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Analysis of beak morphometry of the horned octopus *Eledone cirrhosa* (Cephalopoda: Octopoda) in the Thracian Sea (NE Mediterranean)

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Abstract

Cephalopod beaks are chitinous structures situated in the buccal mass lying at the base of their arms. Because they are among the few hard structures of cephalopods with high resistance to erosion during digestive process in predator stomachs, the study of the beak morphometry is of major importance for the species taxonomy, as well as, for the size estimation of the cephalopods consumed.

In this study new information is provided on the dimensions and pigmentation process of the upper and lower beak of the horned octopus Eledone cirrhosa derived from 67 female and 47 male specimens caught by trawl in the Thracian Sea (NE Mediterranean). The growth of both beaks was allometric in relation to the mantle length and body weight. According to the results of covariance analysis, no difference was found in growth pattern of beaks between sexes. Four degrees of pigmentation were identified in both upper and lower beaks, the darkening process starting in females at a smaller size.

Keywords: Cephalopoda; Octopoda; Eledone; Beaks; Pigmentation; Mediterranean.

Introduction

Cephalopod beaks are chitinous structures situated in the buccal mass lying at the base of their arms. Because they are among the few hard structures of cephalopods with high resistance to erosion during digestive process in predator stomachs (CLARKE, 1962), the study of the beak morphometry is of major importance for the species taxonomy, as well as, for the size estimation of the cephalopods consumed. Most of the existing information on cephalopod beak morphometry has been included in the Handbook for the identification of cephalopod beaks by CLARKE (1986) focusing mainly in decapods from the Atlantic, Pacific, Indian and Antarctic Oceans whereas, particularly for Mediterranean species relative literature is limited to the study of MANGOLD & FIORONI (1966).

Eledone cirrhosa is one of the most abundant cephalopod species in the Mediterraneran Sea (LEFKADITOU *et al.*, 2000) comprising an item of prey for several species of demersal fishes (WÜRTZ AND PALUMBO, 1985; DU BUIT, 1989; VELASCO *et al.*, 2001), sharks (CLARKE & STEVENS, 1974) and marine mammals (CLARKE & PASCOE, 1985; GONZÁLEZ *et al.*, 1994; SANTOS *et al.*, 1994, 1995, 1999; TOLLIT & THOMPSON, 1996). NAEF (1923) published the first drawings of *Eledone cirrhosa* beaks, however a detailed description and criteria for the species identification were designated by MANGOLD & FIORONI (1966), who also reported relationships between mantle length and basic beak dimensions, as well as, information on pigmentation intensity with growth of specimens collected from the Gulf of Lions (western Mediterranean). In this paper new information is provided on the growth of several dimensions and darkening process of the upper and lower beak of the horned octopus *Eledone cirrhosa*, based on specimens from the Thracian Sea.

Materials and Methods

The particular *Eledone cirrhosa* used in this study were obtained from trawlers landing in the port of Kavala, Greece. Beaks were extracted from the buccal mass of 67 female and 47 male freshly caught or defrosted specimens after recording measurements of mantle length (in mm), body weight (in gr) and sex.

Beaks were kept in 70% ethanol. The measured dimensions referring to upper and lower mandibles are as follows: rostral length (RL), hood length (HL), crest length (CL), wing length (WL), distance between jaw angles (JAd) on both upper (U) and lower (L) mandible, amplitude of the lateral wall (LWa) in the upper beak and length of base line (BL) in the lower beak (Fig.1). The terms used for the different beak components followed the nomenclature established by CLARKE (1962). Measurements were taken to the nearest 0.01 mm using a computer-enhanced video image-analysis system interfaced with a compound stereoscope.

Each beak measurement was related to mantle length and body weight, as well as, to hood length of respective beak, which is the standard measurement to describe the size of lower and upper beaks for octopods (CLARKE, 1986). Regression equations were estimated after the transformation of all variables into their natural logarithms.

To investigate possible differences between the beaks of males and females, the variance of the beak morphometry data was studied by covariance analysis. All regressions and statistics were performed using the software package STATGRAPHICS - Plus 2.0.

Further analysis of the beaks was focused on the development of pigmented zones in relation to increasing animal size. Definition of pigmentation stages was mainly based on darkening of the lateral wall for upper beak and the wing for lower beak, where the highest variation of pigmentation extension with increasing size was observed. To quantify stages of pigmentation development, dimensions of the darkened part of the upper beak's lateral wall amplitude (UDLWa) and the lower beak's wing length (LDWL) were measured and their proportions to the respective total lengths were calculated.

