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DESCRIPTION OF *Illex argentinus* BEAKS AND ROSTRAL LENGTH RELATIONSHIPS WITH SIZE AND WEIGHT OF SQUIDS *

by

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RESUMEN

Descripción de las mandíbulas de *Illex argentinus* y relaciones del largo rostral con la talla y el peso de los calamares. Se presenta una descripción de las mandíbulas de *Illex argentinus* realizada sobre la base de caracteres cuali y cuantitativos. Asimismo se proponen las ecuaciones que representan las relaciones existentes entre el largo del rostro de cada mandíbula y el largo del manto y peso total de los calamares, como herramienta para la reconstrucción de los mismos.

Un total de 291 ejemplares, abarcando todo el rango de tallas, desde juveniles a adultos, fueron analizados para este propósito. La descripción morfométrica se realizó sobre un total de 90 ejemplares, efectuándose, sobre cada mandíbula, las siguientes mediciones: largo del rostro, largo del capuchón, largo de la cresta, largo del ala y ancho del ala.

Los resultados demostraron que las mandíbulas de *Illex argentinus* responden al esquema típico de aquellas correspondientes a la familia Ommastrephidae, a la cual pertenece la especie. La mandíbula inferior posee un capuchón amplio, con el rostro y las alas largas, y se caracteriza por la presencia de una estructura notable, denominada diente, sobre la base del ángulo mandibular. La cresta es corta y las paredes laterales moderadamente largas. Fue detectada una notable alometría en el crecimiento del capuchón y la cresta con respecto al rostro. La mandíbula superior también presenta un capuchón amplio, con el rostro largo y curvado y las alas pequeñas; en tanto la cresta y las paredes laterales son largas. El crecimiento del capuchón respecto del rostro es de tipo alométrico, en tanto que el de la cresta es isométrico. La coloración de ambas mandíbulas se intensifica con el crecimiento, especialmente a partir de los 200 mm LM.

SUMMARY

A description of *Illex argentinus* beaks, made on the basis of qualitative and quantitative characteristics, is presented. Likewise the equations that represent the relationships between the rostral length of each beak with the mantle length and total weight of squids are proposed, as a tool for reconstructing them.

A total of 291 squids, comprising the complete size range, from juveniles to adults, were analyzed for the latter purpose. The morphometric description was made on a total of 90 individuals, taking the following measurements on each beak: rostral length, hood length, crest length, wing length and wing width.

Results showed that *Illex argentinus* beaks present the general scheme of that corresponding to the Ommastrephidae Family, to which this species belongs. The lower beak characteristically has a wide hood, with long rostrum and wings, and a notable knob situated on the basis of the mandibular angle. The crest is short and the lateral walls slightly long.

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A strong growth alometry between hood and crest in relation to the rostrum was detected. The upper beak also has a wide hood, with a long curved rostrum and small wings, whereas the crest and lateral walls are long. Hood growth in relation to that of the rostrum was detected to be alometric, but that corresponding to the crest was isometric. Pigmentation of both beaks intensified with growth, specially from 200 mm ML on.

Palabras clave: *Illex argentinus*, calamar, pico, largo rostral.
Key words: *Illex argentinus*, argentine shortfinned squid, beak, rostral length.

INTRODUCTION

Beaks are the most useful structures for the identification of squid species from the stomach contents of their predators, since the shape and the relative dimensions of the parts that constitute them vary enough between species to allow identification. Thus, many works have dealt with the description of the beaks of species that coexist, determining the morphological and morphometrical characteristics that distinguish each species (Clarke, 1962, 1983, 1986; Mangold and Fioroni, 1966; Iverson and Pinkas, 1971; Wolff and Wormuth, 1979; Mercer *et al.*, 1980; Wolff, 1984; Perez-Gandaras, 1986; Pineda *et al.*, 1996).

Illex argentinus is the most abundant and widely distributed squid in the Southwest Atlantic region, where it is the object of a high predation caused by fish, birds and mammals (Clarke *et al.*, 1980; Angelescu and Prenski, 1987; Prenski and Bezzi, 1991; Aguiar dos Santos, 1992; Crespo *et al.*, 1994; Prenski *et al.*, MS). Considering this fact, the necessity of having a description of the species beak arises, as well as the equations that allow the reconstruction of the sizes and weights of the preyed individuals, from their mandibules, are required. The only previous work, in this sense, is the key to identify beaks of five species of ommastrephids proposed by Aguiar dos Santos (1992), on the basis of qualitative characteristics of beaks found in the stomach contents of various predators which inhabit the southern Brazil area.

