterranean Studies

UDK 5 Letnik 29, Koper 2019, številka 1 ISSN 1408-533X (Print)
ISSN 2591-1783 (Online)

VSEBINA / *INDICE GENERALE / CONTENTS 2019(1)*

received: 2019-01-24 DOI 10.19233/ASHN.2019.13

SPATIAL DISTRIBUTION OF THREE SPECIES OF *PALAEMON* SHRIMP (CRUSTACEA: DECAPODA: CARIDEA) IN BADAŠEVICA RIVER (SW SLOVENIA)

Jure JUGOVIC & Živa MUHIČ
Department of Biodiversity, Faculty of Mathematics, Natural Sciences and Information Technologies, University of Primorska, Glagoljaška 8, 6000 Koper, Slovenia
e-mail: jure.jugovic@upr.si

ABSTRACT

We investigated the presence, spatial distribution and possible co-existence of Palaemon *species from Badaševica river and its draining channels. We used inverted bottles with a bait to trap the shrimp and recorded three species (*P. elegans, P. adspersus, P. antennarius*) from six out of seven surveyed localities. The localities mostly differed in distance from the coastline (0–3.6 km) and salinity (3.9–36.2), while high variation was recorded in other hydrological, physio-chemical and biochemical parameters among the localities and species.* P. elegans *was present only at the river mouth at salinity of 33.2, while* P. antennarius *was predominantly found at localities in a distance more than 2 kilometres inland.* P. adspersus *was most common and prevailed at localities with denser vegetation. Although* P. adspersus *and* P. elegans *were both found at a single locality, their microhabitat clearly differed (*P. elegans *was recorded exclusively at the river mouth,* P. adspersus *ca. 50 metres inland). A single specimen of* P. antennarius *was trapped together with* P. adspersus *but in general their spatial and ecological segregation was well expressed. Presence of ovigerous females in brackish environment was confirmed* for P. adspersus *and* P. antennarius. *Males outnumbered females in all three species.*

Key words: brackish environment, spatial segregation, co-occurrence, Palaemonidae, salinity

DISTRIBUZIONE SPAZIALE DI TRE SPECIE DI GAMBERI DEL GENERE *PALAEMON* (CRUSTACEA: DECAPODA: CARIDEA) NEL FIUME CORNALUNGA (SLOVENIA SUD-OCCIDENTALE)

SINTESI

Gli autori hanno studiato la presenza, la distribuzione spaziale e la possibile coesistenza di specie del genere Palaemon *nel fiume Cornalunga e nei suoi canali di drenaggio. Con l'uso di bottiglie rovesce con un'esca, hanno intrappolato tre specie di gamberetti (*P. elegans, P. adspersus, P. antennarius*) in sei delle sette località campionate. Le località sono posizionate a distanze differenti dalla costa (0-3,6 km), con diverse salinità (3,9-36,2) e ampie differenze pure negli altri parametri idrologici, fisico-chimici e biochimici tra località e specie.* P. elegans è *presente solo alla foce del fiume (salinità pari a 33.2), mentre* P. antennarius è *presente prevalentemente in località a una distanza maggiore ai 2 km verso l'entroterra.* P. adspersus è *più comune, trovato prevalentemente in località con vegetazione più densa. Sebbene* P. adspersus *e* P. elegans *sono stati trovati in una sola località, il loro microhabitat differisce chiaramente (*P. elegans *presente esclusivamente alla foce del fiume, metre* P. adspersus *a circa 50 metri di distanza verso l'entroterra). Un singolo esemplare di* P. antennarius è stato trovato *intrappolato insieme a* P. adspersus*, ma in generale la loro segregazione spaziale ed ecologica* è *ben espressa. La presenza di femmine ovigere in ambiente salmastro è stata confermata per* P. adspersus e P. antennarius. *Per tutte le specie i maschi campionati superavano in numero le femmine.*

Parole chiave: ambiente salmastro, segregazione spaziale, co-occorrenza, Palaemonidae, salinità

INTRODUCTION

Palaemonidae are diagnosed by the size of their second chelipeds that are always larger (in some species slightly and in other extremely) than the first chelipeds (Bauer, 2004; De Grave *et al*., 2008; Christodoulou *et al*., 2016). The genus *Palaemon* consists of 87 species (De Grave & Ashelby, 2013; Carvalho *et al*., 2014; Tzomos & Koukouras, 2015), however there are only two genera and 14 species in the Palearctic region (De Grave *et al*., 2008; Tzomos & Koukouras, 2015). In Slovenia, five species of Palaemonidae shrimps are reported (Manning & Stevčić, 1982; Christodoulou *et al*., 2016), although this family is one of the most speciose within the Caridea (de Grave *et al*., 2008; Christodoulou *et al*., 2016) following the Atyidae (43 genera) with 14 genera in total (Christodoulou *et al*., 2016).