Results

Changes in beak dimensions and shape with growth

The relationships of mantle length and body mass with each beak dimension are shown in Table 1, whereas, those of hood length with other dimensions in the upper and lower mandible are presented in Table 2. According to the results of covariance analysis, no significant differences were detected in growth pattern of beaks between sexes at the 90% or higher confidence level, so that data for the two sexes were pulled together. Growth of beak dimensions was generally allometric in relation to the mantle length and body weight, as shown by the slopes of the regressions (Table 1). In the upper beak growth of rostrum, crest and wing appeared isometric to that of hood, whereas, in lower beak rostrum grew faster

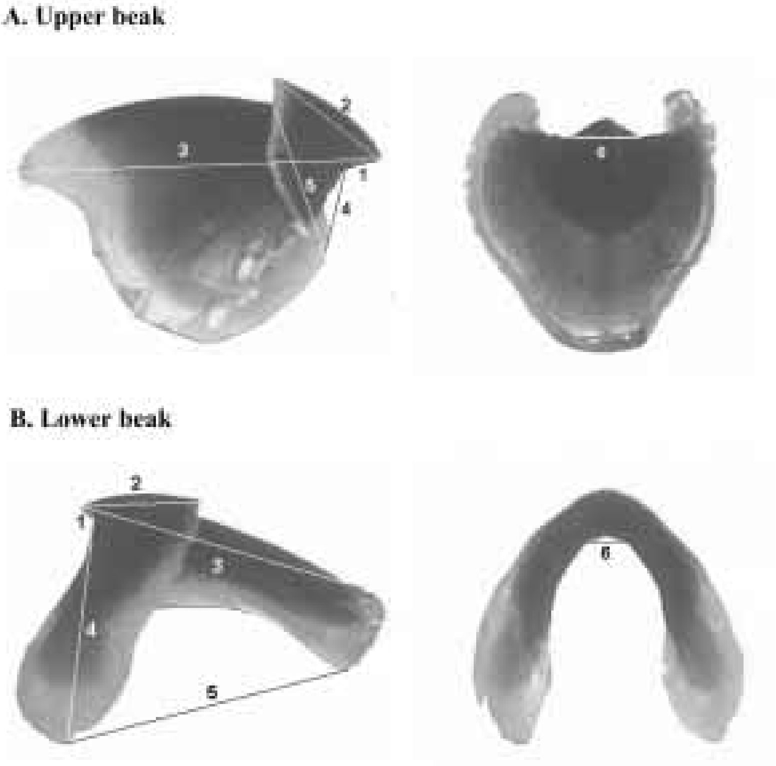

Fig. 1: Measurements of (A) upper and (B) lower beak of Eledone cirrhosa.
(A) Upper beak: 1-Rostral Length (URL), 2-Hood Length (UHL), 3-Crest Length (UCL), 4-Wing Length (UWL), 5-Lateral Wall amplitude (ULWa), 6-Jaw Angles distance (UJAd).
(B) Lower beak: 1-Rostral Length (LRL), 2-Hood Length (LHL), 3-Crest Length (LCL), 4-Wing Length (LWL), 5-Baseline Length (LBL), 6-Jaw Angles distance(LJAd)

Table 1
Intercepts (a), slopes (b) and correlation coefficient (r) estimated for equations $Y = a \times X^b$ relating upper and lower beak dimensions to mantle length (ML) and body weight (BW) of *Eledone cirrhosa*. Both sexes pooled together.

Y	X= ML			X = BW		
	a	b	r	a	b	r
URL	0.04636	0.69587	0.624	0.31486	0.24946	0.658
UHL	0.31358	0.57141	0.871	1.57076	0.19627	0.883
UCL	0.48248	0.69772	0.931	3.43223	0.24101	0.954
UWL	0.11572	0.74655	0.863	0.93151	0.26084	0.887
ULWa	0.20116	0.73036	0.913	1.55489	0.25414	0.934
UJAd	0.02274	0.99311	0.803	0.36817	0.34445	0.820
LRL	0.04190	0.58809	0.590	0.22253	0.19956	0.589
LHL	0.22395	0.58797	0.855	1.15960	0.20508	0.876
LCL	0.44405	0.63251	0.925	2.63036	0.21839	0.939
LWL	0.24288	0.72376	0.913	1.84693	0.25143	0.932
LBL	0.46979	0.64343	0.924	2.85052	0.22365	0.944
LJAd	0.04346	0.75905	0.838	0.36675	0.26252	0.852

than hood (Table 2). Rostral length values, however, show a great dispersion in relation to other variables.