In this work we present a qualitative and morphometric description of the beaks of *Illex argentinus* and propose the equations to calculate the mantle length and total weight of the squids from the rostral length of each beak.

MATERIALS AND METHODS

The specimens were gathered during various research cruises carried out on the Argentinian continental shelf and slope. In total 291 squids, whose sizes varied between 45 and 350 mm mantle length (ML), were sampled to record, besides the mentioned ML, the following data: total weight (TW) in grams, sex and sexual maturity stage (Brunetti, 1990). After extraction from the buccal mass, the beaks were immersed for ten minutes in a solution of 50% hypochlorite to remove excess tissue that normally remain stuck, and then washed with abundant water. Finally they were stored in 5% formalin.

The rostral lengths (RL) of both beaks were measured for all the individuals to obtain the relationships between them and ML and TW. The criterium of the minimum relative mean error between the lineal, potential, exponential and logaritmic models was used to select which of them best describes those relationships.

A total of 90 squids, whose sizes ranged between 45 and 285 mm ML, were analyzed for the morphometric description. Five measurements were taken on each beak: hood length (HL), crest length (CL), wing length (WL), wing width (WW), and the RL mentioned above (Figure 1). These dimensions, excepting WW, were proposed by Clarke (1962, 1986). WW was measured, only on the upper beak, by Wolff and Wormuth (1979) and Wolff (1984), and it was adapted to the lower beak in this work. All the measurements were made under binocular microscope, using a graduate ocular, and then transformed to millimeters. Mean relative ratios between the dimensions of the different structures were calculated and utilized to describe the beaks. In order to detect possible changes associated with growth in the relative size of the different structures, HL, CL, WL and WW were tested, as dependant variables, against RL (independant variable), to determine what regression model offered the best adjustment (according to the minimum relative mean error). Finally, Student's t-test for H_0: b = 1 (isometry) was applied in those cases where potential regressions had been found (confidence level = 0.99).

