

## Age, growth and length–weight relationship of *Coelorinchus caelorhincus* (Risso, 1810) in the Adriatic Sea

Igor ISAJLOVIĆ<sup>1\*</sup>, Nedo VRGOČ<sup>1</sup>, Barbara ZORICA<sup>1</sup>, Melita PEHARDA<sup>1</sup>,  
Svjetlana KRSTULOVIĆ ŠIFNER<sup>2</sup> and Corrado PICCINETTI<sup>3</sup>

<sup>1</sup> *Institute of Oceanography and Fisheries, P.O. Box 500, 21000 Split, Croatia*

\* *Corresponding author, e-mail: igor@izor.hr*

<sup>2</sup> *University of Split, Center for Marine Studies, Livanjska 5, 21000 Split, Croatia*

<sup>3</sup> *Laboratory of Marine Biology and Fisheries, University of Bologna, Viale Adriatico 1/N  
61032- Fano (PU), Italy*

*Samples of Coelorinchus caelorhincus were collected by bottom trawl during MEDITS ("Mediterranean International Trawl Survey") in June 2003 in the northern and central Adriatic Sea. A total of 175 specimens of C. caelorhincus were used for analysis, of which 90 were males, 84 females and 1 indeterminate. Pre-anal length (PAL) in males ranged between 39 and 77 mm ( $\bar{x}=50.91\pm 7.63$  mm) and in females between 29 and 115 mm ( $\bar{x}=55.86\pm 16.3$  mm). The length-weight relationship for the whole sample was  $W=0.0004PAL^{2.65}$  ( $r^2=0.922$ ) indicating negative allometric growth. The age structure of C. caelorhincus was determined from sagittal otolith readings. Maximum otolith length (LO) increased proportionally to fish length ( $LO=2.585+0.09PAL$ ,  $r^2=0.946$ ). Age ranged from 2 to 8 years, with the majority of specimens being 3 (30%) and 4 (31%) years old. The von Bertalanffy growth parameters were:  $L_\infty = 128$  mm,  $K = 0.105$  year<sup>-1</sup> and  $t_0 = -1.277$  year.*

**Key words:** age, growth, length-weight relationship, *C. caelorhincus*, Adriatic Sea

### INTRODUCTION

The hollowsnout grenadier *Coelorinchus caelorhincus* (Risso, 1810) is a non-commercial benthopelagic fish found at depths between 90 and 1250 m (REINER, 1996), though usually inhabiting muddy bottoms of the continental slopes between 200 and 500 m (COHEN *et al.*, 1990). Its distribution is wide, from the Mediterranean northward to southern Norway and across to the Shetlands, the Faroes, off southern Iceland and south-eastern Greenland (FILIZ *et al.*, 2006). In the Adriatic Sea, *C. caelorhincus* is

found in the Jabuka and South Adriatic pits and is mainly caught with deep sea bottom trawls as by-catch (JARDAS, 1996).

Investigation of the deep sea fauna of the Adriatic Sea had not been conducted systematically until recently, and data from the commercial fishery and from official statistics are also lacking because deep-sea areas are not major fishing grounds. Therefore, detailed knowledge about biological characteristics of these organisms is very limited. In this paper we provide the first information about age, growth and length–weight relationship of *C. caelorhincus*

in the Adriatic Sea and compare these aspects of the species' biology with those of populations from other areas in the Mediterranean and the Atlantic.

## MATERIALS AND METHODS

The samples of *C. caelorhincus* were collected during the MEDITS expedition in June 2003 in the central and northern Adriatic Sea (Fig. 1) using a bottom trawl net GOC 73 specially designed for MEDITS surveys; see BERTRAND (1995) and BERTRAND *et al.* (2002) for a detailed description on the survey, gear design and sampling scheme. The trawling depth of the fishing ground of the entire expedition in the north and central Adriatic Sea ranged from 14 to 623 m.

