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A PRELIMINARY STUDY ON THE GROWTH OF THE OCTOPUS *Octopus vulgaris* (Cuvier, 1797)

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ABSTRACT: *The ageing of Cephalopoda through growth rings on statoliths, is a time consuming process and often impossible to perform. Length frequency analysis is a promising alternative for growth studies on this taxonomic group. Cephalopods do not show a regular growth pattern; growth rate fluctuates under the influence of temperature and food availability. The new methodology, known as seasonally oscillating von Bertalanffy growth model, was applied to* Octopus vulgaris *collected from the western part of the Gulf of İzmir. Paying additional effort to length - weight relationship of this species, the growth of* O. vulgaris *was investigated.*

AHTAPOTLARIN, *octopus vulgaris* (CUVIER, 1797) BÜYÜMESİ ÜZERİNE BİR ÖN ÇALIŞMA

ÖZET: *Sefalopodların yaşlarının, özellikle statolitlerindeki büyüme halkalarından okunması zaman alıcı ve çoğu zaman mümkün olmayan bir yöntemdir. Boy-frekans analizleri bu taksonomik grup üzerine yapılacak büyüme çalışmaları için alternatif bir yöntem olarak düşünülmüştür. Sefalopodlar düzenli bir büyüme eğrisi göstermezler; büyüme hızı sıcaklık ve uygun besin miktarına bağlı olarak dalgalanma gösterir. Oldukça yeni bir method olan mevsimsel salınımlı büyüme modeli İzmir körfezinin batısından toplanan* Octopus vulgaris *türüne uygulanmıştır. Ayrıca çalışmada aynı türdeki boy-ağırlık ilişkisi de dikkate alınarak* O. vulgaris' *in büyümesi incelenmiştir.*

INTRODUCTION

Due to an overall decline in the total fish production in the oceans, attention has been diverted to cephalopod stocks since the 1970s. While the production of most fish stocks has steadily decreased, yield from cephalopod stocks has increased remarkably. In addition to the increasing commercial importance of cephalopods, they have gained scientific importance as well. Past studies (1, 2, 3 and 4) have established several reasons for the explosive growth of cephalopod populations. JONES (2) attributed the increase in cephalopod production to a direct consequence of the reduction of fin fish predation on larval and prerecruit stages. According to CADDY (3), cephalopods are highly opportunistic species. They are capable of rapidly expanding their population size to occupy the niches left unoccupied by the depletion of other resources, as in the case of over-fishing of teleost fishes. Also, because of their opportunistic feeding patterns and relatively high growth rate, they are likely to be capable of exerting significant ecological pressure especially on fish stocks.

In the Mediterranean Sea, cephalopods have been actively fished and sought by consumers for a long time. At present, only the western basin is exploited by Italian and Spanish fishermen. In the Turkish fishing fleet, there is no specific fishing technique applied to cephalopods; these species are caught as 'by catch', together with demersal fishes and shrimps. Therefore, in Turkiye this group of organisms did not gain either the commercial or scientific recognition it deserved.

The annual landings of Turkish aquatic resources have been reported by the State Institute of Statistics, D.I.E, since 1968. If the statistics given by this institute is examined, a steady increase in fin fish and cephalopod production for the past 10 years is apparent in the Marmara, Aegean and Mediterranean coasts of Turkiye. The most pronounced increase among the cephalopods was reported for the Aegean sea. The total yield from commercial landings started to increase considerably after 1978, finally leveled out at approximately 500, 000 tons in 1983. Similarly, the octopus and total cephalopod catch increased slightly after 1978, due to an increase in fishing effort (increasing number of boats and increasing engine power). The greatest increase was recorded directly after the reduction in fish production in 1983. This is in good agreement with the above mentioned phenomena about the opposite trends in the fish and cephalopod production (5).

MATERIAL AND METHODS

The primary problems in collecting adequate specimens for the present study are associated with the behavior of *Octopus vulgaris*. First, there is no pronounced aggregation when *O. vulgaris* migrate to inshore waters for spawning. Secondly, *O. vulgaris* specimens show sexual differences in the inhabitation behavior during spawning periods. The female *O. vulgaris* generally lays its eggs into the cavities of large rock blocks or into the walls of self-made nests. They care for the eggs by aerating and repulsing algal growth on egg clusters until they hatched. Meanwhile, they go out of the nest seldom and only for very short times, whereas males maintain their activity freely. Therefore, the solitary nest building activity of females, makes them less vulnerable to trawl nets, which is the most effective fishing gear for a quantitative sampling of this species than the male octopuses. On that premise, it was thought that, collecting samples by means of a spear gun would have an advantage over other fishing gears and the both sexes would have the same probability of capture.