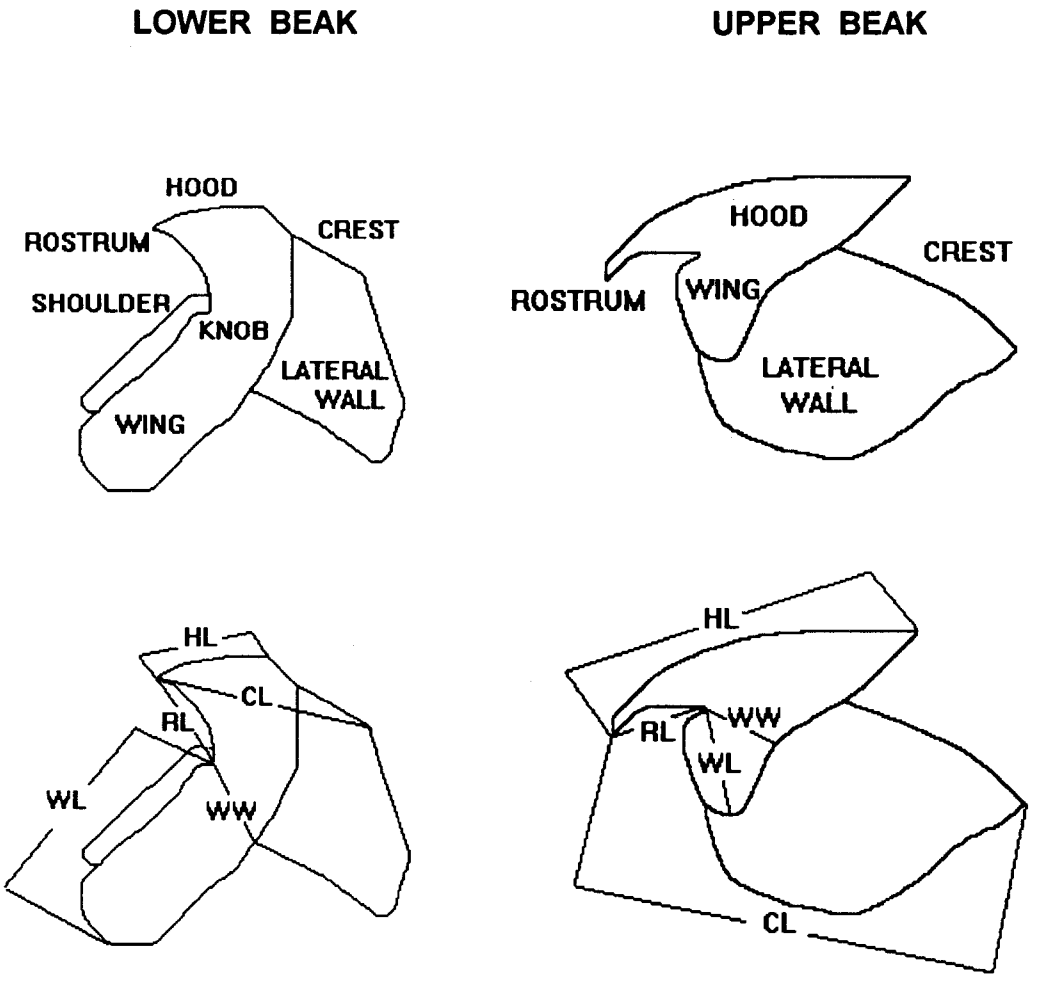

FIGURE 1. Descriptive scheme of the lower and upper beaks of Illex argentinus and dimensions measured on them (RL: rostral length, HL: hood length, CL: crest length, WL: wing length, WW: wing width).

FIGURA 1. Esquema descriptivo de las estructuras que conforman las mandíbulas inferior y superior de *Illex argentinus* y de las mediciones realizadas sobre ellas (RL: largo rostral, HL: largo del capuchón, CL: largo de la cresta, WL: largo del ala, WW: ancho del ala).

RESULTS

Beak Description

The description of the beaks was made taking into account the general morphology of the total of the squids analyzed. Particular attention to the characteristics used by Wolff (1984) for the identification of the beaks of 18 species of cephalopods from the Pacific Ocean was given. Figure 1 shows the general structure of each beak, as well as the different parts on which the descriptions are based, while Table 1 contains the mean relative ratios between the dimensions taken.

Lower Beak

The lower beak has a wide hood, its length being 58% of CL on average, with a deep notch in the posterior edge

TABLE 1. Mean relative ratios and standard deviations between different dimensions of the lower and upper beaks (RL: rostral length, HL: hood length, CL: crest length, WL: wing length, WW: wing width).

TABLA 1. Indices relativos medios y desviaciones estándar entre las mediciones realizadas en las mandíbulas inferior y superior (RL: largo rostral, HL: largo del capuchón, CL: largo de la cresta, WL: largo del ala, WW: ancho del ala).

Ratio		Lower beak	Upper beak
RL/HL	mean	0.6534	0.3085
	SD	0.1050	0.0217
RL/CL	mean	0.3796	0.2283
	SD	0.0426	0.0158
HL/CL	mean	0.5865	0.7410
	SD	0.0435	0.0349
WL/WW	mean	2.0997	1.2311
	SD	0.2422	0.1012
WL/CL	mean	0.8264	0.2388
	SD	0.0605	0.0190
WL/HL	mean	1.4178	0.3228
	SD	0.1581	0.0280
WL/RL	mean	2.1954	1.0516
	SD	0.2139	0.1157
WW/CL	mean	0.3908	0.1952
	SD	0.0539	0.0213
WW/HL	mean	0.6866	0.2638
	SD	0.1222	0.0302

(Figure 2). The separation between hood and crest, from the lateral view, is noteworthy. The rostrum is relatively long (65% of HL and 37% of CL) and slightly curved. The angle between rostrum and wing is recessed, but, as the squid grows, is partially hidden, seen from the lateral side, by a fold that appears on the superior edge of the wing. On the basis of this angle there is a knob which is gradually included in the shoulder during growth. The crest shows no curvature or folds and the lateral walls are taller than they are long, without grooves or ridges. The wings are long (82% of CL, 141% of HL) and wide (39% of CL).