A total of 175 specimens of *C. caelorhincus* were caught. All specimens were measured (to the nearest mm in length), weighed (to the nearest g in wet mass), and dissected for macroscopic determination of sex. The length-weight

relationship was determined using the power function

$$W = aPAL^b$$

where  $W$  is the fish weight (g) and  $PAL$  is the pre-anal length (mm). The hypothesis of isometric growth (i.e.  $b=3$ ) was tested by Student's  $t$ -test.

Both sagittal otoliths were collected, washed in freshwater, dried and stored in plastic tubes prior to ageing. The maximum length and width of undamaged otoliths were measured to the nearest 0.1 mm in order to describe the shape of the sagitta. The aspect ratio ( $A_R$ ), as one dimensionless shape factor, was calculated (PONTON, 2006) as:

$$A_R = LO \cdot W^{-1}$$

This factor is a simple proxy of the compactness of the sagitta; the more elongated the otolith, the larger the aspect ratio is. The relation-

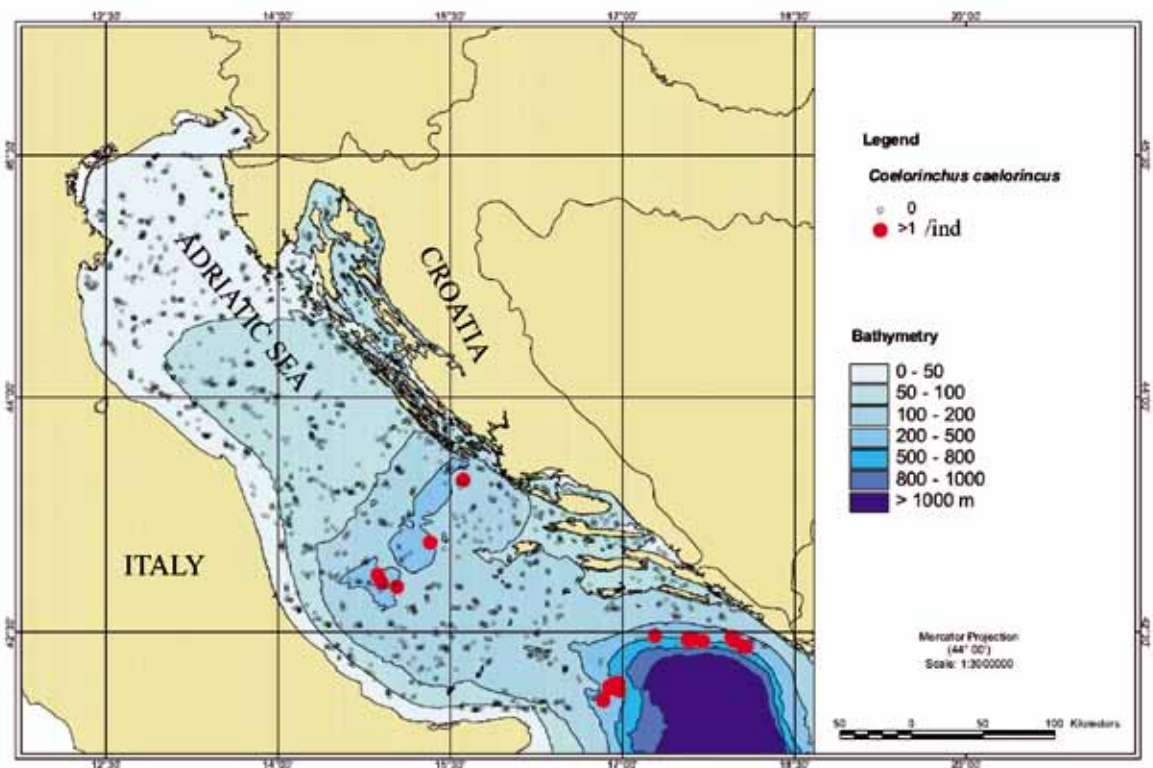


Fig. 1. Bathymetry of the Adriatic Sea and distribution of all sampling hauls and hauls with catches of *Coelorinchus caelorhincus* during MEDITS 2003 survey