Table 2
Intercepts (a), slopes (b) and correlation coefficient (r) estimated for equations $Y= a \times X^b$ relating hood length to other dimensions in upper and lower beak of *Eledone cirrhosa*. Both sexes pooled together.

X	Y	a	b	r
	URL	4.48357	1.09896	0.641
	UCL	2.42020	1.07324	0.935
UHL	UWL	0.71633	1.07482	0.817
	ULWa	1.09833	1.11625	0.918
	UJAd	0.25208	1.45143	0.766
	LRL	4.11151	0.75622	0.515
	LCL	2.57904	0.93634	0.934
LHL	LWL	1.91322	1.02270	0.888
	LBL	2.96095	0.90372	0.891
	LJAd	0.42416	0.96612	0.732

Changes in pigmentation with growth

Four stages of pigmentation were identified (Fig. 2) based mainly on darkening degree of lateral wall and wing in upper and lower mandibles respectively. Although darkening is generally extending with increasing mantle length there is a considerable overlap of animal sizes corresponding to different stages of beak pigmentation (Table 3, Fig. 3, Fig. 4). In females all four pigmentation stages appeared to a wider range of animal sizes, whereas, the second and third stage were reached at a smaller ML than in males. Dimensions of the darkened part of the upper beak's lateral wall amplitude (UDLWa) and the lower beak's wing length (LDWL) were found to have significant correlation to hood and mantle length (Table 4).

Table 3
Stages of pigmentation and proportions of darkened part of lateral wall amplitude (UDLWa) in upper beak and wing (LDWL) in lower beak of *Eledone cirrhosa*. Both sexes pooled together.

Stage of pigmentation	Proportion of darkened ULWa			Proportion of darkened LWL		
	Range	Mean	STD	Range	Mean	STD
1	0.65 - 0.76	0.72	0.02	0.52 - 0.67	0.61	0.04
2	0.72 - 0.79	0.75	0.02	0.65 - 0.75	0.70	0.03
3	0.73 - 0.85	0.78	0.03	0.72 - 0.81	0.76	0.02
4	0.75 - 0.88	0.80	0.04	0.78 - 0.86	0.81	0.02

Table 4
Intercepts (a), slopes (b) and correlation coefficient (r) estimated for equations $Y= a \times X^b$ relating darkened length of lateral wall amplitude (UDLWa) in upper beak and darkened length of wing (LDWL) in lower beak to mantle length (ML) and hood length (HL) of respective beak. Both sexes of *Eledone cirrhosa* pooled together.

Y	X	a	b	r
UDLWa	ML	0.00317	0.87198	0.910
	UHL	0.352008	1.31849	0.904
LDWL	ML	0.000372	1.10467	0.900
	LHL	0.549387	1.54357	0.860

Discussion

Growth of *Eledone cirrhosa* beaks in relation to the animal size is characterized by negative allometry as has been shown for other octopod species, as well as, for horned octopuses from other areas (CLARKE, 1962; MANGOLD & FIORONI, 1966; NIXON, 1973; ROBINSON & HARTWICK, 1983; PÉREZ-GÁNDARAS, 1983). Beaks of horned octopuses from the Thracian Sea seem to have an even slower growth rate than that of specimens from the Gulf of Lions (MANGOLD & FIORONI, 1966), as indicated by the slopes

