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SOME PRELIMINARY DATA ON BIOLOGICAL ASPECTS OF THE MUSKY OCTOPUS, *Eledone moschata* (LAMARCK, 1798) (CEPHALOPODA: OCTOPODIDAE) IN MONTENEGRIN WATERS

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ABSTRACT

Some biological aspects of *E. moschata* are presented in this paper — length frequency distribution, length–weight relationship, length at 50% maturity and gonadosomatic index (GSI). A total of 173 individuals were examined: 83 males, 88 females and 2 of undetermined sex. The samples were collected during 2009 and 2010 from commercial trawlers. Length–weight relationship calculated for the whole sample, for each sex individually and by season showed relatively low allometric growth ($b < 3$). The length at 50% maturity showed that males mature at smaller mantle lengths than females. Compared to males, the GSI of females showed greater variations.

KEY WORDS: Musky octopus, *Eledone moschata*, biological aspects, Montenegrin waters

INTRODUCTION

The musky octopus, *Eledone moschata* (Lamarck, 1798) (Cephalopoda: Octopodidae), is an octopod species found in the entire Mediterranean Sea, including the Adriatic, and spreading as far as the southern coast of Portugal, west coast of Gibraltar, and the Gulf of Cádiz in the Atlantic Ocean (Roper *et al.*, 1984; Belcari & Sbrana, 1999). In Montenegrin waters (south–eastern Adriatic) it is found in the more shallow littoral region, mostly at depths down to 80 m, only rarely and in small number down to 100 m (Mandić & Stjepčević, 1982; Mandić, 1984; Pastorelli e*t al.*, 1998; Vrgoč *et al.*, 2004). *E. moschata* is one of the most important cephalopod species in Adriatic fisheries. According to Mandić (1984), *E. moschata* makes up to 19.93% of the biomass in the entire cephalopod catch, in Montenegrin waters. In Italian fisheries in south Adriatic, the species made about 50% of the entire cephalopod catch (Pastorelli *et al.*, 1995 and 1998, Vrgoč *et al.*, 2004).

E. moschata is a commercial species fished throughout the Mediterranean and Adriatic, mainly with bottom trawls (Belcari & Sbrana, 1999, Vrgoč *et al.*, 2004).

The biological characteristics of the species were described in several areas of the Mediterranean: Catalan Sea (Mangold–Wirz, 1963; Mangold, 1983), Gulf of Gabes (Ezzedine–Najai, 1997), Gulf of Cádiz (Silva *et al*., 2004), the Aegean Sea (Önsoy & Salman, 2004; Akyol *et al*., 2007), and the Adriatic (Krstulović Šifner, 2004; Krstulović Šifner & Vrgoč, 2009).

MATERIAL AND METHODS

The research was performed on 173 individuals from samples collected during 2009 and 2010. All specimens were caught with bottom trawl of the Mediterranean ("tartana") type, with a 40 mm diamond mesh cod end. The

samples were obtained from 12 hauls by commercial trawlers in period between April 2009 and June 2010, in Montenegrin waters (south–east Adriatic) (Fig. 1). Specimens were kept frozen before further examination in the laboratory.