Among them, three species were known to penetrate rivers and channels, but only *Palaemon anntenarius* H. Milne Edwards, 1837 is treated as a predominantly freshwater species inhabiting lakes and rivers. Nevertheless, it can sometimes be found also in coastal brackish waters such as lagoons and estuaries in the Mediterranean basin (Holthuis, 1961; d'Udekem d'Acoz, 1999; Falciai & Palmerini, 2002; Gottstein-Matočec & Kerovec, 2002). This species is on the list of protected species in Slovenia (Decree on protected wild animal species: Anonymous, 2004). *Palaemon adspersus* Rathke, 1837 and *Palaemon elegans* Rathke, 1837 are predominantly marine species but can be found in anchialine waters, and they can sometimes co-occur (Manning & Stevčić, 1982). In Slovenia, they were found together in few localities in the areas of tidal flats, where another *Palaemon* species, *P. xiphias* (Risso, 1816) can also occur (Manning & Stevčić, 1982). *Palaemon serratus* (Pennant, 1777), a fifth palaemonid species from Slovenia, is frequently reported from the coastal marine environments (Turk & Richter, 2007).

In total, there are only three small rivers with direct outflow into the Adriatic Sea in Slovenia: Dragonja at the border with Croatia in the south, Rižana outflowing into the port of Koper in the north, and Badaševica that is flowing through the artificial channel throughout its lower flow, while in its upper part it flows through agricultural landscape. Spring of Badaševica that was our focal river is at 196 m above sea level and reach the Bay of Koper after 9.5 kilometres with a gradient of only 2.07 %. In its lower part, gradient is even lower, only 0.14 % during the last 2.2 kilometres before the outflow. Owing to its torrential nature, floods were frequent in its lower part, therefore the river channel was highly changed and redirected; the river banks were walled or covered with stone blocks and many draining channels were constructed since 1950s (Plut, 1979). Badaševica had its old channel outflowing in the San Canziano bay, however an artificial new main and some side (draining) channels were constructed south of it and the river has now its main outflow in the Bay of Koper (Plut, 1979). All three main rivers of the Slovenian part of Adriatic basin potentially contribute to the pollution of the gulf of Trieste (Turk, 2016). At their estuaries, freshwater and marine systems are interacting, and anchialinae water is present. According to salinity, habitat categories can be divided in freshwater (i.e. limnetic: 0–0.5) and saline (oligohaline: 0.5–5; mesohaline: 5–15; polyhaline: 18–30; mixohaline: 30–40) environments (Jones & Hallin, 2010).

In the present study we provide the information on spatial distribution of three species of *Palaemon* within

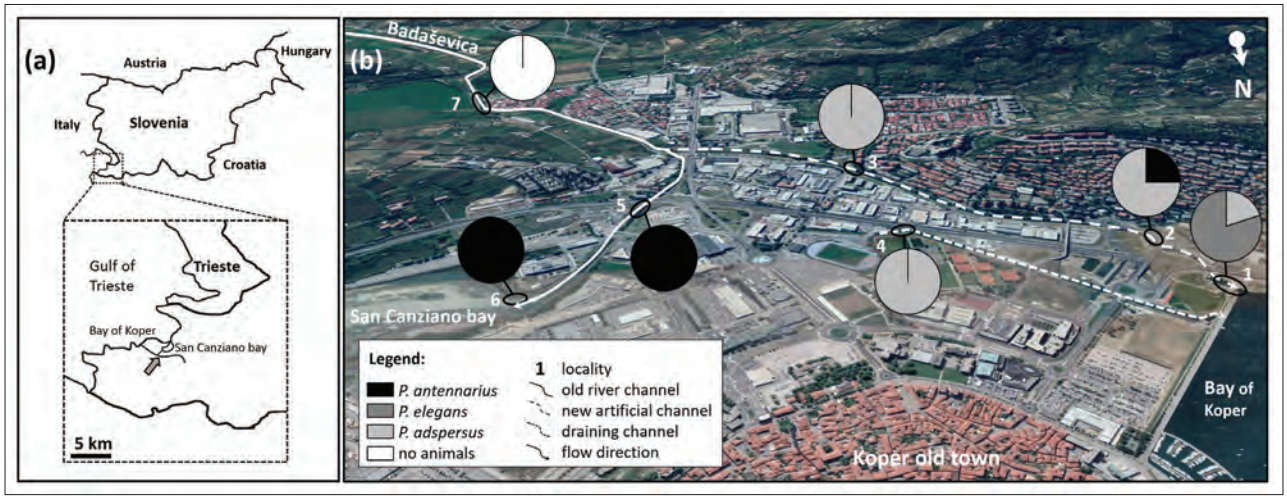

Fig. 1: Geographical position of Badaševica river (arrow) in Slovenia (a) and sampling localities with proportions of sampled Palaemon ***species (b) (map adjusted and redrawn from Google Earth).***
Sl. 1: Geografski položaj reke Badaševice (puščica) v Sloveniji (a) in vzorčna mesta s prikazanimi razmerji ujetih vrst iz rodu *Palaemon* ***(b) (prirejeno po Google Earth).***

Tab. 1: Sampling localities (S) with hydrological, biological, physio-chemical and biochemical parameters (min–max value) in Badaševica river.
Tab. 1: Vzorčna mesta (S) z razponom hidroloških, bioloških, fizikalno-kemijskih in biokemijskih parametrov v reki Badaševici.