Upper Beak

The upper beak presents a large hood, whose length reaches, on average, 74% of CL. Its upper edge is slightly curved while the lower edge, which continues in the wings, also shows a moderate curvature (Figure 2). The rostrum is relatively long (30% of HL, 22% of CL) and curved, and the mandibular angle is deeply recessed. The crest and the posterior edges of the lateral walls are moderately curved. The wings are longer than they are wide (123% WL with respect to WW), but relatively short in relation with the rest of the mandibular structures, representing its length 23% of CL and 32% of HL, while related to RL the values are similar (105%). The wing bases are inserted aproximately on the middle part of the anterior edge of the lateral walls.

Pigmentation

The process of pigmentation follows the same pattern in both beaks. In the juvenile squids (40-90 mm ML) the only coloured zones are the rostrum, with an intense brown pigmentation, and the anterior part of the hood and the superior

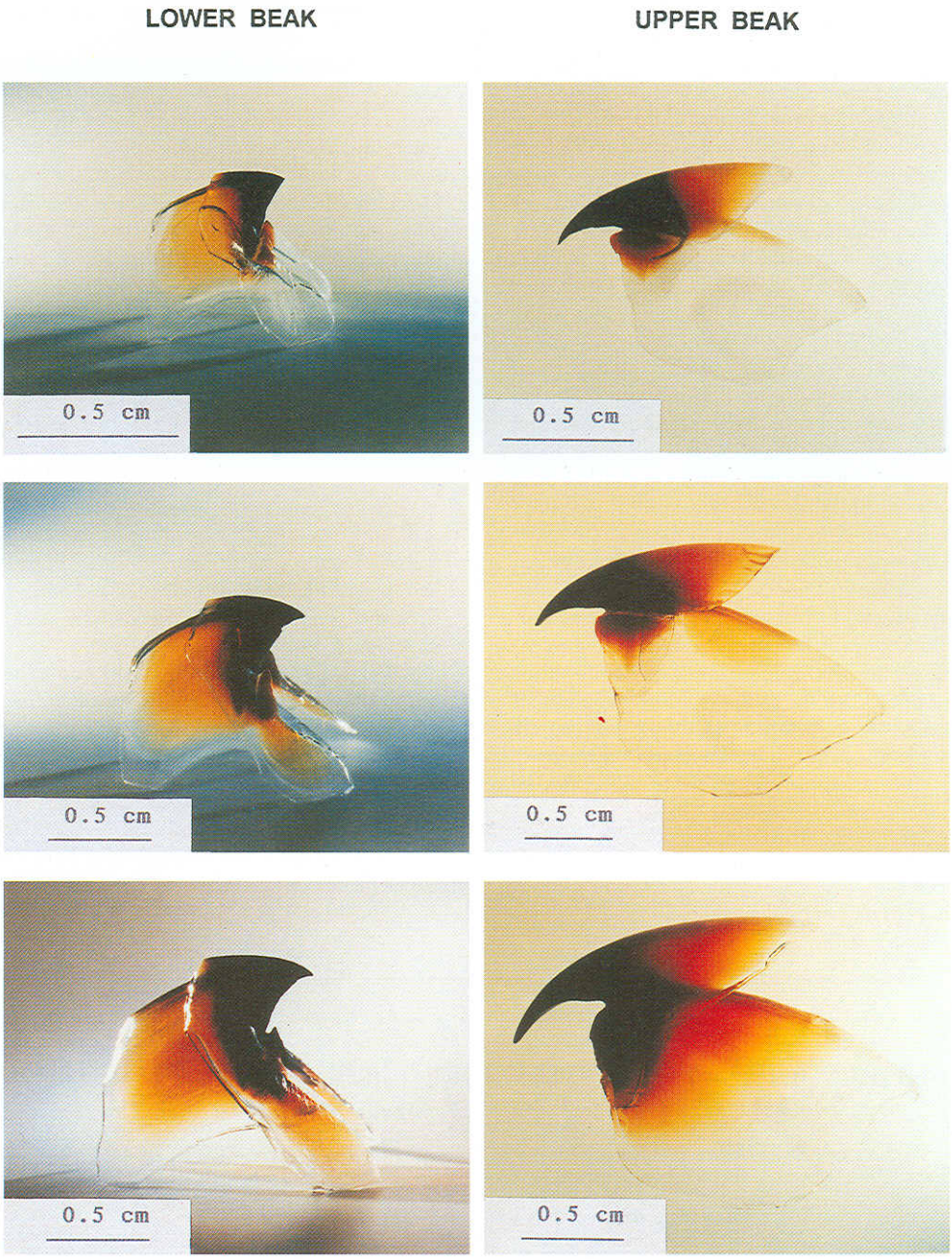

FIGURE 2. Development and pigmentation changes of the lower and upper beaks of Illex argentinus related to size. Top: ML = 139 mm, RL_{lower} = 1.941 mm, RL_{upper} = 2.510 mm. Center: ML = 216 mm, RL_{lower} = 3.576 mm, RL_{upper} = 4.041 mm. Bottom: ML = 255 mm, RL_{lower} = 4.320 mm, RL_{upper} = 4.845 mm.

FIGURA 2. Cambios de la morfología y pigmentación de las mandíbulas inferior y superior de *Illex argentinus* producidos durante el crecimiento. Arriba: ML = 139 mm, $RL_{inferior}$ = 1,941 mm, $RL_{superior}$ = 2,510 mm. Centro: ML = 216 mm, $RL_{inferior}$ = 3,576 mm, $RL_{superior}$ = 4,041 mm. Abajo: ML = 255 mm, $RL_{inferior}$ = 4,320 mm, $RL_{superior}$ = 4,845 mm.

part of the wings, which present a light brown colour, with a lighter stripe extending from the mandibular angle in each beak (Figure 2). The rest of the structures: crest, lateral walls, posterior zone of the hood and lower part of the wings, are completely colourless. Between 100 and 130 mm ML, pigmentation intensifies on both beaks, and the crest and lateral walls of the lower beak start to show some colour.The crest of the upper beak starts to be coloured in the size range of 140-180 mm ML, while this process occurs between 190-200 mm ML in the case of the lateral walls. In the lower beak, while the pigmentation of the coloured structures progresses, the central zone of the wings starts to be pigmentated in the process described by Clarke (1983) as "spot". The knob starts to be included in the shoulder at about 210-220 mm ML and