In the study, 124 *O. vulgaris* specimens were collected from the western part of the İzmir bay (Fig. 1). Two skin divers speared all specimens of *O. vulgaris* they could detect, along their predefined diving route, within a certain depth range, not exceeding 20 meters. While spearing, great attention was made not to eviscerate the individual.

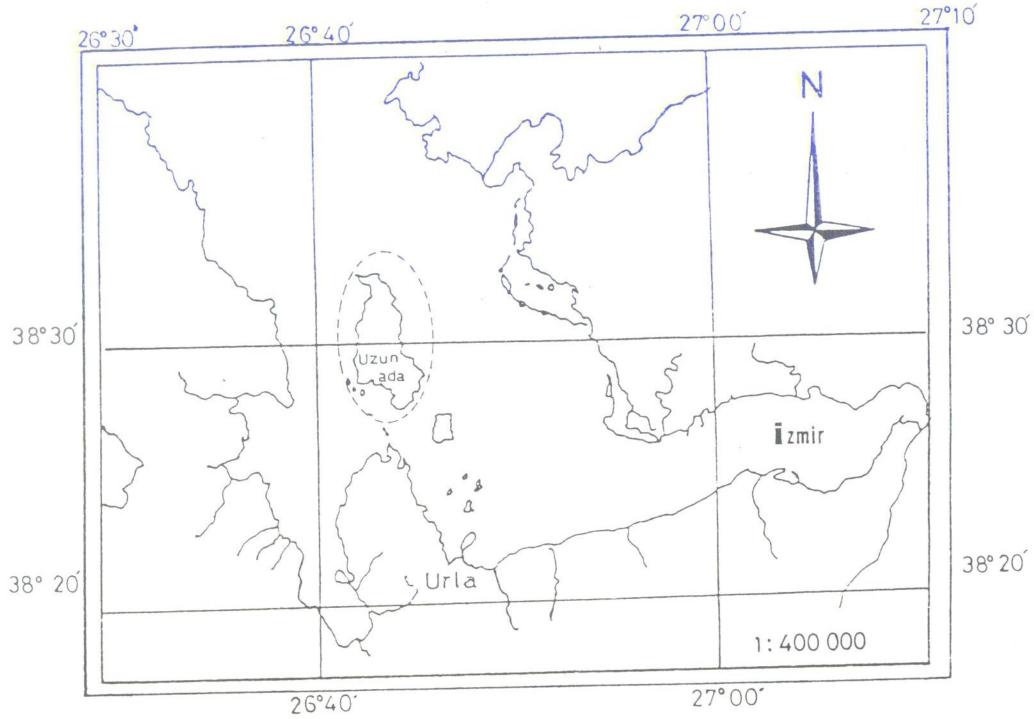

Figure 1. Gulf of İzmir (dashed circle presents sampling area).

Adult *O. vulgaris* specimens migrating into coastal waters for spawning, were collected in April - May 1988. The remnants of parents and their recruiting offsprings were collected in a second period (September - November 1988). Body weight (to the nearest 50 g group), total (TL) and mantle length (ML) were measured to the nearest centimeter group. Mantle length was used as the standard measure for all calculations, rather than total length. All measurements were carried out when the specimen was in relaxed state (3).

Length and weight measurements were tested to determine if the weight-length relationship ($W=aL^b$), which is used for fish populations, could be used for *O. vulgaris*. In this expression, W = weight in grams, L = body length (in this case ML (cm)), and a and b are constants that are estimated from length-weight data pairs using power curve fitting technique. Goodness of fit was also estimated using 'product moment correlation coefficients'.

The seasonalized version of von Bertalanffy equation, which was used in the present study to describe the growth, was proposed by PITCHER and MACDONALD (6), CLOERN and NICHOLS (7), PAULY and GASCHUTZ (8):

$$L_t = L_\infty \left[1 - \exp\left(-K(t - t_o) + \frac{CK}{2\pi} \sin 2\pi (t - t_s) - \frac{CK}{2\pi} \sin 2\pi (t_o - t_a) \right) \right]$$

L_∞ is the asymptotic length, that is the mean length that would be reached if they grew indefinitely; **K** is a growth constant, which may be conceived as a stress factor; **to** is a theoretical value indicating the age at zero length (if they had always grown in the manner described by the equation); **ta** is the winter point where the curve has started to oscillate, **C** determines the amplitude of the oscillation.