S	Geographic coordinates	Distance of traps from the sea [m]	Channel type	Substrate	Vegetation	Tidal influence	T [ºC]	Oxygen [mg/L]	Oxygen [%]	pH	Conductivity [mS/cm]	Salinity	Nitrates [mg/L]	Chl a [µg/L]
1	45º32′32.8″N 13º43′11.4″E	0–80	new artificial channel	silt, mud, rocks, walled	exposed, some different algae	strong	11.1–25.9	7.08–11.75	86.3–116.8	8.05–8.09	16.1–50.2	13.2–33.2	42.3–195.5	0.40–8.10
2	45º32′25.5″N 13º43′14.9″E	250–300	new artificial channel	silt, mud, rocks, walled	some filamentous algae	strong	11.2–25.7	7.16–12.19	87.0–124.0	8.05–8.14	13.1–50.5	10.5–32.6	35.4–196.5	0.61–25.33
3	45º32′09.4″N 13º43′45.8″E	1130–1150	new artificial channel	rocks (artificial), walled (incl. bottom)	some filamentous algae	medium	12.1–25.6	7.09–12.46	86.0–127.4	8.06–8.33	4.16–50.4	3.0–36.2	14.2–193.0	1.90–33.66
4	45º32′23.1″N 13º43′45.3″E	780–820	draining channel	silt, mud	some phylamentous algae, *Phragmites*	low	11.4–25.7	9.31–11.34	102.1–130.6	7.62–8.06	16.46–42.0	6.3–12.7	40.3–130.5	1.41–33.91
5	45º32′16.2″N 13º44′12.1″E	2110–2160 (B*) 3520–3570 (SC*)	old channel	silt, mud	dense filamentous algae	low	13.5–27.1	7.81–15.34	85.3–145.8	8.15–8.20	25.20–47.4	9.5–13.7	59.1–173.5	3.14–34.61
6	45º32′28.7″N 13º44′20.3″E	2500–2550 (B) 3050–3100 (SC)	old channel	silt, mud	filamentous and other algae	low	17.8–28.9	15.34–21.72	175.4–227.2	8.33–8.70	27.1–45.6	15.7–33.9	68.6–151.0	4.41–16.78
7	45º31′48.0″N 13º44′40.0″E	2550–2610	old channel	silt, mud, concrete, small rocks, walled	algae in periphyton	none	10.0–28.4	6.16–11.80	78.5–125.3	7.80–8.30	0.63–38.4	3.9–22.7	0.94–138.5	3.66–41.71

*B – distance measured through new Badaševica channel to open sea; SC – distance measured through San Canziano bay to open sea

a single river system (Badaševica in SW Slovenia) and discuss possible environmental factors influencing their spatial distribution.

MATERIAL AND METHODS

Specimens were collected with trapping at seven localities (Fig. 1) of Badaševica river and its draining channels from the outflow (locality 1) to artificial barrier 2.6 km inland (locality 7) (Fig. 1, Tab. 1). Locality 7 was situated below a two metres high artificial dam, hence no traps were set upstream from the dam. Three plastic bottles (volume 1.5 l) with inverted opening were used per locality and the distance from the sea of each trap was measured (Tab. 1). Crushed mussels (*Mytillus galloprovincialis*) and chicken meat were used as bait and trapping lasted for four days during four sampling sessions in spring 2017. Samples were collected once per month in middle March, April, May and June. Sampling localities were georeferenced using a GPS and physicochemical water quality parameters (dissolved oxygen ($mg*L^{-1}$), oxygen saturation (%), water temperature (°C), conductivity ($mS*cm^{-1}$), and pH) were measured using a Portable multiparameter Aquaprobe AP-200 with a GPS Aquameter (Aquaread AP 2000). At each locality, sediment type and tidal influence (strong, medium, low, none) were assessed by naked eye (Tab. 1). Samples of water were transferred into the laboratory and chlorophyll a ($\mu g*L^{-1}$) was measured shortly afterwards. Salinity was calculated from water temperature and conductivity. Distance from the sea was measured from orto-photo maps for each sampling locality as a range of distances between the three traps.

Specimens were identified using the Olympus SZX7 stereomicroscope with a built-in camera. The identification key of González-Ortegón & Cuesta (2006) was used for species identification. Presence of ovigerous females and male-female ratio were checked. Nomenclature follows De Grave & Ashelby (2013).