its pigmentation joins that of the "spot". In the following sizes the pigmentation is darker in both beaks and the colourless stripe on the mandibular angle disappears. There is a colourless region in the posterior part of the crest and lateral walls, which follows the shape of this structures in the lower beak, but is independent of them in the upper beak. Growth lines can be observed on the lateral walls and wings of the lower beak, while the borders of the wings are translucid. From sizes 230-240 mm ML in males and 250-260 mm ML in females, both beaks are totally pigmented, with the only exception of the thin transparent borders mentioned above. At this stage the colour is brown in almost all the beak, and deep brown, nearly black, in the rostrum, the anterior part of the hood and the superior part of the wings.

Morphometry

The relationships between the wing dimensions (WL and WW) and the RL were represented by a lineal model in both beaks, while those correponding to HL and CL were better described by a potential model (Table 2). The t-tests applied in the latter cases showed that the b values obtained varied significantly from 1, for the relationships corresponding to the lower beak. In the upper beak b was significantly different from 1 for the relationship HL/RL, while for CL/RL there were no significant differences. These results show that an alometric growth would take place between the structures involved, which would be stronger in the case of the lower beak.

Relationships between the rostral length with the mantle length and total weight

Rostral lengths of the upper beak varied between 0.9 and 7 mm, while in the case of the lower beak, they were between 0.5 and 6.0 mm (Figure 3). The maximum RL found here possibly correspond to the biggest beaks of the species, since they were found in females whose sizes were near the maximum (350 mm ML).

A lineal model proved to be the best adjustment for the relationship between RL and ML, while for the RL-TW relationship, a potential model was found to be the most adequate (Table 3).

TABLE 2. Regression equations for the relationships between hood length (HL) and crest length (CL) with rostral length (RL) for both beaks (dimensions in millimeters), and results of Student's t-tests for H_0: b = 1 (confidence level = 0.99).

TABLA 2. Ecuaciones de regresión para las relaciones entre el largo del capuchón (HL) y el largo de la cresta (CL) con el largo rostral (RL) de ambas mandíbulas (mediciones realizadas en milímetros), y pruebas t-Student para H_0: b = 1 (nivel de confianza = 0,99).

