ISSN 1330–061X
CODEN RIBAEG

UDK:594.124(262.3 Pašmanski kanal)
Original scientific paper

DISTRIBUTION AND POPULATION STRUCTURE OF *Arca noae* IN THE PAŠMAN CHANNEL

M. Peharda, N. Stagličić, D. Ezgeta, N. Vrgoč, I. Isajlović, S. Krstulović–Šifner[1]

Summary

Noah's Ark shell *Arca noae* is an edible bivalve that is commercially exploited in the eastern Adriatic and is harvested primarily by SCUBA divers. There are no reliable data catch statistics data for this species nor there any data on distribution and population biology of exploited stocks, all of which are crucial for establishing sustainable level of exploitation. The objective of this research was to determine distribution and population structure of *A. noae* in one of the harvesting area — Pašman channel. Study was conducted in May 2008 using SCUBA visual census method at six transects. Although there are no previous data on distribution of *A. noae* in this area, low population density, length frequency distribution with domination of individuals smaller than 5 cm and sex ratio analysis all indicate that present level of harvesting is unsustainable.

Key words: Adriatic Sea, *Arca noae*, Pašman channel, population structure

INTRODUCTION

Arca noae Linnaeus 1758 is a commercially important bivalve that is distributed in the eastern Atlantic Ocean, the Mediterranean Sea, the Black Sea, and the West Indies (Nordsieck, 1969). It lives attached with solid byssus on rocks or shells, on all types of bottom that contain hard substrate, from the low tide to depths over 100 m and can grow up to 90 mm (Poppe and Goto, 2000).

In the Adriatic Sea, this species is widely distributed and locally common (Hrs–Brenko and Legac, 1996). Traditionally, harvesting sites of *A. noae* were along the western coast of Istria (Hrs–Brenko, 1980), around island

[1] Melita Peharda, Ph.D.; Nika Stagličić (Ph.D. student); Daria Ezgeta (Ph.D. student); Nedo Vrgoč, Ph.D.; Igor Isajlović (Ph.D. student); Svjetlana Krstulović–Šifner, Ph.D. Institute of Oceanography and Fisheries, Šetalište Ivana Meštrovića 63, 21000 Split, Croatia, Contact e–mail: melita@izor.hr

of Pag, in Pašman channel, Kaštela bay and Mali Ston Bay (Annonimus, 1939). Until the Second World War, *A. noae* constitute an important component of the diet of human population along the eastern Adriatic with annual catch rate of >600MT (Hrs–Brenko, 1979, 1980; Zavodnik, 1997). In the late 1940s, its fishery in this region collapsed due to catastrophic mortality caused by an unknown agent and until 1980s it did not fully recover (Hrs–Brenko, 1980).

Today, *A. noae* is besides warty venus (*Venus verrucosa*), Mediterranean scallop (*Pecten jacobaeus*), black mussel (*Mytilus galloprovincialis*), and European flat oyster (*Ostrea edulis*) one of major commercially exploited bivalves in the eastern Adriatic and is harvested primarily by SCUBA divers. Recently, several studies have been conducted concerning biology and ecology of this species in the Adriatic including its growth and age (Peharda et al., 2002A, 2003), population structure (Peharda et al., 2002B, 2003), condition index (Peharda et al., 2003), reproduction (Peharda et al., 2006), predation by *Hexaplex trunculus* (Peharda and Morton, 2006) and functional morphology (Morton and Peharda, 2008).

However, there are no reliable catch statistics data including catch quantities or number of people involved in its exploitation nor there is any data on distribution and population biology of exploited stocks all of which are crucial for establishing sustainable level of exploitation. Therefore, the objective of this research was to determine distribution and population structure of *A. noae* in one of the most important harvesting area — Pašman channel.

MATERIAL AND METHODS

Study of Noah's Ark shell distribution and population structure in Pašman channel was conducted in May 2008 using SCUBA. Distribution was assessed using visual census method at six transects set up to encompass area that was, according to local inhabitants and fisherman, most subjected to harvesting (Figure 1). Visual census transects were marked with a 100 m long rope, except on stations Muntan (Station 5) and western side of island of Babac (Station 3) where, due to unfavorable conditions (fast underwater currents) transects were shorter. Two SCUBA divers noted bivalves up to 1 m away from each side of transect. In order to analyze distribution of *A. noae* according to depth, each transect was divided in 1 m depth steps and total number of *A. noae* on each depth step of transect was determined. In addition, 453 specimens were collected on four stations (1–4) for laboratory analyses of population structure. In laboratory, length of each collected shell was measured using calipers and its sex determined by macroscopic observation of gonads according to Peharda et al. (2006), male gonads were white while those of females had orange–red coloration. Sex ratios were tested using chi–square goodness of fit test ($\chi 2$).