RESULTS

Main observations and measurements on the hydrological and physio-chemical parameters at seven sampling localities are compiled in Tab. 1. Altogether, three species were sampled during the study from localities 1–6, while no animals were recorded at locality 7 (Fig. 1, Tab. 2). Most animals were collected in April and May with 52.6 % and 31.6 % of the total sample size, respectively, while in March and June only 7.9 % of the total sample size in each of those months was collected. *Palaemon adspersus* was most commonly sampled (69.7 % of sampled animals) and was found at four localities (1–4; see Tab. 2).

At locality 4, where only *P. adspersus* was recorded, animals counted for 50.0 % of the total sample size. The ranges of chemical parameters measured at each sampling day and locality overlap among the three species, however, oxygen levels (concentration and saturation) were bit higher at locality 6 (and sometimes at locality 5) than at the other localities. Moreover, the distance from the sea and salinity greatly differ among the localities (Tab. 1). With time (i.e. consecutive sampling periods), *P. adspersus* was recorded progressively further from the coastline (Tab. 2). While it was recorded from localities 1, 2 and 4 (50–820 metres from the coastline) in March, it was found at localities 2, 3 and 4 (250–1150 metres inland) in April, and only at localities 3 and 4 (780–1150 metres inland) during May and June. *P. elegans* (5.3 % of total sample) was found only in one (outermost) of the three traps at the river mouth (locality 1) where salinity at the sampling day was 33.2, which is almost as high as salinity reported for the northern Adriatic Sea (approx. 38–39, *e.g.* Grbec *et al.*, 2007). *P. adspersus* was recorded together with *P. elegans* at locality 1, however it was found there in another trap that was set 50 m from the river mouth, at salinity of 13.2. In total, *P. adspersus* was found 50–1150 m inland, at salinity range 3.2–36.2. *P. antennarius* (25.0 % of total sample size) was found at longest distance from the sea, i. e. at two localities (5, 6) that are situated more than 2 kilometres from the coastline, with salinity range 19.0–30.9. Nevertheless, a single specimen of *P. antennarius* was found also at locality 2 (ca. 300 metres from the coastline) together with *P. adspersus* at salinity 10.5. As in *P. adspersus*, recordings of *P. antennarius* progressed further inland with time (Tab. 2). While the species was recorded at locality 2 in March, it was later recorded only from localities 5 (April, May; ca. 2.1 kilometres from the coastline) and 6 (June; ca. 2.5 kilometres from the coastline).

During April and May, presence of ovigerous females was confirmed for *P. adspersus* (2 and 5 females at localities 2 and 4, respectively) and *P. antennarius* (4 females at locality 5) but not for *P. elegans*. Males outnumbered females in all three species (100 % of males in *P. elegans*, 75.0 % in *P. antennarius* and 78.4 % in *P. adspersus*).

DISCUSSION

We report on a presence and spatial segregation of three *Palaemon* species (*P. adspersus*, *P. elegans*, *P. antennarius*) in Badaševica river and channels nearby. Nevertheless, *P. adspersus* and *P. elegans* are frequently reported from the same environments (Berglund & Bengtsson 1981; Łapińska & Szaniawska 2006; Janas 2013). In estuaries with a low tidal influence both can inhabit meadows of *Zostera marina*, however, Berglund (1980; 1982) reports that in a latter case *P. adspersus* is more abundant, possibly due to larger body size in comparison to *P. elegans*. Moreover, a spatial co-occurence of three species of *Palaemon*, *P. antennarius*, *P. adspersus* and *P. varians* with an ecological niche separation within *Phragmites australis* was reported by Dolmen *et al.* (2004). In this case, *P. adspersus* and *P. elegans* occurred

Tab. 2: A list of species per each sampling locality (S), sampling date (month, in roman numerals) and number of sampled shrimps together with physio-chemical and biochemical parameters measured at each successful sampling. Tab. 2:. Seznam vrst po vzorčnih mestih (S) s podatki o datumu vzorčenja (mesec, označeno z rimskimi številkami) in številu zbranih kozic ter vrednostmi fizikalno-kemijskih in biokemijskih parametrov ob vsakem uspešnem vzorčenju.

S	Species	Month	No.	T [ºC]	Oxygen [mg/L]	Oxygen [%]	pH	Conductivity [mS/cm]	Salinity	NO_3 [mg/L]	Chlorophyll a [µg/L]
1	*P. adspersus*	III	1	11.1	10.44	94	8.09	16.08	13.2	42.3	8.10
	P. elegans	V	4	20.5	9.17	101.3	8.08	45.7	33.2	144.5	3.67
2	*P. adspersus*	III	1	11.2	10.23	92.1	8.14	13.1	10.5	35.4	25.33
		IV	2	16.2	12.19	124	8.13	35.9	27.8	104.5	4.42
	P. antennarius	III	1	11.2	10.23	92.1	8.14	13.1	10.5	35.4	25.33
3	*P. adspersus*	IV	4	16.4	12.46	127.4	8.33	4.97	3.2	26.1	18.92
		V	5	20.4	10.50	111.2	8.13	49.8	36.2	123.5	1.90
		VI	1	25.6	7.09	86.0	8.06	50.4	32.6	193.0	2.88
4	*P. adspersus*	III	3	11.4	11.34	102.9	8.06	16.5	13.4	40.3	18.03
		IV	26	16.8	9.91	102.1	7.95	27.3	20.3	77.1	33.91
		V	8	24.4	9.31	110.6	7.99	42.0	27.3	96.7	1.41
		VI	1	25.7	10.76	130.6	7.62	34.2	21.1	131.5	5.88
5	*P. antennarius*	IV	8	19.6	7.82	85.3	8.17	42.5	30.9	120.5	34.61
		V	7	25.9	8.68	106.0	8.15	31.2	19.0	79.2	3.14
6	*P. antennarius*	VI	4	28.9	15.72	202.2	8.33	39.8	23.3	151.0	15.11