To estimate the parameters of the seasonalized von Bertalanffy formula, the ELEFAN software package was used.

Finally, and index for the comparison of individually estimated growth parameters from different stocks, was calculated. This growth performance index ((Ø')) was proposed by PAULY and MUNRO (9) as;

$Ø' = \log K + 2 \log L_\infty$

where K is expressed on an annual basis and L_∞ in cm.

RESULTS

Weight-length relationships

Results of the length-weight relations valid for specimens ranging from 5 to 33 cm ML, are presented in Table 1 and Figures 2 and 3. It is evident that there is a highly significant correlation between weight and mantle length in all estimates, which suggests that the relation between mantle length and total body weight of *O. vulgaris* can be expressed by $W = aL^b$ equation.

A closer examination of the parameters shows that 'b' is always below 3, thus *O. vulgaris* stocks examined exhibit a negative allometric growth.

Parameter 'a' can be interpreted as an index of the condition of the individuals, in question (1). The value of this parameter is always higher in the spring compared to that of autum (Table 1). Comparing both sexes, females had the highest 'a' values. As mentioned previously, in the spring, adult specimens, which usually overwinter in relatively deeper waters, migrate to inshore waters to spawn (10). During this time of year, before starting spawning migration, maturation of the gonads is almost complete, especially the ovaries, which attain their maximum volume and weight. Since the reproductive stage is one of the main factors positively influencing the condition factor (parameter 'a'), a higher condition factor in the spring may be attributed to the presence of mature gonads.

Table 1. Length-weight relationship of *Octopus vulgaris* (a and b are the regression coefficients; intercept and slope, respectively; r is the correlation coefficient and n is the sample size)

sex	a	-	+	b	-	+	r/n
				Spring			
male	2.27	0.37	17.95	2.33	1.48	3.17	0.86/15
female	9.89	3.18	30.79	1.90	1.41	2.39	0.94/12
f + m	7.09	2.83	17.78	1.99	1.60	2.39	0.90/27
				Fall			
male	1.17	0.39	3.48	2.88	2.41	2.36	0.94/23
female	3.46	1.97	6.09	2.42	2.18	2.67	0.92/74
f + m	2.50	1.54	4.06	2.57	2.36	2.78	0.93/97
				Combined			
male	7.14	2.87	17.78	2.06	1.67	2.46	0.87/38
female	7.54	4.93	11.52	2.06	1.88	2.25	0.92/86
f + m	7.82	5.36	11.42	2.04	1.88	2.21	0.91/124

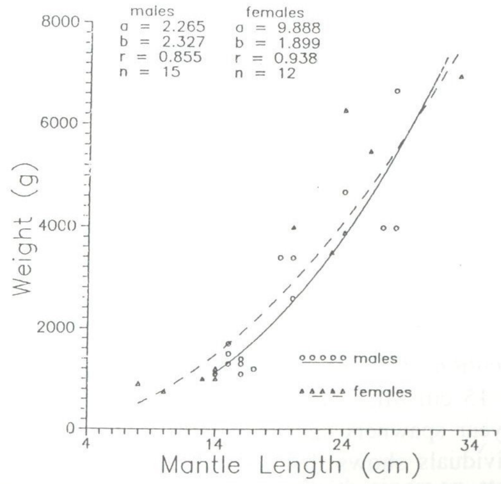

Figure 2. Weight-length relationships of *O. vulgaris* collected in spring 1988.

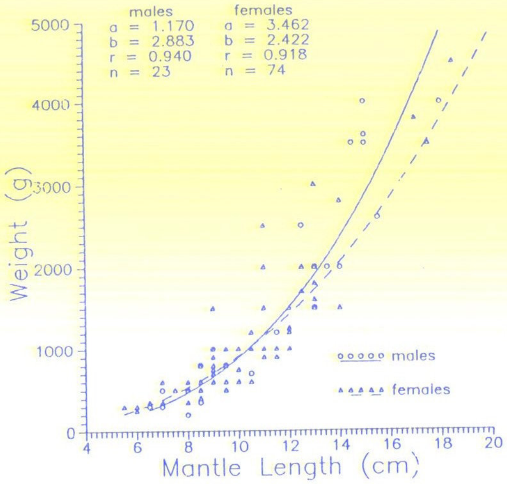

Figure 3. Weight-length relationships of *O. vulgaris* collected in fall 1988.