ship between the pre-anal length of the fish and otolith length was estimated from a least squares linear regression model. The outer concave face of the otolith was ground and polished until the core was reached; the otolith was then immersed in glycerine and observed under reflected light against a dark background with the acoustic sulcus facing downwards. The lowest magnification (1.6x) of an Olympus SZX12 binocular microscope was used. The translucent zones (appearing dark in reflected light) were considered as annuli and counted for age estimation according to LABROPOULOU & PAPACONSTANTINO (2000). Two readers read otoliths independently and blind on the major axis of the proximal surface on two occasions, approximately two months apart. Otoliths (N=6), whose two readings differed because of false rings, were considered as unreadable and were rejected. A von Bertalanffy growth model was fitted to the age and length data of all readable otoliths (n=169):

$$L_t = L_\infty (1 - e^{-K(t-t_0)})$$

where  $L_t$  is pre-anal length (mm) at age  $t$ ,  $L_\infty$  the asymptotic length (mm),  $K$  the growth coefficient ( $\text{years}^{-1}$ ), and  $t_0$  the theoretical age at zero length (years). The growth performance index phi-prime ( $\phi'$ ) was estimated to compare the growth parameters obtained in this paper with those reported by other authors. This index was calculated by the equation:

$$\phi' = \log K + 2\log L_\infty \text{ (MUNRO \& PAULY, 1983).}$$

Longevity was calculated using TAYLOR'S (1958) equation:

$$t_{max} = \frac{3}{k}$$

where  $t_{max}$  is the longevity (maximum age reached by the species).

## RESULTS AND DISCUSSION

Pre-anal length (PAL) of 175 analysed specimens of *C. caelorhincus* collected during the

survey ranged from 29 to 115 mm, most frequently from 41 to 54 mm (mean  $53.28 \pm 12.80$  mm) (Fig. 2). PAL of males (N=90) ranged from 39 to 77 mm (mean  $50.91 \pm 7.63$  mm), while for females (N=84) ranged from 29 to 115 mm ( $55.86 \pm 16.31$  mm). The length distribution pattern as well as the mean PAL observed in this study is somewhat lower than the value reported by MOREY *et al.* (2003) (mean PAL of 59.4 mm) for the hollowsnout grenadier caught in the western Mediterranean. The analysed sample of hollowsnout grenadier showed a small number of large individuals, especially males. A similar situation for macrourid species was described by MERRETT & HAEDRICH (1997) and D'ONGHIA *et al.* (1999, 2000).

The regression of total wet body weight as a function of length was  $0.0004\text{PAL}^{2.65}$  ( $r^2=0.922$ ) (Table 1) indicating that the hollowsnout grenadier exhibits negative allometric growth. The value of parameter  $b$  in the length-weight relationship was statistically different from 3 (N=175,  $t=14.225$ ,  $P>0.05$ ); therefore, the hypothesis of isometric growth for this species was rejected. This result is in accordance with values previously obtained for populations in the north Aegean Sea ( $b=2.74$ ) by FILIZ & BILGE (2004) and for those in the Ionian Sea ( $b=2.42$ ) by LABROPOULOU & PAPACONSTANTINO (2000). Somewhat higher values of coefficient  $b$  were found by FILIZ *et al.* (2006) for populations in Sigacik Bay (eastern part of the Aegean Sea):  $b=3.008$  for the total sample, 3.170 for males, and 2.969 for females. Our parameters for the length-weight relationship are different from the results obtained in the western

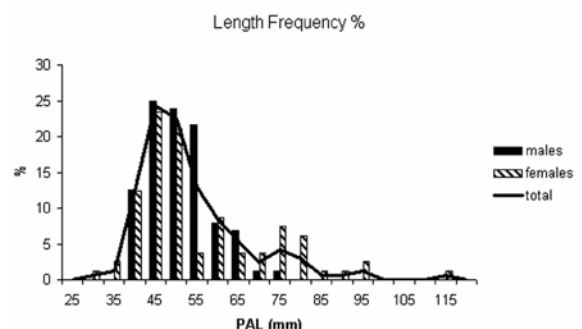


Fig. 2. Length frequency distribution of *Coelorinchus caelorhincus* collected during MEDITS expedition, 2003