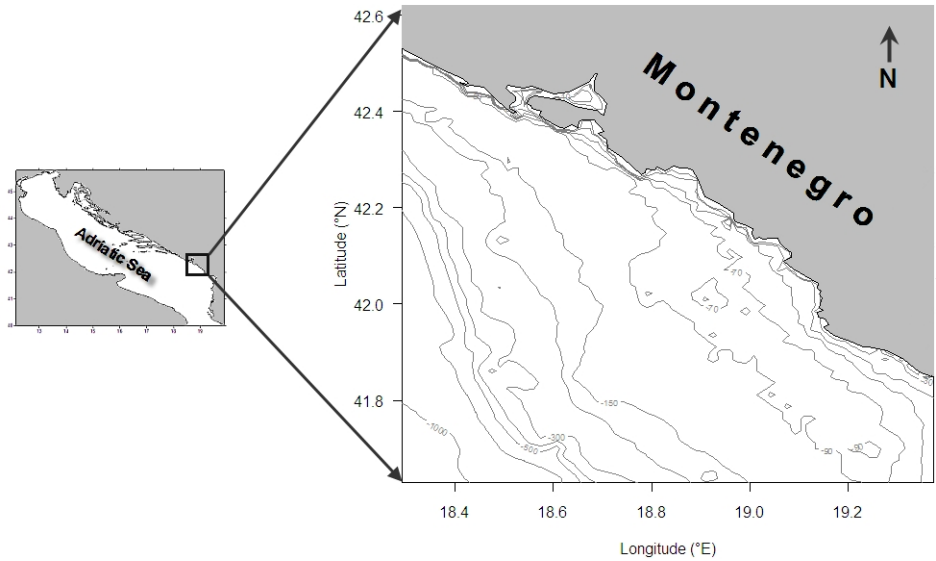

Figure 1. Study area in Montenegrin waters (south–east Adriatic)

Mantle length (ML) was measured laterally, to the nearest mm. For purposes of length frequency distribution (LFD), samples were grouped in length categories rounded to the nearest 5 mm interval. Weight was measured on a high–precision (0.01 g) electronic balance Sartorius Extend ED4202S.

Gonad maturity stages were determined according to the MEDITS codes for sexual maturity, with MEDITS stages 2B and 3 being considered mature for purposes of length at maturity determination.

Length–weight relationship was calculated according to the formula $W = a \cdot L^b$. Parameters a and b were estimated using ordinary least–square regression after transforming the data in common logarithms to base 10

($\log W = \log a + b \cdot \log L$) (Huxley, 1924; Jensen, 1986). Statistical significance level of b compared to 3 was tested using Student's t–test.

Pearson's goodness–of–fit χ^2–test was used to test whether the length frequency distribution followed the normal distribution curve, and the χ^2–test was used to determine whether there was any significant difference between the number of males and females. Both tests were done using the R environment for statistical computing. Single–factor analysis of variance (ANOVA) was done to see whether there was any significant difference in mantle length variances of males and females.

Sex–ratio was given as a proportion of females in the sample, according to the formula:

$$SR = \frac{N_f}{N_f + N_m} \cdot 100 .$$

The aim of this paper is to provide new biological data on *E. moschata* in the south Adriatic region. As there has been no research in Montenegrin waters dedicated to cephalopods since 1984, all studies on this group of marine organisms, especially on commercially important species as *E. moschata*, are very important as they help in further understanding of their complex biology and also provide some valuable information important for the management of the Montenegrin fisheries.

RESULTS AND DISCUSSION

A sample of 173 individuals was analysed, out of which 83 (48%) were males, 88 (50.9%) were females, and 2 (1.2%) specimens were of undetermined sex. The χ^2–test showed that there was no significant difference between the number of males and females ($\chi^2 = 0.212$, $p = 0.6454$). The total sample of sexed specimens consisted of 101 (59.1%) immature or maturing

individuals and 70 (40.9%) mature individuals. Of the total number of females, 72 (81.8%) were immature or maturing and 16 (18.2%) were mature, while 29 (35%) of males were immature and 54 (65.1%) were mature (Fig. 2). There were no specimens in the post–spawning (spent) stage.