Estimation of Growth Parameters

Estimated growth parameters are given in Table 2. and fitted growth curves are presented in Figure 4. The results reveal that growth in *O. vulgaris* exhibits sexual dimorphism. Each sex has a different K (per year) constant, hence, males which have a higher K constant grow faster than females, and attain larger sizes, as already outlined by CADDY (3).

Table 2. Estimated growth parameters (L∞ = Asymptotic length; K = Growth constant; C = Amplitude of seasonal oscillation; WP = Winter Point; Ø ' = growth performance index)

sex	L∞	K	C	WP	Ø
male	34.0	1.00	1.0	0.15	3.06
female	33.0	0.80	1.0	0.15	2.94
combined	35.0	0.30	1.0	0.16	2.57

In length frequency distribution of spring period (Fig. 4.), main bulk of the first year spawners are apparent (around 15 cm ML). However, some other larger individuals which could not included to the first year spawners can be seen in the same period (Fig. 4.) The existence of these larger individuals shows that although octopuses are known to be terminal spawners, i.e. the female dies after brooding, some of the parents can survive after the critical brooding period and they can return back to the inshore waters next year for spawning.

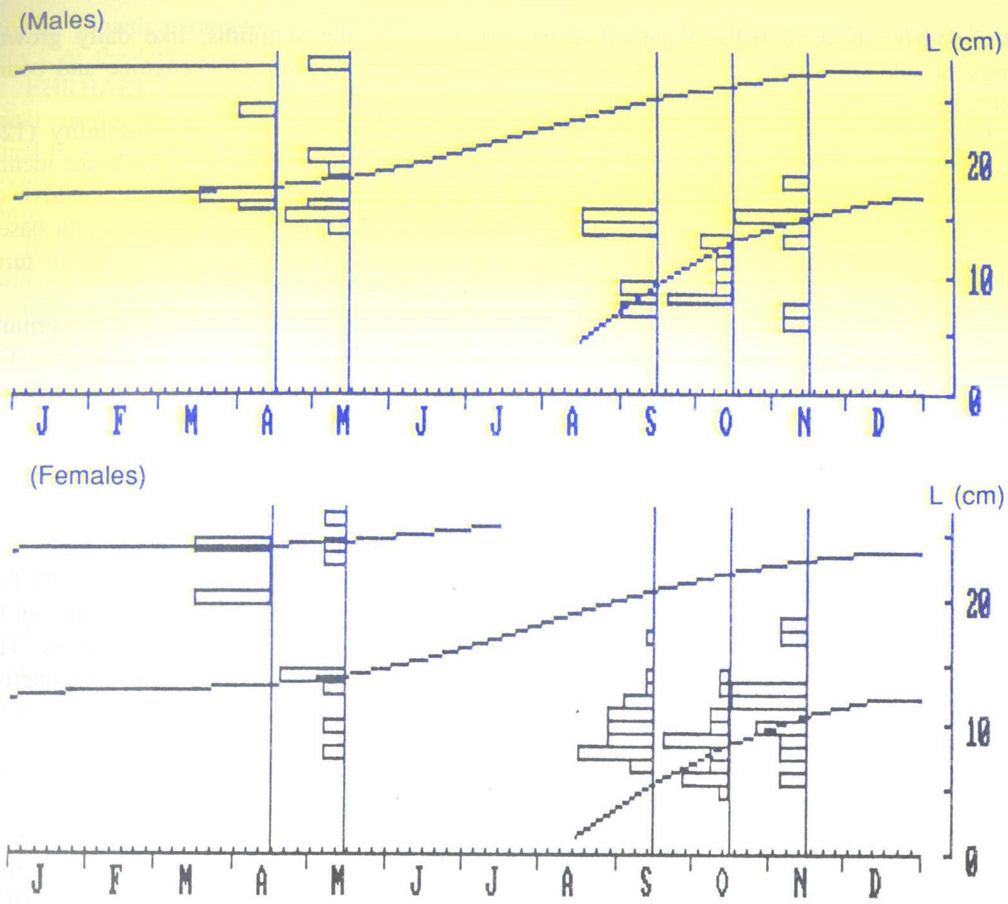

Figure 4. Estimated growth parameters and fitted growth curve for *O. vulgaris*

In the present study, newly recruited individuals dominated the samples during the later summer. The growth rate was so high during this phase of their life that growth could be expressed linearly. During the following winter, growth slowed down possibly due to the combined effects of decreased temperature and food availability. In the spring, growth remained low, because of winter-related stress and because adults stop feeding while brooding their eggs.