	Lower beak	Upper beak
HL/RL	ln HL = 0.5825 + 0.8037 ln RL	ln HL = 1.1380 + 1.0413 ln RL
	r^2 = 0.9714	r^2 = 0.9881
	N = 90	N = 90
	t = -13.4251 **	t = 3.4158 *
CL/RL	ln CL = 1.0676 + 0.8736 ln RL	ln CL = 1.4727 + 1.0067 ln RL
	r^2 = 0.9855	r^2 = 0.9858
	N = 90	N = 90
	t = -11.2462 **	t = 0.5266 ns

TABLE 3. Regression equations for the relationships between mantle length (ML, in mm) and total weight (TW, in g) with rostral length (RL, in mm) for both beaks.

TABLA 3. Ecuaciones de regresión calculadas para las relaciones entre el largo del manto (ML, en mm) y el peso total (TW, en g) con el largo rostral (RL, en mm) para ambas mandíbulas.

	Lower beak	Upper beak
ML	ML = 24.6648 + 54.1825 RL $r^2 = 0.9675$ N = 291	ML = 2.0133 + 53.4128 RL $r^2 = 0.9635$ N = 291
TW	ln TW = 2.1342 + 2.6311 ln RL $r^2 = 0.9752$ N = 291	ln TW = 0.9559 + 3.2198 ln RL $r^2 = 0.9745$ N = 291

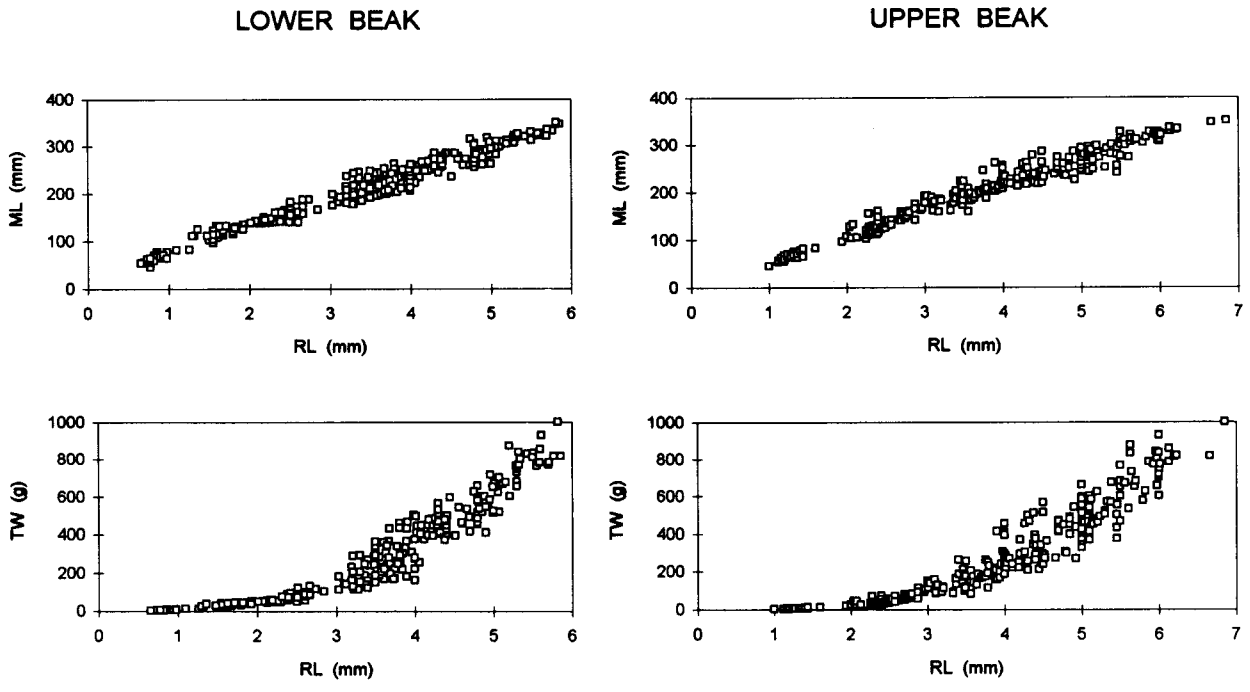

FIGURE 3. Relationships between the rostral lengths (RL) of each beak with the mantle length (ML) and total weight (TW) of Illex argentinus.