in a microhabitat with lower and *P. varians* with higher density of *P. australis* (Dolmen *et al.*, 2004). On the other hand, where a tidal influence is strong, *P. adspersus* and *P. elegans* in most cases select different microhabitats (Dolmen *et al.*, 2004). In our case, selection of different microhabitats of the two species would be in line with observations of a strong tidal influence at our localities; whereas *P. elegans* was found only at the final point of the riverine mouth, *P. adspersus* occupied brackish part of the river up to approx. one kilometre from the coastline. Both species usually prefer well aerated systems with salinity higher than 15 (mostly polyhaline and mixohaline environments) (Barnes, 1994; Dolmen *et al.*, 2004).

Despite that there are records of occurrence of *P. elegans* below 6.5 of salinity from the Baltic sea (mesohaline to oligohaline waters; Dolmen *et al.*, 2004; Łapínska & Szaniawska, 2006), both species are euryhaline, however in Badaševica only *P. adspersus* was found in a wide range of salinity (oligohaline to mixohaline). During our study, *P. elegans* was found only in mixohaline water. Berglund & Bengtsson (1981) reported that *P. elegans* is more prone to hypoxy than *P. adspersus*. In our case, oxygen levels were similar for a locality with *P. elegans* and for localities with *P. adspersus*. Therefore, we cannot see the oxygen as a factor influencing spatial segregation of the two species in our case. Both species are mainly nocturnal (Berglund 1980; Hagerman & Ostrup, 1980; Guerao & Abello, 1996; Janas & Baranska, 2008), however pronounced nocturnal activity is usually less stressed in *P. adspersus* (Berglund, 1980; Hagerman & Ostrup, 1980). Since *P. elegans* is not a habitat specialist, more prone to hypoxia, more active and quicker in feeding than *P. adspersus*, it can occupy sites that are not preferential for stronger and larger *P. adspersus* (Berglund & Bengtsson, 1981). Especially when found in marine environments, *P. adspersus* prefers meadows of marine flowering plants (e.g. *Posidonia*, *Zostera*, *Cymodocea*) (Manent & Abella-Gutiérrez, 2006), while *P. elegans* can be abundant also at sandy and unprotected bottom (Berglund & Bengtsson, 1981). This could be in line with our case as the environment at the site with *P. elegans* was open and unprotected. Moreover, we recorded *P. adspersus* only at localities where dense vegetation was present. It should be noted that *P. adspersus* was by far most abundant at the end of a draining channel at locality 4 (73.1 % of a *P. adspersus* sample) with densest vegetation. Since it has been reported that *P. adspersus* rather avoid open spaces since it can be quickly detected by the predators owing to its large size, this locality seemingly offers this species an optimal habitat and reproduction site, and is probably lacking shrimp predators. Moreover, at the localities closest to the coastline (1, 2), shrimps were found only at the beginning of the sampling period (at locality 1, a

single specimen in March, and at locality 2, a single and two specimens in March and April, respectively). No additional animals were found there during the continuation of the sampling period (May, June), and a species reached a peak of abundance in April at locality 4 (50.0 % of a *P. adspersus* sample).

P. anntenarius represented 25.0 % of the total sample size and was found in two localities where neither of the above mentioned species occurred. *P. antennarius* is reported to be oligohaline species that inhabits freshwater to brackish environments with muddy bottom. Most commonly it is mentioned as a true freshwater species (Dalla Via, 1987; Gottstein-Matočec *et al.*, 2006; Anastasiadou *et al.*, 2009, 2014; Christodoulou *et al.*, 2016). During our study it was found in mesohaline and polyhaline waters and always above 15 of salinity, however, this is not contradicting its euryhaline nature as Dalla Via (1987) reports that it can be found at a wide range of salinity from 5 to 30. This species can adapt to quick salinity changes by metabolic adjustment if the changes in salinity are short-termed, while at higher salinities (>19) oxygen uptake strongly increases. Populations that inhabit brackish environments with higher salinity can adapt up to approximately 25 of salinity but in the same time brackish populations cannot easily adapt to low salinities (Dalla Via, 1987). This is in line with our results as this species was found at the range of salinity above 10.5 (but even higher than reported in literature, up to 30.9) and most abundant at the two localities (5, 6) with highest oxygen levels. Gottstein-Matočec *et al.*, 2006 reported that *P. antennarius* shows higher reproductive success in environments with stable salinity, however during the reproductive period brackish waters were preferred (Dalla Via, 1987; Gottstein-Matočec *et al.*, 2006) over waters with lower salinity in delta of Neretva (SE Croatia). Sheltered bays with stable environment (low tidal influence, stable salinity, warm temperature, abundance of food) and muddy bottom can therefore be optimal for the reproduction of the species, such as probably at localities 5 and 6 in our case where it was recorded after the beginning of its breeding season in April. Nevertheless, a single specimen of *P. antennarius* was found before the breeding season in March also at locality 2 in the main channel of the Badaševica river, in this case together with *P. adspersus*. We failed to find the data on a sympatric occurrence of those two species in the literature, so we think this co-occurence was coincidetial. However, we cannot exclude the option that *P. antennarius* can occasionally be present in the main channel of the river, possibly due to drift or active spreading of the species.