Table 1. Length-weight relationship of *Coelorinchus caelorhincus* from the Adriatic caught during MEDITS

| $W = aL^b$ |     |                         |                         |        |        |       |
|------------|-----|-------------------------|-------------------------|--------|--------|-------|
| Sex        | N   | $L_{\min}$ - $L_{\max}$ | $W_{\min}$ - $W_{\max}$ | $a$    | $b$    | $r^2$ |
| Total      | 175 | 29-115                  | 5.37-121.24             | 0.0004 | 2.6501 | 0.922 |
| Males      | 90  | 39-77                   | 5.41- 50.33             | 0.0004 | 2.6668 | 0.844 |
| Females    | 84  | 29-115                  | 5.37-121.24             | 0.0005 | 2.6173 | 0.948 |

Mediterranean (MOREY *et al.*, 2003;  $b=3.1417$ ) and in the area off southern Portugal (BORGES *et al.*, 2003;  $b=3.106$ ). These differences are probably associated with the different size structure of the hollowsnout grenadier population included in the length-weight relationship analysis or with interannual changes in the nutritional condition of the organisms.

The otoliths of macrourids show distinct opaque and translucent rings around an opaque nucleus, corresponding to the fast and slow growth phase (D'ONGHIA *et al.*, 1999). Two morphometric measurements of sagitta were analysed. The values of individual maximum otolith lengths (LO) were between 5.0 and 12.8 mm (mean  $7.38 \pm 1.241$ ), while the width of otoliths varied from 3.7 to 7.9 mm (mean  $4.93 \pm 0.614$ ). The maximum otolith length was linearly related to PAL ( $r^2=0.946$ ,  $P<0.050$ ) (Fig. 3). The shape factor aspect ratio ( $A_R$ ) ranged from 1.326 to 1.814 (mean  $1.492 \pm 0.092$ ). The age groups in the sample ranged from 2 to 6 yr (mean  $3.7 \pm 1.0$

yr) for males and from 2 to 8 yr (mean  $4.0 \pm 1.5$  yr) for females (Table 2). Similar age ranges were observed by other authors: D'ONGHIA *et al.* (2000) as 0-8 yr ( $N=272$ ); LABROPOULOU & PAPACONSTANTINO (2000) 3-11 yr ( $N=244$ ); and FILIZ *et al.* (2006) 1-10 yr ( $N=205$ ).

The von Bertalanffy growth curve equation was

$$PAL_t = 128(1 - e^{-(0.105)(t+1.277)})$$

and it provided a good fit to observed PAL length-age data, as the coefficient of determination was highly significant ( $r^2=0.794$ ) (Fig. 4). These parameters indicate that hollowsnout grenadier is a slow-growing species. Slight differences between our results and results obtained by other authors for growth parameters of *C. caelorhincus* were noticed. The estimated longevity ( $t_{max}=3/K$ ) was 28 years and the growth performance index or phi-prime test ( $\phi'$ ) was 3.24 (Table 3).

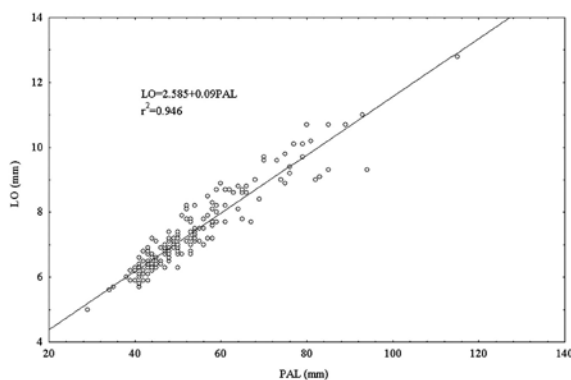


Fig. 3. Relationship between pre-anal length (PAL) and maximum otolith length (LO) of *Coelorinchus caelorhincus* collected during MEDITS 2003