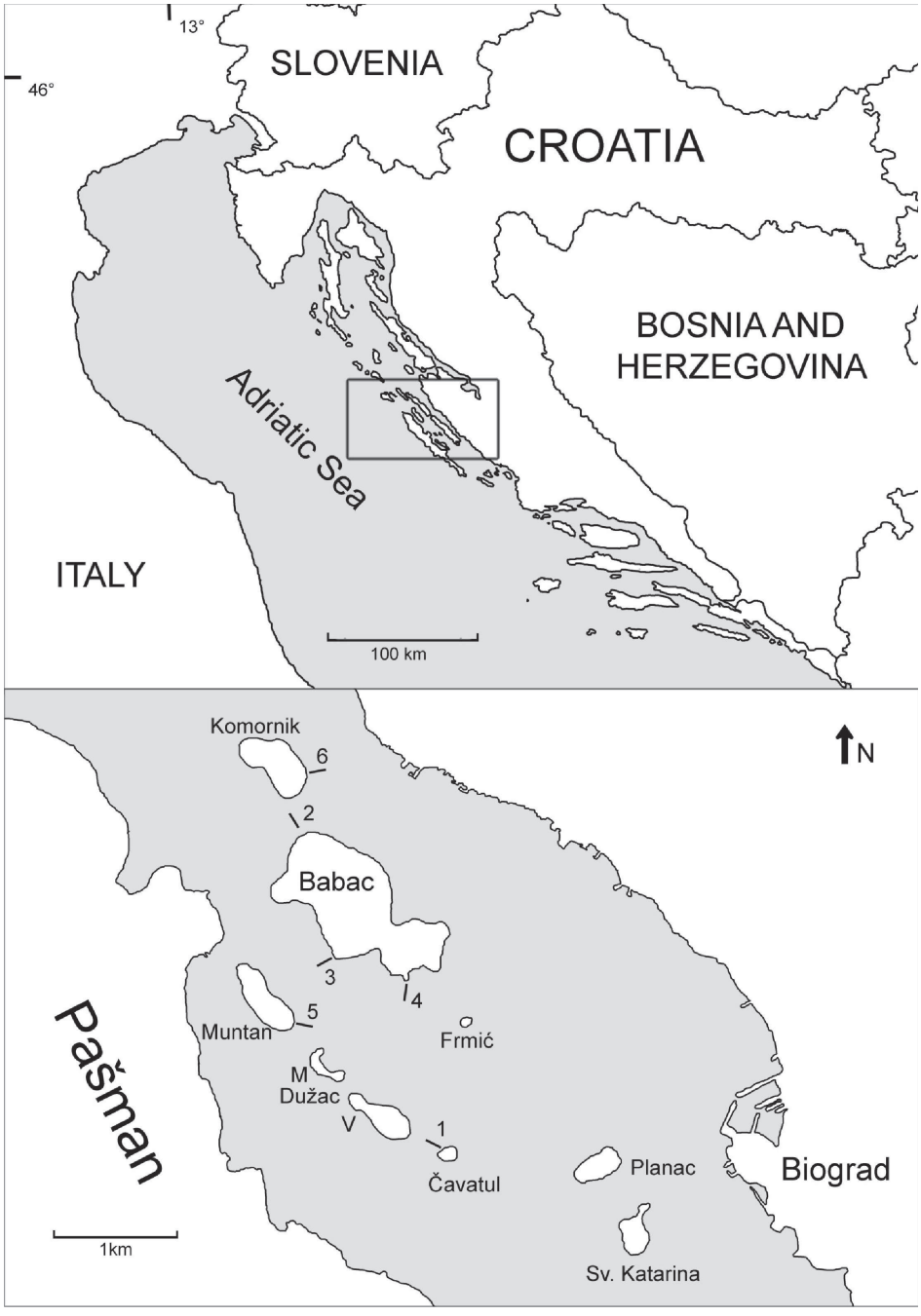

Figure 1. Map of Pašman channel with sampling transects
Slika 1. Karta Pašmanskog kanala s naznačenim profilima uzorkovanja

RESULTS AND DISCUSSION

Sampled area is characterized by degradation of substrate caused by extensive date shell, *Lithophaga lithophaga*, harvesting. Presence of sea grass communities was noted at two transects. At transect 4, *Cymodocea nodosa* meadow was observed at depths greater than 4 m, while at transect 3 dense sea meadow of *Posedonia oceanica* was observed at depths greater than 7.5 m. On all six visual census transects in Pašman channel *A. noae* specimens were found living attached to rocks as separate individuals. Only at few places small clumps of two to three individuals were observed.