Sex ratio in our samples strongly deviates towards males and this contradicts the reports for all three species where females are usually more abundant (Gottstein-Matočec *et al.*, 2006; Łapínska & Szaniawska, 2006; Manent & Abelle-Gutiérrez, 2006). *P. adspersus* for which a reproductive period lasts from March to August (Guerao & Ribera, 1995; Manent & Abella-Gutiérrez, 2006) females were frequently noticed to lay eggs in shallow coastal marine waters (Barnes, 1994; Guerao & Ribera, 1999; Glamuzina *et al.,* 2014). Nevertheless, we noticed some ovigerous females in the river channel itself (28.6 % of all ovigerous females at locality 2), however, it is possible that some of them move towards the sea for egg laying which could cause their deficit upstream. Since most of ovigerous *P. adspersus* females (71.4 %) were found at locality 4 it is also possible that ovigerous females seek for protected and well-hidden places where they remain for the most of time. Hence, their trapping probability could be lower than for males and estimated sex ratio is then biased towards males. In *P. antennarius*, reproductive period lasts from April until August with a maximum in June (Gottstein-Matočec *et al.*, 2006). This is in line with our data for Slovenian mesohaline and polyhaline environments, while no conclusions can be made on unusual sex ratio in *P. antennarius* (but see above for *P. adspersus*) and *P. elegans*. For the latter, a small sample size may prevent a more accurate conclusion.

CONCLUSIONS

In this study we reported on a well expressed spatial and ecological segregation among three species of *Palaemon* in a brackish environment of a river Badaševica. The following conclusions can be made:

1. *P. elegans* and *P. adspersus* select different habitats near the river outflow that is under a strong tidal influence (*P. elegans* occupies more exposed rocky bottom at higher salinity at the final point of the outflow, and *P. adspersus* is present at a microsite with lower salinity in a better protected river channel only few tens of meters inland);
2. *P. antennarius* and *P. adspersus* seem to be ecologically and spatially well separated as the vast majority of *P. adspersus* was found in a drainage channel and upper the river channel with dense vegetation (mostly macrophytes), and *P. antennarius* was found predominantly at sites more than 2 kilometres inland with low tidal influence in a well aerated water;
3. Presence of ovigerous females was confirmed for *P. adspersus* and *P. antennarius*.

ACKNOWLEDGEMENTS

Authors thank Felicita Urzi for help in a laboratory, Martina Jeklar for help on the field and Domen Trkov for useful information on distribution of *Palaemon* shrimps in the area of Koper. Authors also thank two anonymous referees for constructive comments on the manuscript.

PROSTORSKA RAZPOREDITEV TREH VRST KOZIC IZ RODU *PALAEMON* (CRUSTACEA: DECAPODA: CARIDEA) V BADAŠEVICI (JZ SLOVENIJA)

Jure JUGOVIC & Živa MUHIČ
Department of Biodiversity, Faculty of Mathematics, Natural Sciences and Information Technologies, University of Primorska, Glagoljaška 8, 6000 Koper, Slovenia
e-mail: jure.jugovic@upr.si