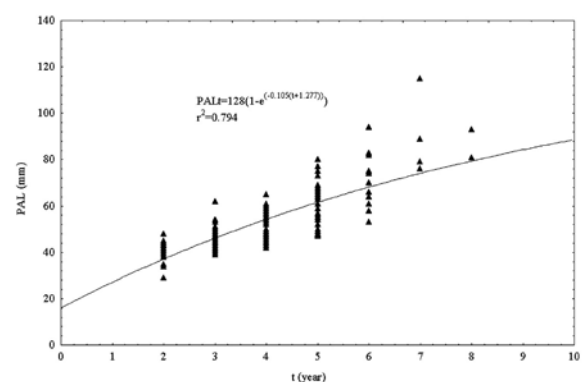


Fig. 4. Length (PAL) at age group of *Coelorinchus caelorhincus* from MEDITS 2003 ( $N=169$ ) and von Bertalanffy growth curve

Table 2. Age-length key of *Coelorinchus caelorhincus*

| PAL (mm) | Age |    |    |    |    |   |   |  | Total |
|----------|-----|----|----|----|----|---|---|--|-------|
|          | 2   | 3  | 4  | 5  | 6  | 7 | 8 |  |       |
| 28-30    | 1   |    |    |    |    |   |   |  | 1     |
| 31-33    |     |    |    |    |    |   |   |  | 0     |
| 34-36    | 2   |    |    |    |    |   |   |  | 2     |
| 37-39    | 2   | 1  |    |    |    |   |   |  | 3     |
| 40-42    | 9   | 8  | 1  |    |    |   |   |  | 18    |
| 43-45    | 4   | 16 | 6  |    |    |   |   |  | 26    |
| 46-48    | 1   | 9  | 15 | 2  |    |   |   |  | 27    |
| 49-51    |     | 9  | 7  | 5  |    |   |   |  | 21    |
| 52-54    |     | 6  | 9  | 2  | 1  |   |   |  | 18    |
| 55-57    |     |    | 5  | 4  |    |   |   |  | 9     |
| 58-60    |     |    | 8  | 1  | 1  |   |   |  | 10    |
| 61-63    |     | 1  | 1  | 2  | 1  |   |   |  | 5     |
| 64-66    |     |    | 2  | 3  | 2  |   |   |  | 7     |
| 67-69    |     |    |    | 3  |    |   |   |  | 3     |
| 70-72    |     |    |    |    | 2  |   |   |  | 2     |
| 73-75    |     |    |    | 2  | 2  |   |   |  | 4     |
| 76-78    |     |    |    | 1  |    | 2 |   |  | 3     |
| 79-81    |     |    |    | 1  |    | 2 | 1 |  | 4     |
| 82-84    |     |    |    |    | 2  |   |   |  | 2     |
| 85-87    |     |    |    |    |    |   |   |  | 0     |
| 88-90    |     |    |    |    |    | 1 |   |  | 1     |
| 91-93    |     |    |    |    |    |   | 1 |  | 1     |
| 94-96    |     |    |    |    | 1  |   |   |  | 1     |
| 97-99    |     |    |    |    |    |   |   |  | 0     |
| 100-102  |     |    |    |    |    |   |   |  | 0     |
| 103-105  |     |    |    |    |    |   |   |  | 0     |
| 106-108  |     |    |    |    |    |   |   |  | 0     |
| 109-111  |     |    |    |    |    |   |   |  | 0     |
| 112-114  |     |    |    |    |    |   |   |  | 0     |
| 115-117  |     |    |    |    |    | 1 |   |  | 1     |
| Total    | 19  | 50 | 54 | 26 | 12 | 6 | 2 |  | 169   |

The deep-sea fauna is sensitive to the influence of increasing fishery pressure and other human activities; hence, it requires specific observation. Data on age, growth, and length–weight relationship for hollowsnout grenadier inhabiting this part of the Adriatic Sea are presented in this paper for the first time, but further biological studies should be carried out especially with larger samples collected multi-seasonally and in different depth strata in order to completely reveal the biology of this species in the Adriatic Sea.