DISCUSSION

Growth has been measured by analysis of growth rings on statoliths, by experiment in tanks, and by length frequency analysis. Age determination by counting growth rings on the statoliths is time consuming (both, in preparation of a statoliths and in interpretation). Since

O. vulgaris is a short-lived animal, finer structures on the statoliths, like daily growth rings, should be examined, rather than closer seasonal depositions. To recognize and count finer structures, expensive auxiliary instruments are required.

Growth is directly related to the ambient temperature (11) and food availability (12). Therefore, for the case of experimental tank work, unless conditions in the tank are identical to those of environment, results obtained experimentally would not be representative of the stocks, where temperature and food are crucial factors. Therefore, fitting a length based growth model to the *O. vulgaris* is of great importance for studying growth and, in turn, for population dynamics of this species.

EHRHARDT et al. (13) attempted to fit the normal von Bertalanffy growth formula (VBGF) to *Dosidicus gigas* in the Gulf of California; however, the results were not satisfactory. They concluded that the growth of *D. gigas* demonstrated a linear pattern and the influence of season relation to temperature and food availability was very high.

A similar study that reported linear growth in cephalopods, was carried out by BAKHAYOKHO (14) on cuttle fish *(Sepia officinalis)*. He added that his work dealt primarily with young individuals, therefore during a specific period of their life, growth would eventually be faster and correspond to the rapid growth phase of the von Bertalanffy's model.

The limited success in the parameterization of the growth by means of von BERTALANFFY equation can briefly be attributed to the seasonal variation in the growth of *O. vulgaris* This variation may be explained by the spawning behavior of the species. The most female octopuses undergo a single spawning season. Completion of all reproductive activities (until brooded egg mass completely hatch), is often followed shortly afterwards by death of the female (3). Moreover, while brooding the eggs, the female octopus stops feeding. O'DOR et al. (12) experimentally showed that food availability is the primary factor limiting growth. LONGHURST and PAULY (15) reviewed the maximum size of squids in different parts of their range and comparing the intraspecific variations as a function of temperature, they concluded that growth is a function of temperature. This consequetly, brought about an inconsistent and contradictory growth model. LONGHURST and PAULY (15) summarized the most crucial points of this new model as 1) linear growth of small species in the absence of food limitation, 2) cyclic growth related to environmental temperature, and 3) sigmoid, asymptotic and even exponential growth throughout life. Therefore, unless these points are taken into account, the validity of the von Bertalanffy growth model is doubtful, especially in cases, where seasonal limitations in feeding and temperature may be paramount.

GUERRA (16) applied modal progression analysis to a large number of *O. vulgaris* from Mediterranean Sea and could estimate growth parameters without indicating any problem related to the seasonality of the growth pattern. However, from the results plotted in his article, seasonal fluctation is apparent, especially in the smaller size groups see Figure 1 in GUERRA, (16)]. Nevertheless, growth parameters estimated in his work, is still consistent with the parameters estimated in the present study.

MANGOLD and BOLETZKY (11) was investigated reproduction and growth of *O. vulgaris* and estimated montly growth rates experimentally. Extrapolating these growth rates to the growth parameters obtained in the present study, it was observed that *O. vulgaris* stock of the Urla region grows slightly faster than the individuals used in their study.

EHRHARDT et al. (13) investigated the length-weight relation of the giant squid *(D. gigas)* in the Gulf of California, The only point which is not consistent with the results obtained here, is the isometric growth of *D. gigas*. The difference between both studies, may be explained by the more rigid body form of *D. gigas* compared to the plastic shape of octopuses.

BAKHAYOKHO (14) studied the mantle length vs. body weight relation of *Sepia officinalis* in the Indopacific and found negative allometric growth using similar methodology.