POVZETEK

Preiskovali smo prisotnost, prostorsko razporeditev in možnost sobivanja vrst iz rodu Palaemon *v reki Badaševici in njenih odvodnih kanalih. Za pasti smo uporabili plastenke z navznoter obrnjenim ustjem. Zabeležili smo tri vrste (*P. elegans, P. adspersus, P. antennarius*) s šestih od sedem preiskovanih vzorčnih mest. Vzorčna mesta so se najbolj razlikovala po oddaljenosti od morja (0–3.6 km) in slanosti (3.9–36.2), pri ostalih beleženih hidroloških, fizikalno-kemijskih in biokemisjkih parametrih pa smo zabeležili veliko stopnjo variabilnosti tako med vzorčnimi mesti kot vrstami kozic.* P. elegans *smo zabeležili le na ustju reke pri slanosti 33.2,* P. antennarius *pa smo skoraj izključno našli le na vzorčnih mestih, ki so od morja oddaljena več kot 2 km.* P. adspersus *je bila najštevilnejše zastopana vrsta in se je pojavljala v velikem številu predvsem na lokacijah z gosto vegetacijo. Čeprav smo* P. adspersus *in* P. elegans *našli na istem vzorčnem mestu ob izlivu reke v morje, smo opazili, da se izbira njunega mikrohabitata razlikuje (*P. elegans *smo našli neposredno na izlivu reke v morje,* P. adspersus *pa smo zabeležili prb. 50 m po toku navzgor).* P. antennarius *smo le enkrat (en osebek) našli na eni od vzorčnih mest skupaj s* P. adspersus*, a je bila sicer prostorska in ekološka ločitev med vrstami jasno vidna. Prisotnost ovigerih samic smo potrdili za vrsti* P. adspersus *in* P. antennarius*. Samci so bili pri vseh treh vrstah številnejši od samic.*

Ključne besede: somorno okolje, prostorska ločitev, sobivanje, Palaemonidae, slanost

REFERENCES

Anastasiadou, C., R. Liasko & D.I. Leonardos (2009): Biometric analysis of lacustrine and riverine populations of *Palaemonetes antennarius* (H. Milne-Edwards, 1837) (Crustacea, Decapoda, Palaemonidae) from northwestern Greece. Limnologica, 39, 244-254.

Anastasiadou, C., C. Gkenas, I. Kagalou & D. I. Leonardos (2014): Shrimps of an ancient Balkan lake: Bionomy and conservation. Biologia, 69(7), 895-904.

Anonymous (2004): Uredba o zavarovanih prosto živečih živalskih vrstah (Decree on protected wild animal species) (Uradni list RS, št. 46/04, 109/04, 84/05, 1 15/07, 32/08 – odl. US, 96/08, 36/09, 102/11, 15/14 in 64/16) (in Slovene).

Barnes, R.S.K. (1994): The brackish-water fauna of northwestern Europe: a guide to brackish-water habitats, ecology, and macrofauna for field workers, naturalists, and students. Cambridge University Press, Cambridge, 304 pp.

Bauer, R.T. (2004): Remarkable shrimps: natural history and adaptations of the carideans. Norman, University of Oklahoma Press, 316 pp.

Berglund, A. (1980): Niche differentiation between two littoral prawns in Gullmar Fjord, Sweden: *Palaemon adspersus* and *P. squilla*. Holarctic Ecol., 3, 111-115.

Berglund, A. (1982): Coexistence, size overlap and population regulation in tidal vs. nontidal *Palaemon* prawns. Oecologia, 54, 1-7.

Berglund, A. & J. Bengtsson (1981): Biotic and abiotic factors determining the distribution of two prawn species: *Palaemon adspersus* and *P. squilla*. Oecologia, 49, 300-304.

Christodoulou, M., C. Anastasiadou, J. Jugovic & T. Tzomos (2016): Freshwater shrimps (Atyidae, Palaemonidae, Typhlocarididae) in the Broader Mediterranean Region: distribution, life strategies, threats, conservation challenges

and taxonomic issues. In: Kawai, T. & N. Cumberlidge (eds.): A global overview of the conservation of freshwater decapod crustaceans. Springer, Berlin, pp. 199-236.

Dalla Via, G.J. (1987): Salinity responses in brackish water populations of the freshwater shrimp *Palaemonetes antennarius* – oxygen consumption. Comp. Biochem. Physiol., 87A(2), 471-478.

Dolmen, D., J.D. Hindley & E. Kleiven (2014): Distribution of *Palaemonetes varians* (Leach) (Crustacea, Decapoda) in relation to biotope and other caridean shrimps in brackish waters of southern Norway and southwestern Sweden. Sarsia, 89, 8-21.

Falciai, L. & E. Palmerini (2002): Larval development of the freshwater shrimp, *Palaemonetes antennarius* (H. Milne Edwards, 1837) (Decapoda, Palaemonidae) reared in the laboratory. Crustaceana, 74(11). 1315- 1333. doi: 10.1163/15685400152885264

Glamuzina, L., A. Conides, I. Prusina, M. Ćukteraš**, D. Kloudatos, P. Zacharaki & B. Glamuzina (2014):** Population structure, growth, mortality and fecundity of *Palaemon adspersus* (Rathke 1837; Decapoda: Palaemonidae) in the Parila Lagoon (Croatia, SE Adriatic Sea) with notes on the population management. Turk. J. Fish. Aquat. Sc., 14, 677-687.

González-Ortegón, E. & J.A. Cuesta (2006): An illustrated key to species of *Palaemon* and *Palaemonetes* (Crustacea: Decapoda: Caridea) from European waters, including the alien species *Palaemon macrodactylus*. J. Mar. Biol. Assoc. UK, 86, 93-102.

Gottstein-Matočec, S. & M. Kerovec (2002): *Atyaephyra desmaresti* and *Palaemonetes antennarius* (Crustacea: Decapoda, Caridea) in the Delta of the Neretva River (Croatia). Biologia (Bratisl), 57, 181-189.