FIGURA 3. Relaciones entre el largo rostral (RL) de cada mandíbula con el largo del manto (ML) y el peso total (TW) en *Illex argentinus.*

DISCUSSION

Illex argentinus beaks show the general scheme of that corresponding to the Ommastrephidae Family, to which this species belongs, so they can be easily differentiated from other squids that are distributed in the same area, specially loliginids (Pineda *et al.*, 1996). The identification could be more complex when other ommastrephid species are involved, such as *Martialia hyadesi or Ommastrephes bartramii*, whose distributional areas overlap that of Illex *argentinus* in certain zones. The key for the identification of beaks of five species of ommastrephids, made by Aguiar dos Santos (1992) on the basis of beaks found in the stomach contents of their predators in the southern part of Brazil, is highly useful for this purpose. Anyhow, the best way to identify morphologically similar beaks, is the combined use of qualitative characteristics together with some morphometric variables. These variables have produced good results when applied in discriminant analysis techniques, for the identification of species of the same or different genera (Wolff and Wormuth, 1979; Perez-Gandaras, 1986; Pineda *et al.*, 1996).

Mean ratios obtained for the lower beak showed higher variability than those corresponding to the upper beak. This fact could be due to two factors: the variability inherent to the process of measurement or the morphological changes that take place in the beak. The degree of difficulty involved when different measurements of the lower beak are taken is higher, due to its shape, than in the upper beak, which would bring a higher error. On the other hand, it was observed that the shape of both beaks changes with growth, at least for two of the structures considered in this work, hood and crest, when their lengths are related to the RL. This change is higher in the lower beak, where these relationships showed a strong alometry, while in the upper beak a slight alometry in the relationship HL/RL and isometry for CL/RL were detected. These results reflect what could be perceived intuitively from the direct observation of beaks of different sizes (Figure 2). While the shape of the upper beak remains relatively invariable for all the sizes, the lower beak of an adult looks different from that of a juvenile, specially for the different proportions between hood and crest.

Four indices of the upper beak obtained in this work were compared with those corresponding to eight species of the Ommastrephidae family, showing that the values were similar (Wolff, 1984; Figure 4). The HL/CL index presented the highest differences, with a value lower than the other species. No comparisons of this type were made on the lower beak, since different measurements were taken in both works.

Pigmentation changes associated with growth described here are similar to those observed for other ommastrephids (Clarke, 1962; 1980; 1986; Mangold and Fioroni, 1966). Clarke (1962) suggested that the beaks darkening starts to be evident and fast from the onset of the lower beak wings pigmentation, and this is coincidental with the begining of sexual maturation. The process of darkening takes place, in *Illex argentinus*, at about 200 mm ML, and, at this size, the highest proportiont of the squids of both sexes are maturing (maturity stages III-IV), which would indicate that a similar situation to that described by Clarke (1962) also occurs in this species.

The models that describe the relationships between the rostral length of each beak with the mantle length and total weight were calculated with no distinction between sexes, considering that the principal objective was to have a useful tool for the reconstruction of sizes and weights of squids from beaks found in the stomach contents of their predators. Even though there is a high possibility that these relationships differ between sexes, due to their different growth, it would not be useful to have a model for each one, since it is impossible to know if the beaks found in the stomach contents belong to males or females. Mercer *et al.* (1980), by using morphometric measurements in discrimant analysis, identified the beaks of each sex in *Illex illecebrosus*, being possible, then, that this fact could be verified also in a related species, such as *Illex argentinus*. Nevertheless, for the practical use that we propose, we believe that the relationships obtained are highly useful. Moreover, these relationships are similar to those proposed by Aguiar dos Santos (1992):

Lower beak $ML = 5.95 + 60.89\ RL$ $\ln TW = 1.05 + 3.25 \ln RL$
Upper beak $ML = 3.54 + 51.05\ RL$ $\ln TW = 0.91 + 3.03 \ln RL$

in the case of the upper beak, while those correponding to the lower beak are significantly different. The differences are probably due to the fact that different lower rostral lengths were recorded in both works. RL taken by Aguiar dos Santos (1992) are apparently higher than those presented here, since they were measured including the knob situated in the base of the mandibular angle, as it is showed in the graph presented by the author, while in our case the RL was measured between the rostral tip and the proper angle. Figure 4 also shows that even though a high variability is presented in the b values corresponding to the lower beak relationships between RL and TW, comparing sixteen species of ommastrephids, for the three *Illex* species involved the values were similar.