Results of this study are not accurate enough to represent the octopus stocks of Gulf of İzmir, because coverage of the sampling area was limited to Urla. In population dynamic studies carried out around the Gulf of İzmir, cephalopods have been excluded so far, due to difficulties in the age determination and in the estimation of growth parameters. This study is an attempt to show that the seasonally oscillating version of von Bertalanffy growth equation can be effective for determining the growth pattern of *O. vulgaris* stocks. Henceforth, applying this relatively simple and computerized methodology, *O. vulgaris* stocks can be evaluated as rapid as teleost fish stocks. This is also promising for utilizing the other fish population dynamic models in *O. vulgaris* stocks as well.

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REFERENCES

1. *Pauly, D., 1979. Theory and Management of Tropical Multispecies Stocks: A Review, With Emphasis on the Southeast Asian Demersal Fisheries. ICLARM Stud. Rev. 1, 1-35.*

2. *Jones, R., 1982. Ecosystems, Food Chains Fish Yields. In:* Theory and Management of Tropical Fisheries. *Eds. D. Pauly and G. I. Murphy. pp. 195-239. ICLARM Manila*

3. *Caddy, J.F., 1983. The Cephalopods: Factors Relevant to Their Population Dynamics and to the Assessment and Management of Stocks. [Ed.] Caddy, J.F.* Advances in Assessment of World Cephalopod Resources. FAO Fish. Tech. Pap. *(231): 452 p.*

4. *Worms, J., 1983. World Fisheries for Cephalopods: A Synoptic Overview. [Ed.] Caddy, J.F.* Advances in Assessment of World Cephalopod Resources. FAO Fish. Tech. Pap. *(231) : 452 p.*

5. *DIE, 1974-1989. Fishery Statistics 1970-71. State Institute of Statistics, Publ. , No., 718, 874, 947, 966, 1007, 1066, 1129, 1166, 1265, 1389.*

6. *Pitcher, T.J. and P.D.M. Macdonald, 1973. Two Models for Seasonal Growth in Fishes. J. Appl. Ecol. 10: 597-606.*

7. *Cloern, J. E. and F.H. Nichols, 1978. A von Bertalanffy Growth Model With a Seasonal Varying Coefficient. J. Fish. Res. Board Can., 35: 1479-82.*

8. Pauly, D. and G. Gashutz, 1979. A Simple Method for Fitting Oscillating Length Growth Data, With a Program for Poket Calculators. ICES C.M. 1979/g: 2426p.

9. Pauly, D and J. L. Munro, 1984. Once More on Growth Comparison in Fish and Invertebrates. Fishbyte 2 (1): 21.

10. Roper, C.F.E., M.J. Sweeney and C.E. Nuen, 1984. FAO Species Catalogue. Vol. 3. Cephaloods of the World. An Annotated and Illustrated Catalogue of Species of Interest to Fisheries. FAO Fish. Synop., (125) Vol. 3. : 277 p.

11. Mangold K. and S. V. Boletzky, 1973. New Data on the Reproductive Biology and Growth of Octopus vulgars. *Mar. Biol. 19: 382 p.*

12. O'Dor, R.K., Durwood, R.D., Vessey, E. and Amaratunga, T., 1980. Feeding and Growth in Captivity Squid, Illex illecibrosus, and the Influence of Food Availability of Growth in the Natural Population. ICNAF Sel. Pap. 6, 15-21.

13. Ehrhardt, N.M., Jacoquemin , P.S., Garcia, F.B., Gonzales, G.D., Lopez, J.M., Ortiz, J.C. and N.A. Solis, 1983. On the Fisheries and Biology of the Giant Squid Dosidicus gigas in the Gulf of California, Mexico. [Ed.] Caddy, J.F., Advances in Assessment of World Cephalopod Resources. FAO Fish. Tech. Pap. *(231): pp . 306-340.*

14. Bakhayokho, M., 1983. Biology of the Cuttlefish Sepia officinalis hierredda off the Senegalese Coast. [Ed.] CADDY, J.F. Advances in Assessment of World Cephalopod Resources. FAO Fish. Tech. Pap. *(231): 204-265.*

15. Longhurst, A.R. and D. Pauly, 1987. Ecology of the Tropical Oceans. Academic Press Inc. California. 407 p.

16. Guerra, A., 1979. Fitting a Von Bertalanffy Expression to Octopus vulgaris Growth. Inv. Pesq. 43 (1) pp. 310-326.