Highest density of *Arca noae* in Pašman channel was recorded at depths between 8 and 10 m at transect 4 (Table 1), while density of over 1 ind/m^2 was noted only at two transects (3 and 4) at depths greater than 5 m. At other depths and transects surveyed, density of *A. noae* was significantly smaller or *A. noae* was not even present. In comparison, in a protected area of Mali Ston Bay, the highest *A. noae* density of up to 11.75 ind/m^2 was noted at depths from 4 to 5 m, while average density at ten visual census transects was 1.57 ind/m^2 (Peharda Uljević, 2003). In Malo jezero (Mljet National Park) in study conducted in 1998 and 1999, *A. noae* density of up to 13.14 ind/m^2 was recorded at depths from 5 to 10 m, while average density was 2.82 ind/m^2 (Peharda et al., 2002B).

Lengths of *A. noae* sampled in Pašman channel ranged from 13 mm to 85 mm (X= 43.68±12.83, N=453) (Figure 2). Over 74% of specimens collected in this area were smaller that minimal legal landing size of 50 mm (Official Gazette 101/2002). Further on, real length frequency of *A. noae* population in Pašman channel probably differs from the sampled one, since it was hard to sample smaller individuals that were observed attached in crevices of exposed *L. lithophaga* holes. This downside of SCUBA sampling of *A. noae* on hard bottom was also noted by Bello and Paparella (2001).

In Mali Ston Bay shell lengths of *A. noae* ranged from 6 to 80 mm (X= 45.04±13.68), and 61% of collected specimens were smaller than 50 mm (Peharda et al., 2003). Although mean shell length is similar to the one found in Pašman channel, length frequency histograms point out the difference in population structure between these two areas. In Mali Ston Bay, *A. noae* lives primarily in clumps, that is individuals are attached to each other (Peharda et al., 2003), what enables more representative sampling of smaller specimens. Similar clumping of *A. noae* was noted in Malo jezero (Mljet) where the largest *A. noae* clump consisted of 21 individuals with a mean group size of 3.68±3.31 individuals (Peharda et al., 2002B). Bello and Paparella (2001) noted significant differences in the length frequency distributions of *A. noae* at three sites in Bari region exposed to different harvesting and protection. In the Gulf of Manfredonia, where a dredge fishery is carried out on the bivalve beds, only small length classes (up to 25 mm) were well represented. Along Bari's coast, where arks are exploited by SCUBA–div-

Table 1. Density of Arca noae *on six visual census transects in Pašman channel (ind/m^2)*
Tablica 1. Gustoća naseljenosti školjkaša Arca noae *na šest profila u Pašmanskom kanalu (jed./m^2)*

Depth Dubina	Čavatul (1)	NW / SZ Babac (2)	W / Z Babac (3)	S / J Babac (4)	SE / JI Muntan (5)	NE / SI Komornik (6)
0–1	0	–	–	–	–	0
1–2	0	0.35	–	–	0.08	0.03
2–3	0.14	0.51	–	–	0	0
3–4	0.11	–	–	–	0	0.06
4–5	0	–	–	–	0.10	0.04
5–6	0	–	1.23	1.13	0.27	0.08
6–7	–	–	3.09	0.90	0.55	–
7–8	–	–	1.94	2.13	–	–
8–9	–	–	–	5.80	–	–
9–10	–	–	–	7.63	–	–