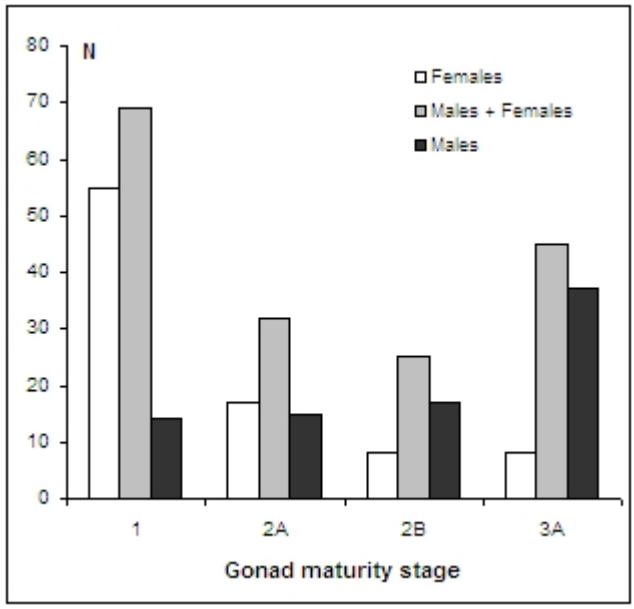

Figure 2. Gonad maturity stages of the *E. moschata*, for males, females and both sexes together

Pearson's goodness–of–fit χ^2–test showed that length frequency distribution for both males and females followed the normal distribution curve ($P_{♂} = 7.0723$, $p_{♂} = 0.6296$; $P_{♀} = 6.9091$, $p_{♀} = 0.6466$). Females had a minimum mantle length of 40 mm, a maximum at 116 mm, with the average length of 77.7 mm. The minimum mantle length for males was 52 mm, and the maximum was 117 mm, with the average mantle length of 80.5 mm. The median value for both males and females was very close to the average ($\mu_{½♂} = 8.1$, $\mu_{½♀} = 7.7$) (Fig. 3). A single–factor analysis of variance (ANOVA)

showed that there was no significant statistical difference between length frequency distributions of males and females ($F = 2.0405$, $F_{crit} = 3.8971$).

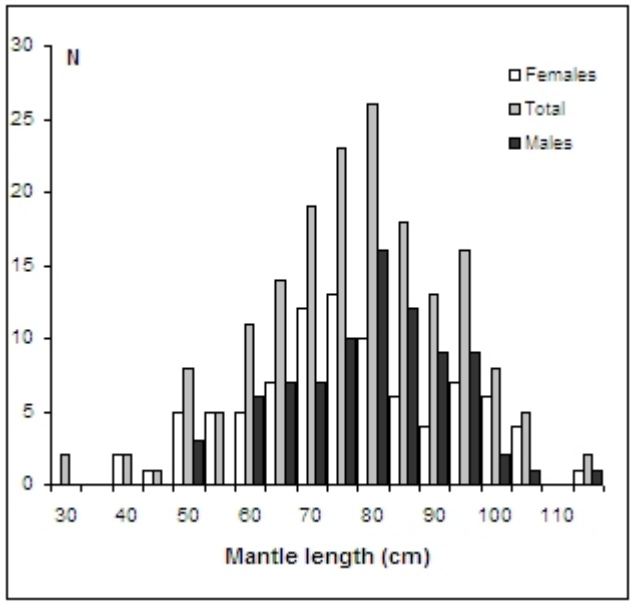

Figure 3. Length frequency distribution of males, females and individuals of undetermined sex

The length–weight relationship showed that allometric exponents were $b_{♂} = 2.4708$ for males, $b_{♀} = 2.2291$ for females and $b_{TOT} = 2.3551$ for both sexes together (Fig. 4). Parameters of the length–weight relationships for the entire sample and for each sex, as well as those of immature and mature/maturing individual and for each sex by season are shown in Table 1. In all cases b was significantly different from 3 ($t < 0.01$) indicating relatively slow allometric increase in weight.. These results are somewhat lower compared to those from the central and northern Adriatic reported by Krstulović Šifner (2004), Krstulović Šifner and Vrgoč (2009) ($b_{♂} = 2.7656$, $b_{♀} = 2.6644$, $b_{TOT} = 2.7152$), Merella (*et al.*, 2007) in western Mediterranean ($b = 2.9100$), and Silva (*et al.*, 2004) in Gulf of Cádiz ($b_{♂} = 2.794$, $b_{♀} = 2.660$, $b_{TOT} = 2.702$). Forsythe and

Van Heukelem (1987) report a significantly higher *b* value for both sexes together ($b = 3.04$) in the Mediterranean. However, the obtained results are very similar to those reported by Marano (1993) and Vrgoč (*et al.*, 2004) ($a = 0.8580$, $b = 2.3890$) from the south Adriatic.