Gottstein-Matočec, S., A. Kuzman & M. Kerovec (2006): Life history traits of the grass shrimp *Palaemonetes antennarius* (Decapoda, Palaemonidae) in the delta of the Neretva River, Croatia. Limnologica, 36, 42-53.

De Grave, S., Y. Cai., & A. Anker (2008): Global diversity of shrimps (Crustacea: Decapoda: Caridea) in freshwater. Hydrobiologia, 595, 287-293. doi: 10.1007/s10750-007-9024-2

De Grave, S. & C. W. Ashelby (2013): A re-appraisal of the systematic status of selected genera in Palaemoninae (Crustacea: Decapoda: Palaemonidae). Zootaxa, 3734, 331-344. doi: 10.11646/zootaxa.3734.3.3

Guerao, G. & P. Abello (1996): Patterns of activity in the sympatric prawns *Palaemon adspersus* and *Processa edulis* (Decapoda, Caridea) from a shallow Mediterranean bay. Sci. Mar., 60(2-3), 319-324.

Guerao, G. & C. Ribera (1995): Growth and reproductive ecology of *Palaemon adspersus* (Decapoda, Palaemonidae) in the western Mediterranean. Ophelia, 43(3), 205-213.

Grbec, B., I. Vilibić, A. Bajić, M. Morović, G. Beg Paklar, F. Matić & V. Dadić (2007): Response of the Adriatic Sea to the atmospheric anomaly in 2003. Ann. Geophys., 25, 835-846.

Hagerman L. & J. Ostrup (1980): Seasonal and diel activity variations in the shrimp *Palaemon adspersus* from a brackish, non-tidal area. Mar. Ecol. Prog. Ser., 2, 329-335.

Holthuis, L.B. (1961): Report on a collection of Crustacea Decapoda and Stomatopoda from Turkey and the Balkans, Zool. Verh., 47, 1-67.

Janas U. & A. Baranska (2008): What is the diet of *Palaemon elegans* Rathke, 1837 (Crustacea, Decapoda), a non-indigenous species in the Gulf of Gdańsk (southern Baltic Sea)? Oceanologia, 50(2), 221-237.

Janas U., M. Piłka & D. Lipińska (2013): Temperature and salinity requirements of *Palaemon adspersus* Rathke, 1837 and *Palaemon elegans* Rathke, 1837. Do they explain the occurrence and expansion of prawns in the Baltic Sea? Mar. Biol. Res., 9, 293-300.

Jones, C. & S. Hallin (2010): Ecological and evolutionary factors underlying global and local assembly of denitrifier communities. ISME J., 4, 633-641. doi: 10.1038/ismej.2009.152.

Łapínska E. & A. Szaniawska (2006): Environmental preferences of *Crangon crangon* (linnaeus, 1758), *Palaemon adspersus* Rathke, 1837 and *Palaemon elegans* Rathke, 1837 in the littoral zone of the gulf of Gdánsk. Crustaceana, 79(6), 649-662.

Manent P. & J. Abella-Gutiérrez (2006): Population biology of *Palaemon adspersus* Rathke, 1837 (Decapoda, Caridea) in Fornells bay, Balearic Islands, Western Mediterranean. Crustaceana, 79(11), 1297-1308.

Manning R.B. & Z. Števčić **(1982):** Decapod fauna of Piran gulf. Quadern. Laboratoria Technologia di Pesca, 3(2-5), 285-304.

Özcan, T. & S.A. Ergüden (2013): New locality for grass shrimp, *Palaemonetes antennarius* (H. Milne-Edwards, 1837) (Decapoda: Palaemonidae) in the Seyhan river basin (Turkey). J. FisheriesSciences.com, 7(3), 266-270.

Plut, D. (1979): Geografske značilnosti poplavnega sveta ob Rižani in Badaševici. Geografski zbornik, XIX, 101–152.

Turk, T. & M. Richter (2007): Pod gladino Mediterana. Modrijan, Ljubljana, 590 pp.

Tzomos, T. H. & A. Koukouras (2015): Redescription of *Palaemon antennarius* H. Milne Edwards, 1837 and *Palaemon migratorius* (Heller, 1862) (Crustacea, Decapoda, Palaemonidae) and description of two new species of the genus from the circum-Mediterranean area. Zootaxa, 3905, 27-51. doi: 10.11646/zootaxa.3905.1.2

d'Udekem D'Acoz, C.D. (1999): Inventaire et Distribution des Crustacés Décapodes de l'Atlantique Nord-Oriental, de la Méditerranée et des Eaux Continentales Adjacentes au Nord de 25°N [Inventory and Distribution of Crustacea Decapoda in the Northeastern Atlantic Ocean, the Mediterranean Sea and Adjacent Continental Waters, North of 25°N]. Patrimoines Naturels (M.N.H.N./S.P.N.), 40, 1-383.