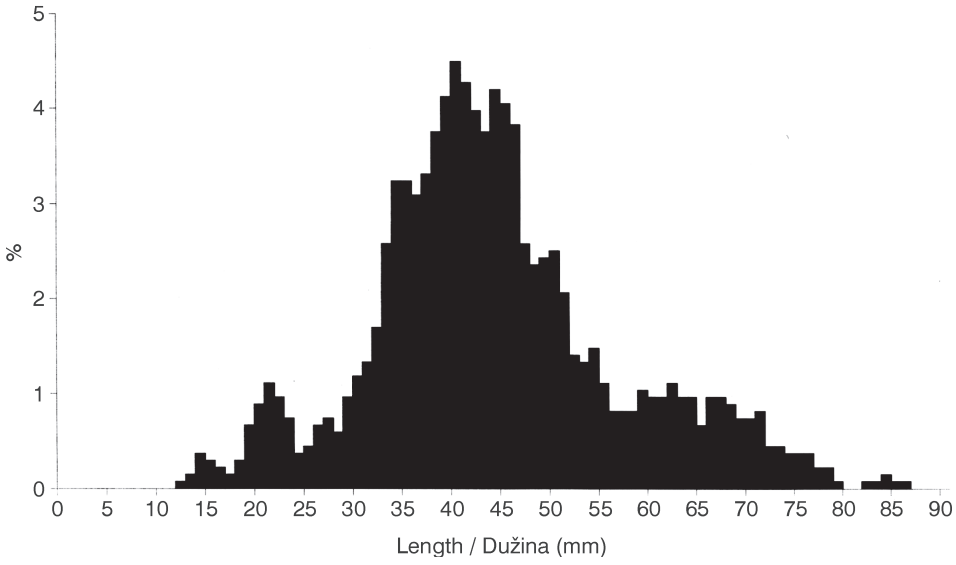

Figure 2. Length frequency histogram of Arca noae *population in Pašman channel*
Slika 2. Histogram dužinskih frekvencija populacije Arca noae *u Pašmanskom kanalu*

Table 2. The analysis of Arca noae *sex ratios according to shell length categories (χ^2 — chi–square goodness of fit test).*
Tablica 2. Analiza omjera spolova kod vrste Arca noae *ovisno o dužinskim kategorijama (χ^2 hi–kvadrat test)*

Shell Length (mm) Dužina ljušture (mm)	Male Mužjaci	Female Ženke	χ^2	p
<30	46	3	37.74	<0.001
30–39	109	25	52.66	<0.001
40–49	109	48	22.94	<0.001
50–59	24	31	0.89	0.345
>60	23	35	2.48	0.115
Total / Ukupno	311	142	37.22	<0.001

ing fishermen, the most represented length classes ranged from 40 to 65 mm, while in the Pinosa nature reserve *A. noae* ranged in length from 36 to 84 mm.

According to previous study, *A. noae* had one spawning peak that occurred in June and July in the Mali Ston Bay area (P e h a r d a et al., 2006). Therefore this research was conducted in May when individuals were assumed to be ripe thus enabling macroscopic sex determination. In this study males dominated smaller size categories (up to 50 mm), while at larger size categories there were no significant difference in number of males and females (Table 2). This situation is different than one found in Mali Ston Bay, where males dominated at lengths up to 40 mm, at lengths between 40 and 50 mm there was no difference in number of observed males and females, while females dominated sex–ratios in the largest size categories (P e h a r d a et al., 2006).

CONCLUSIONS

In the last decade an extensive exploitation of *A. noae* in Pašman channel by SCUBA divers has been taking place (B a v č e v i ć, pers. comm.). Although we have no previous data on distribution of *A. noae* in this area, low population density, length frequency distribution with domination of individuals smaller than 5 cm and sex ratio analysis all indicate that present level of harvesting is unsustainable. Absence of large females in Pašman channel caused by present level of exploitation coupled with relatively slow growth rates of this species (P e h a r d a et al., 2002A, 2003) can have negative long term effects on *A. noae* recruitment. In order to enable sustainable exploitation of *A. noae* in Pašman channel, and other areas of the Adriatic existing regulation measures need to be implemented and monitoring set up. Further on, alternative forms of regulation need to be considered such as concessions for harvesting in specific area.

ACKNOWLEDGEMENTS

This research was financed by AiA project through EC INTERREG funds and national research projects »Biodiversity and management of pelagic and demersal resources of the Adriatic Sea (001–0013077–0532)« supported by the Ministry of Science, Education and Sports of the Republic of Croatia.

Sažetak

RASPODJELA I SASTAV POPULACIJE KUNJKE *Arca noae* U PAŠMANSKOM KANALU

M. Peharda, N. Stagličić, D. Ezgeta, N. Vrgoč, I. Isajlović, S. Krstulović–Šifner[1]

Kunjka (*Arca noae*) jestivi je školjkaš koji se komercijalno sakuplja u istočnom dijelu Jadrana, primarno metodom autonomnog ronjenja. Nema pouzdanih statističkih podataka o sakupljanju ove vrste kao ni podataka o raspodjeli i sastavu populacija iskorištavanih »stokova«, što je nužno za uspostavu održive razine eksploatacije. Cilj je ovog istraživanja bio određivanje raspodjele i sastava populacije vrste *A. noae* u jednom od područja sakupljanja — Pašmanskom kanalu. Istraživanje je provedeno u svibnju 2008. godine metodom vizualnog cenzusa na šest profila autonomnog ronjenja. Iako nema prethodnih podataka o raspodjeli vrste *A. noae* na ovom području, niska gustoća naseljenosti, histogram dužinskih frekvencija na kojem prevladavaju jedinke manje od 5 cm i omjer spolova upućuju na to da je postojeća razina eksploatacije neodrživa.