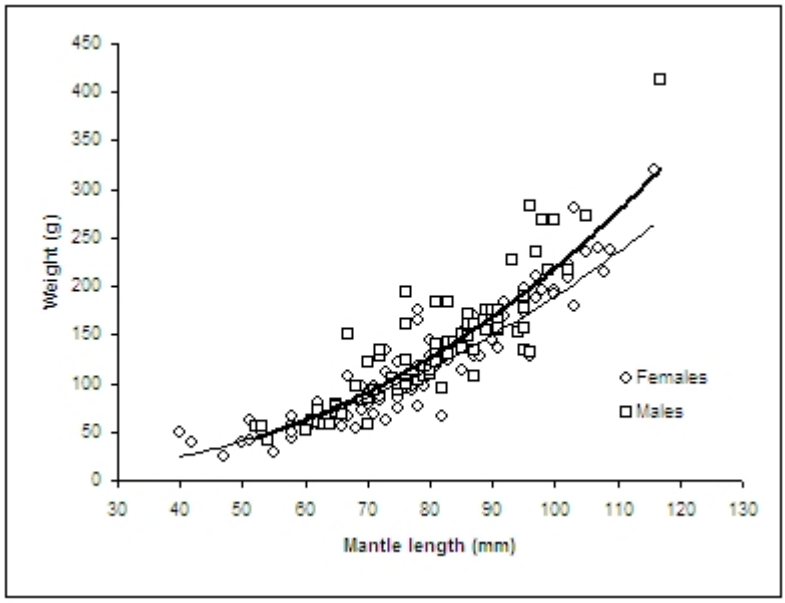

Figure 4. Length–weight relationship of *E. moschata* males and females

Table 1. Length–weight relationships of *E. moschata* from Montenegrin waters by sex in the total sample and by season and maturity stage (immature and maturing/mature): Imm, immature; Mat, maturing/mature; N, number of individuals; ML, mean mantle length; σ, standard deviation; R^2, correlation coefficient; a and b, parameters; S, significance level of b compared to 3 (* – P<0.05; ** – P<0.01; ns – not significant)

Sex	N	ML range (mm)	ML±σ (mm)	BW range (g)	BW±σ (g)	R^2	*a*	*b*	S†
♂	83	52–117	80.58±12.93	41.59–412.54	137.97±63.85	0.8074	0.0027	2.4558	**
♀	88	40–116	77.68±16.57	23.98–319.9	117.92±61.53	0.8459	0.0066	2.2291	**
Tot	171	33–117	78.70±15.60	12.22–412.54	126.69±63.13	0.8291	0.0044	2.3300	**
Imm	70	40–103	68.80±12.54	23.98–170.73	82.99±34.43	0.7237	2.0050	1.9031	**
Mat	103	58–117	86.32±18.82	59.1–412.54	59.10±412.54	0.7674	1.1505	2.2655	**
Spring									
♂	25	52–99	81.04±12.94	41.59–283.63	137.44±62.40	0.7968	0.7655	2.4479	**
♀	20	53–116	81.70±17.83	43.64–319.9	123.01±77.11	0.8474	0.5654	2.5081	**
Summer									
♂	22	53–117	81.59±15.63	50.88–412.54	159.56±82.99	0.8311	0.8121	2.4767	**
♀	19	42–108	77.53±21.11	23.98–279.86	125.76±78.01	0.9026	0.6778	2.4808	**
Autumn									
♂	17	61–91	74.65±9.87	58.62–158.63	101.51±33.83	0.9123	0.7531	2.4230	**
♀	26	40–107	71.04±13.67	39.98–239.03	96.81±43.08	0.7686	2.9150	1.7613	**
Winter									
♂	17	65–102	85.00±9.29	75.96–215.96	146.10±37.60	0.7444	1.3470	2.1792	**
♀	16	76–100	88.13±7.56	94.76–209.69	153.08±32.59	0.8200	1.0581	2.2796	**