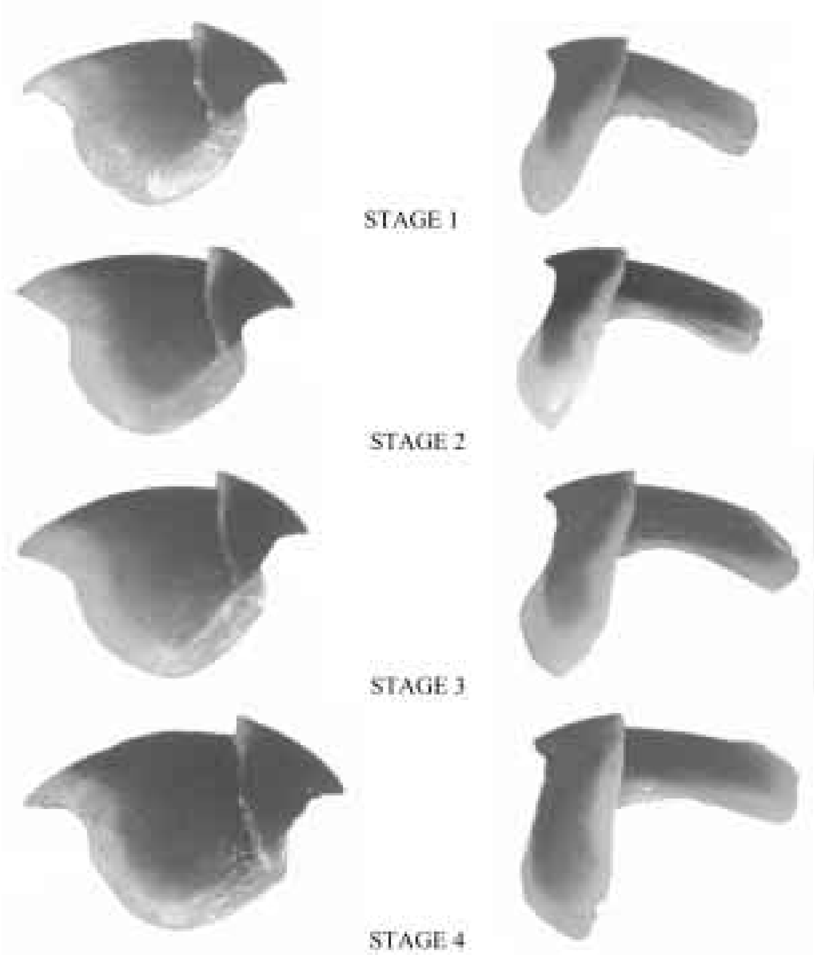

Fig. 2: Representative images of the four stages of pigmentation identified in upper and lower beaks of *Eledone cirrhosa.*

of allometric relationships between hood length, crest length and mantle length of both mandibles. Cephalopod growth, including that of their hard parts such as beaks and statoliths, is highly affected by environmental conditions (BOYLE & BOLETZKY, 1996; VILLANUEVA 2000), which shows the necessity to study one species beak morphometry in several geographic areas and probably during several time periods.

Rostral length and distance between jaw angles showed the lower correlation coefficients among the measured beak dimensions. This is common for octopod species because jaw angle is usually indistinct and rostral length cannot be accurately determined (CLARKE, 1962). Moreover the hard exoskeleton of crustaceans, that are the favorite prey of eledonids (BOYLE, 1983), is most probably causing high erosion of the rostrum.

Close relationships between mantle length and dimensions of darkened parts of both upper beak lateral wall and lower beak wing

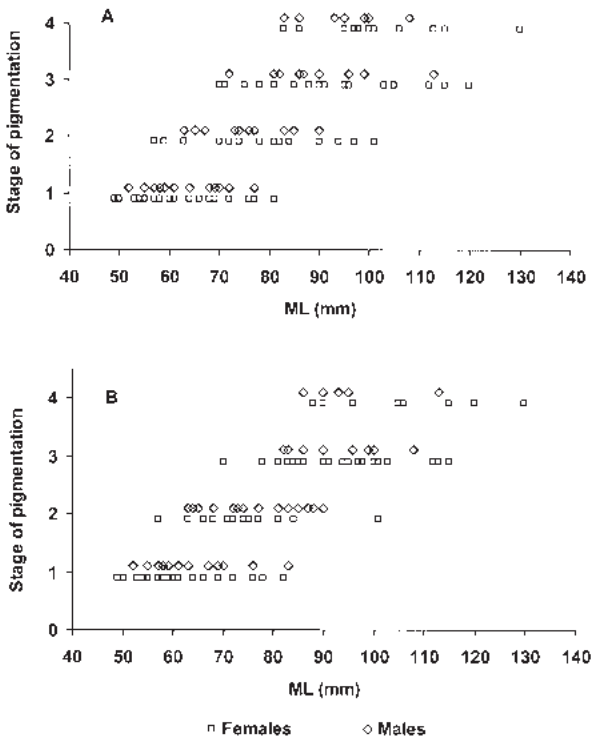

Fig. 3: Variation in pigmentation stage of (A) upper and (B) lower beak with mantle length (ML) for female and male *Eledone cirrhosa*.

have been shown. Thus, measurements of darkened parts in beak zones with highest pigmentation variation could be useful both for the beaks taxonomy and the size estimation of the animals from which they came and should be recommended, since digestion in a predator's stomach often removes transparent regions of the cephalopod beaks (CLARKE, 1962).

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