Ključne riječi: Jadransko more, *Arca noae*, Pašmanski kanal, sastav populacije

LITERATURE

Annonimus (1939): Statistika morskog ribarstva — godina 1938. Kraljevina Jugoslavija, Hrvatska štamparija, Split, 174 pp.

Bello, G., Paparella, P. (2001): Struttura di popolazioni di *Arca noae* (Bivalvia, Arcidae) insediate su sustrati diversi nell'Adriatico meridionale. Atti Soc. it. Sci. nat. Museo civ. Stor. nat. Milano, 141/2000 (II), 175–185.

---

[1] Doc. dr. sc. Melita Peharda; Nika Stagličić, dipl. ing.; Daria Ezgeta, dipl. ing.; doc. dr. sc. Nedo Vrgoč; Igor Isajlović, prof., dr. sc. Svjetlana Krstulović–Šifner, Institut za oceanografiju i ribarstvo, Šetalište Ivana Meštrovića 63, 21000 Split, kontakt e–mail: melita@izor.hr

Hrs–Brenko, M. (1979): Shellfish as food: the natural populations of edible shellfish in the Adriatic Sea. Prehrambeno–tehnološka revija, 17, 125–130.

Hrs–Brenko, M. (1980): Preliminary survey of populations of the bivalve Noah's Ark (*Arca noae*, Linne) in the northern Adriatic Sea. Aquaculture, 21, 357–363.

Hrs–Brenko, M., Legac, M. (1996): A review of bivalve species in the eastern Adriatic Sea: II. Pteromorphia (*Arcidae* and *Noetidae*). Natura Croatica, 5, 221–247.

Morton, B., Peharda, M. (2008): The biology and functional morphology of *Arca noae* (Bivalvia: Arcidae) from the Adriatic Sea, Croatia, with a discussion on the evolution of the bivalve mantle margin. Acta Zoologica, 89, (1), 19–28.

Nordsieck, F. (1969): Die europäischen Meeresmuscheln (Bivalvia). Stuttgart: Fischer Verlag, 256 pp.

Official Gazette (101/2002) Naredba o zaštiti riba i drugih morskih organizama.

Peharda, M., Bolotin, J., Vrgoč, N., Jasprica, N., Bratoš, A., Skaramuca, B. (2003): A study of the Noah's ark shell (*Arca noae* Linnaeus 1758) in Mali Ston bay, Adriatic Sea. Journal of Shellfish Research, 22, (3), 705–709.

Peharda, M., Hrs–Brenko, M., Onofri, V., Lučić, D., Benović, A. (2002B): A visual census of bivalve distribution in the saltwater lake Malo jezero (Mljet National Park, South Adriatic Sea). Acta Adriatica, 43, (1), 65–75.

Peharda, M., Mladineo, I., Bolotin, J., Kekez, L., Skaramuca, B. (2006): The reproductive cycle and potential protoandric development of the Noah's Ark shell, *Arca noae* L.: Implications for aquaculture. Aquaculture, 252, (2–4), 317–327.

Peharda, M., Morton, B. (2006): Experimental prey species preference of *Hexaplex trunculus* (Gastropoda: Muricidae) and predator–prey interactions with the Black mussel *Mytilus galloprovincialis* (Bivalvia: Mytilidae). Marine Biology, 148, 1011–1019.

Peharda, M., Richardson, C.A., Onofri, V., Bratoš, A., Crnčević, M. (2002A): Age and growth of the bivalve *Arca noae* L. in the Croatian Adraitic Sea. Journal of Molluscan Studies, 68, 307–310.

Peharda Uljević, M. (2003): Rasprostranjenost i sastav prirodnih populacija školjkaša (Mollusca, Bivalvia) u Malostonskom zaljevu. Doktorska disertacija. Sveučilište u Zagrebu, Prirodoslovno–matematički fakultet, 112 pp.

Poppe, G.T., Goto, Y. (2000): European seashells Voll. II Scaphopoda, Bivalvia, Cephalopoda. Conch Books, 221 pp.

Zavodnik, D. (1997): Nekonvencionalni izvori hrane iz mora na tržištu istočnog Jadrana. pp. 637–656. In: B. Finka (ed). Tisuću godina prvog spomena ribarstva u Hrvata. Hrvatska akademija znanosti i umjetnosti, Zagreb, Hrvatska, 692 pp.

Received: 2. 10. 2008.
Accepted: 25. 3. 2009.