Length at which 50% of the population reaches maturity ($ML_{50\%}$) was calculated at 72 mm ML for males, 95 mm for females, and 87 mm for both sexes (Figs. 5, 6, 7). Krstulović Šifner and Vrgoč (2009) reported identical length at 50% maturity for females ($ML_{50\%♀}$ = 95 mm) in northern and central Adriatic, but their value for males is somewhat higher ($ML_{50\%♂}$ = 85 mm). Krstulović Šifner (2004), on the other hand, gives similar value for males ($ML_{50\%♂}$ = 75 mm), and a lower value for females ($ML_{50\%♀}$ = 85 mm), also in

northern and central Adriatic. Soro and Piccinetti Manfrin (1989) reported mantle length at first sexual maturity for females in Adriatic at 90 mm (Vrgoč *et al*., 2004). Mantle lengths at which 25% ($ML_{25\%}$) and 75% ($ML_{75\%}$) of the species reach maturity are given in Table 2, along with relevant logistic curve parameters. Observed values of both males and females fit the expected values ogive, while those of both sexes together differ somewhat from the predicted values.

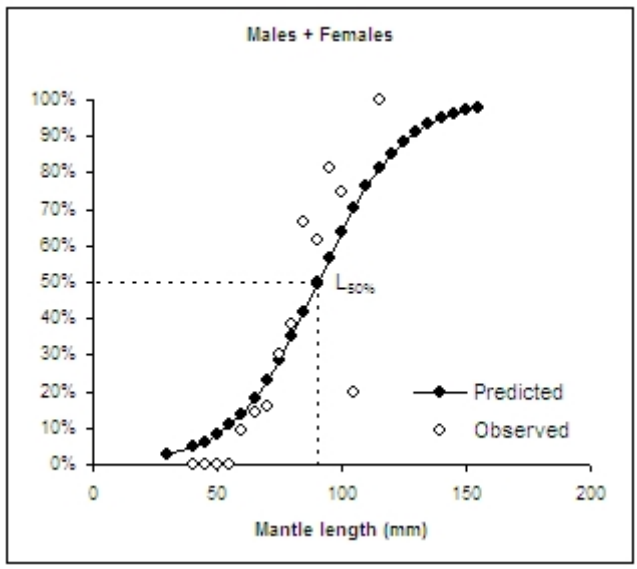

Figure 5. Length at 50% of maturity for *E. moschata* males

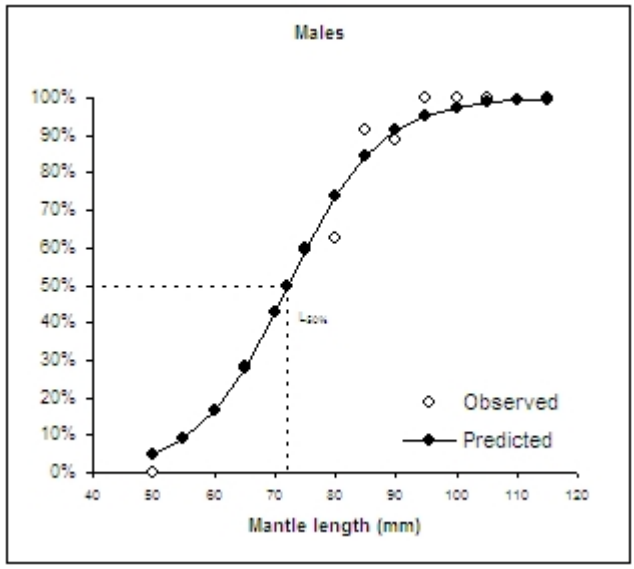

Figure 6. Length at 50% of maturity for *E. moschata* females

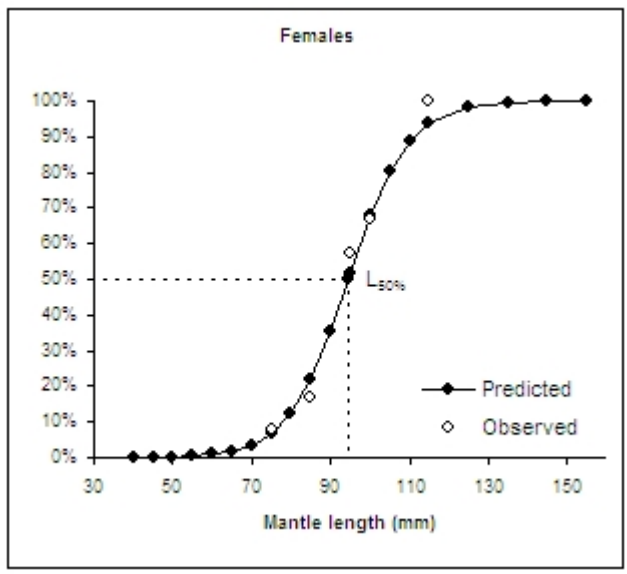

Figure 7. Length at 50% of maturity for *E. moschata* for both sexes together

Table 2. Length at 25, 50 and 75% maturity, by sex in the total sample (R^2, correlation coefficient; a and b, parameters)

Sex	$ML_{25\%}$	$ML_{50\%}$	$ML_{75\%}$	R^2	a	b
♂	64	72	81	0.9352	9.5390	0.1321
♀	86	95	103	0.9740	12.7639	0.1350
♂+♀	72	87	102	0.7972	6.4764	0.0742