### ACKNOWLEDGEMENTS

The study was funded through MEDITS project “International Bottom Trawl Survey in the Mediterranean Sea” supported by the European Community, and through the national research project “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. We would also like to thank two anonymous referees for their constructive comments which helped improve the manuscript.

Table 3. Von Bertalanffy growth parameters estimated for *Coelorinchus caelorhincus*

| $L_{\infty}$ (mm) | $k$   | $t_0$  | $t_{max}$ | Area                          | $\phi'$ | Note | Source                              |
|-------------------|-------|--------|-----------|-------------------------------|---------|------|-------------------------------------|
| 114.9 (males)     | 0.15  | -1.05  | 20        | Ionian Sea                    | 3.30    | PAL  | D’Onghia <i>et al.</i> 2000         |
| 127.6 (females)   | 0.13  | -1.06  | 23.1      | Ionian Sea                    | 3.33    | PAL  | D’Onghia <i>et al.</i> 2000         |
| 107.0             | 0.132 | -1.535 | 22.7      | Ionian Sea                    | 3.18    | PAL  | Labropoulou & Papaconstantinou 2000 |
| 249.0             | 0.115 | -3.494 | 26.1      | Sigacic Bay (Aegean Sea)      | 3.85    | TL   | Filiz <i>et al.</i> 2006            |
| 128.0             | 0.105 | -1.277 | 28        | Central and Northern Adriatic | 3.24    | PAL  | This study                          |

## REFERENCES

- BERTRAND, J.A. 1995. Campagnes internationales de chalutage démersal en Méditerranée (MEDITS) Campagne 1994 Manuel des protocoles (International bottom trawl surveys in the Mediterranean (MEDITS); Handbook). Rapp de Contract EC- IFREMER-IEO-SIBM-NCMR (MED 93:020 018 006004): 27.
- BERTRAND, J.A., L. GIL DE SOLA, C. PAPACONSTANTINOU, G. RELINI & A. SOUPLLET. 2002. The general specifications of the MEDITS surveys. *Sci. Mar.*, 66: 9-17.
- BORGES, T.C., S. OLIM & K. ERZINI. 2003. Weight – length relationships for fish species discarded in commercial fisheries of the Algarve (southern Portugal). *J. Appl. Ichthyol.*, 19: 394-396.
- COHEN, D.M., T. INADA, T. IWAMOTO & N. SCIALABBA. 1990. FAO species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fish. Synop. 10 (125): 442 pp.
- D'ONGHIA, G., M. BASANISI, F. MATARRESE & F. MEGLI. 1999. Reproductive strategies in macrourid fish: seasonality or not? *Mar. Ecol.Prog. Ser.*, 184: 189-196.
- D'ONGHIA, G., M. BASANISI & A. TURSI. 2000. Population structure, age and growth of macrourid fish from the upper slope of the Eastern - Central Mediterranean. *J. Fish Biol.*, 56: 217-1238.
- FILIZ, H. & G. BILGE. 2004. Length-weight relationship of 24 fish species from the North Aegean Sea, Turkey. *J. Appl. Ichthyol.*, 20: 431-432.
- FILIZ, H., G. BILGE, E. IRMAK, M. TOGUGLA, D. UCKUN & S. AKALIN. 2006. Age and growth of hollowsnout grenadier, *Caelorinchus caelorhincus* (Risso, 1810), in the Aegean Sea. *J. Appl. Ichthyol.*, 22: 285-287.
- JARDAS, I. 1996. Jadranska ihtiofauna (Adriatic Ichthyofauna). Školska knjiga. Zagreb, 533 pp.
- LABROPOULOU, M. & C. PAPACONSTANTINOU. 2000. Comparison of otolith growth and somatic growth in two macrourid fishes. *Fish. Res.*, 46: 177-188.
- MERRETT, N.R. & R. HAEDRICH. 1997. Deep-sea demersal fish and fisheries. Chapman & Hall. London, 267 pp.
- MOREY, G., J. MORANTA, E. MASSUTI, A. GRAU, M. LINDE, F. RIERA & B. MORALES NIN. 2003. Weight-length relationships of littoral to lower slope fishes from the western Mediterranean. *Fish. Res.*, 62: 89-96.
- MUNRO, J.L. & D. PAULY. 1983. A simple method for comparing growth of fishes and invertebrates. *ICLARM Fishbyte*, 1: 5-6.
- PONTON, D. 2006. Is geometric morphometrics efficient for comparing otolith shape of different fish species? *J. Morphol.* (1931), 267: 750-757.
- REINER, F. 1996. Catálogo dos peixes do Arquipélago de Cabo Verde (Fish catalogue of Cape Verde archipelago). Publicações avulsas do IPIMAR No. 2: 339 pp.
- TAYLOR, C.C. 1958. Cod growth and temperature. *J. Cons.*, 23: 366-370.