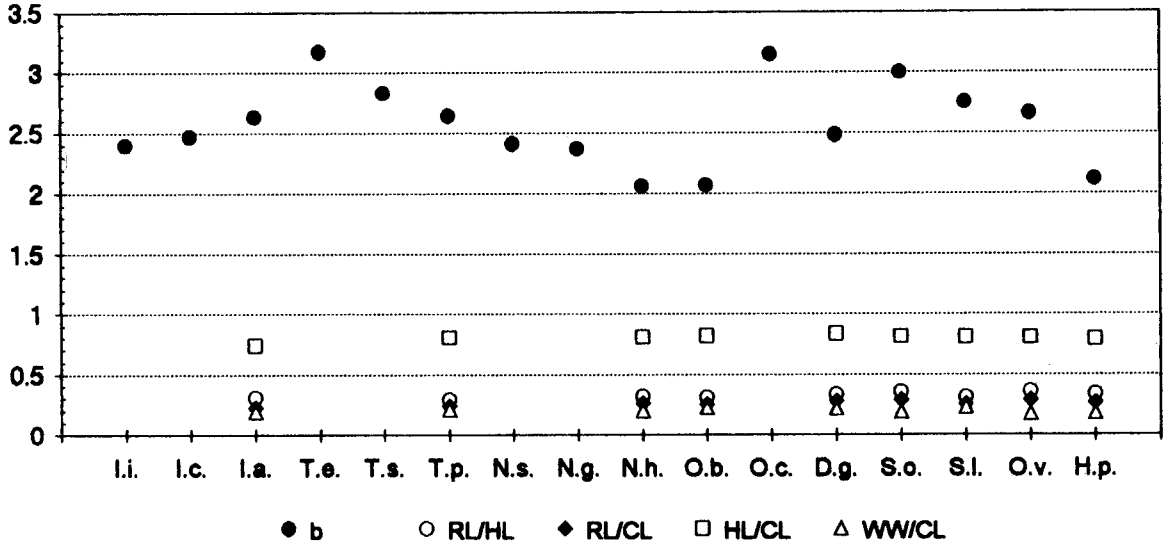

FIGURE 4. Comparison of four mean relative ratios of the upper beak and the b values of the rostral length/total weight relationships of the lower beak of sixteen ommastrephid species: I.i.: Illex illecebrosus, I.c.: Illex coindeti, I.a.: Illex argentinus, T.e.: Todaropsis eblanae, T.s.: Todarodes sagittatus, T.p.: Todarodes pacificus, N.s.: Nototodarus sloani, N.g.: Nototodarus gouldi, N.h.: Nototodarus hawaiiensis, O.b.: Ommastrephes bartramii, O.c.: Ommastrephes caroli, D.g.: Dosidicus gigas, S.o.: Symplectoteuthis oualaniensis, S.l.: Symplectoteuthis luminosa, O.v.: Ornithoteuthis volatilis, H.p.: Hyaloteuthis pelagica. Data taken from Wolff (1984) and Clarke (1986). (RL: rostral length, HL: hood length, CL: crest length, WW: wing width).

FIGURA 4. Comparación de cuatro índices relativos medios calculados para la mandíbula superior y de los valores de b correspondientes a las regresiones entre el peso total y el largo del rostro de la mandíbula inferior entre dieciseis especies de calamares ommastréfidos: I.i.: *Illex illecebrosus*, I.c.: *Illex coindeti*, I.a.: *Illex argentinus*, T.e.: *Todaropsis eblanae*, T.s.: *Todarodes sagittatus*, T.p.: *Todarodes pacificus*, N.s.: *Nototodarus sloani*, N.g.: *Nototodarus gouldi*, N.h.: *Nototodarus hawaiiensis*, O.b.: *Ommastrephes bartramii*, O.c.: *Ommastrephes caroli*, D.g.: *Dosidicus gigas*, S.o.: *Symplectoteuthis oualaniensis*, S.l.: *Symplectoteuthis luminosa*, O.v.: *Ornithoteuthis volatilis*, H.p.: *Hyaloteuthis pelagica*. Datos tomados de Wolff (1984) y Clarke (1986). (RL: largo rostral, HL: largo del capuchón, CL: largo de la cresta, WW: ancho del ala).

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