Gonadosomatic index (GSI) of females showed an increase in the spring–summer period, then a steep drop in the summer–autumn period when it reached its lowest point, followed by a recovery in autumn–winter. The GSI of males drops slightly through spring and summer, reaching the minimum in autumn (Fig. 8). This differs from reports by other authors (Krstulović Šifner, 2004; Krstulović Šifner and Vrgoč, 2009), who reported the highest GSI values for the northern and central Adriatic area in late winter and early spring, and the lowest values in summer, for both sexes.

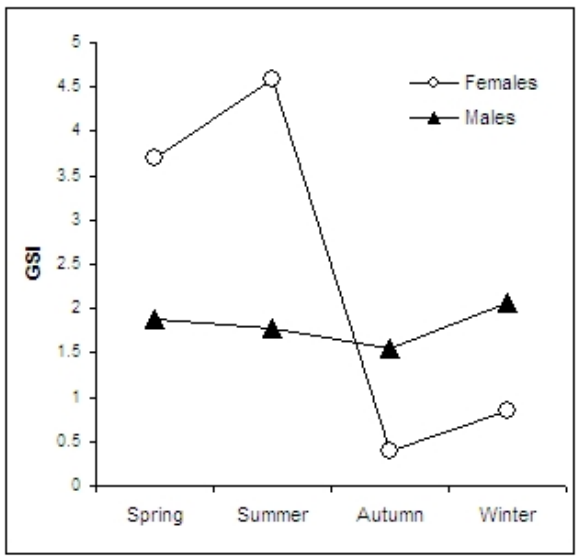

Figure 8. Gonadosomatic index (GSI) for *E. moschata* males and females

CONCLUSION

There is still much to be learned about the biology of *E. moschata* in Montenegrin waters. The data presented in this paper differ in some aspects from data presented by various authors for this species. This could be due to the relatively small number of specimens examined in this research, but it could also be attributed to the regional specificities of the population inhabiting the south–eastern Adriatic. Whatever the explanation, further and more detailed studies on the species are required to confirm the results obtained.

ACKNOWLEDGMENTS

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REFERENCES

Akyol, O., H. Şen and H. T. Kinacigil (2007): Reproductive biology of *Eledone moschata* (Cephalopoda: Octopodidae) in the Aegean Sea (Izmir Bay, Turkey). J. Mar. Biol. Ass., 87: 967–970.

Belcari P. and M. Sbrana (1999): *Eledone moschata*. *In:* Relini, G., Bertrand, J., Zamboni, A. *Eds.* Synthesis of the knowledge on bottom fishery resources in Central Mediterranean (Italy and Corsica). Biol. Mar. Medit., 6 (suppl. 1).