Received: 29 August 2008

Accepted: 20 March 2009

## Starost, rast i dužinsko – maseni odnos morskog miša *Coelorinchus caelorhincus* (Risso, 1810) u Jadranskom moru

Igor ISAJLOVIĆ<sup>1\*</sup>, Nedo VRGOČ<sup>1</sup>, Barbara ZORICA<sup>1</sup>,  
Melita PEHARDA<sup>1</sup>, Svjetlana KRSTULOVIĆ ŠIFNER<sup>2</sup> i Corrado PICCINETTI<sup>3</sup>

<sup>1</sup> *Institut za oceanografiju i ribarstvo, P.P. 500, 21000 Split, Hrvatska*

\* *Kontakt adresa, e mail: igor@izor.hr*

<sup>2</sup> *Sveučilišni centri za studije mora, Livanjska 5, 21000 Split, Hrvatska*

<sup>3</sup> *Laboratorij za biologiju mora i ribarstvo, Sveučilište u Bolonji,  
Viale Adriatico 1/N 61032- Fano (PU), Italija*

### SAŽETAK

Uzorci morskog miša *Coelorinchus caelorhincus* sakupljeni su pridnenom povlačnom mrežom kočom tijekom ekspedicije MEDITS (“Mediterranean International Trawl Survey”) u lipnju 2003. u sjevernom i srednjem Jadranu. Za analizu je spremljeno sveukupno 175 primjeraka *C. caelorhincus* od čega 90 mužjaka, 84 ženke i 1 nedeterminirani primjerak. Pre-analna dužina kod mužjaka kretala se u rasponu od 39 do 77 mm ( $\bar{x}=50.91\pm 7.63$  mm), a kod ženki od 29 do 115 mm ( $\bar{x}=55.86\pm 16.3$  mm). Dužinsko - maseni odnos za cjelokupni uzorak iznosio je  $W=0.0004PAL^{2.65}$  ( $r^2= 0.922$ ) i ustanovljena je negativna alometrija. Starost *C. caelorhincus* je procijenjena očitavanjem otolita. Maksimalna dužina otolita (LO) je proporcionalna dužini tijela ( $LO=2.585+0.09PAL$ ,  $r^2=0.946$ ). Starost se kretala od 2 do 8 godina, a većina primjeraka bila je stara između 3 (30%) i 4 (31%) godine. Von Bertalanffy parametri rasta iznosili su:  $L_\infty = 128$  mm,  $K = 0.105$  godina<sup>-1</sup> i  $t_0 = -1.277$ .

**Ključne riječi:** starost, rast, dužinsko – maseni odnos, *C. caelorhincus*, Jadransko more