Ezzedine–Najai, S. (1997): Sexual maturation in *Eledone moschata* (Cephalopoda, Octopoda) from the gulf of Gabes (Tunisia, eastern Mediterranean). Vie Milieu, 47(1): 69–76.

Forsythe, J. W. and W. F. Van Heukelem (1983): Growth. *In:* Boyle, P. R. *Ed.* Cephalopod life cycles, Vol. 2, Comparative reviews. Academic Press. 137–157 pp.

Huxley, J. S. (1924): Constant differential growth–ratios and their significance. Nature. London. 114. 895 pp.

Jensen, A. L. (1986): Functional regression and correlation analysis. Can. J. Fish. Aquat. Sci. 43: 1742–1745.

Krstulović Šifner, S. (2004): Dinamika populacija crnog muzgavca, *Eledone moschata* (Lamarck, 1798), u Jadranskom moru, Ph.D. Thesis, Univ. Zagreb, 180 pp.

Krstulović Šifner, S. and N. Vrgoč (2009): Reproductive cycle and sexual maturation of the musky octopus *Eledone moschata* (Cephalopoda: Octopodidae) in the northern and central Adriatic Sea, Sci. Mar. 73(3): 439–447.

Mandić, S. (1984): Cephalopoda južnog Jadrana. Stud. Mar. 15–16: 3–176.

Mandić, S., J. Stjepčević and R. Dragović (1982): Pojave migracija kod nekih vrsta cephalopoda u južnom Jadranu, Stud. Mar. 11–12: 95–102.

Mangold, K. (1983): *Eledone moschata*. *In:* Boyle, P. R. *Ed.* Cephalopod life cycles, Vol. 1. Species Accounts. Academic Press. 387–400 pp.

Mangold–Wirz, K. (1963): Biologie des Cephalopods bentiques et nectonique de la Mer Catalane. Vie Milieu, 13: 83–91.

Marano, G. *Ed* (1993): Valutazione delle risorse demersali dell'Adriatico meridionale dal promotorio del Gargano al capo d'Otranto: Relazione finale triennio '90–'93. Min. Mar. Mer., Roma

Merella, P., A. Quetglas, F. Alemany and A. Carbonell (1997): Length–weight relationship of fishes and cephalopods from the Balearic Islands (western Mediterranean). Naga ICLARM Q. 20(3/4):66-68.

Önsoy, B. and A. Salman (2004): Reproduction Patterns of the Mediterranean endemic, *Eledone moschata* (Lamarck, 1798) (Octopoda: Cephalopoda) in the Eastern Mediterranean. Turk. J. Aquat. Life, 2(2): 55–60.

Pastorelli, A. M., R. Vaccarella and V. de Zio (1995): Distribuzione dei cefalopodi commerciali nel basso Adriatico. Biol. Mar. Medit., 2(2): 501–502

Pastorelli, A. M., R. Vaccarella and V. de Zio (1998): Valutazione delle risorse demerzali nel basso Adriatico pugliese (1990–1995): Cefalopodi. Biol. Mar. Medit., 5 (2): 326–335.

Silva, L., F. Ramos and I. Sobrino (2004): Reproductive biology of *Eledone moschata* (Cephalopoda: Octopodidae) in the Gulf of Cádiz (south-

western Spain, ICES Division IXa). J. Mar. Biol. Ass. U.K., 84: 1221–1226.

Soro, S. and G. Piccinetti Manfrin (1989): Biologia e pesca di Cefalopodi in Adriatico. Nova Thalassia, 10(1): 493–498.

Vrgoč, N., E. Arneri, S. Jukić–Peladić, S. Krstulović Šifner, P. Mannini, B. Marčeta, K. Osmani, C. Piccinetti and N. Ungaro (2004): Review of current knowledge on shared demersal stocks of the Adriatic Sea. FAO–MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GSP/RER/010/ITA/TD–12. AdriaMed Tech. Doc., 12: 91 pp.