Mediterranean Marine Science
Volume 10/1, 2009, 25-34

Studies on the allometric growth of the caramote prawn *Melicertus kerathurus* (Decapoda, Penaeidae) in Western Greece (E. Mediterranean)

K. KAPIRIS and A. CONIDES

Hellenic Centre for Marine Research, Institute of Marine Biological Resources,
47o km Athens-Sounio, Mavro Lithari P.O. Box 712, 19013, Anavissos, Attica, Greece

e-mail: kkapir@ath.hcmr.gr

Abstract

The relative growth of eleven body parts (carapace length, height, width, abdominal length, height and width, rostral length and telson length) of males and females of the caramote prawn Melicertus kerathurus *was studied in samples from the Amvrakikos Gulf (Western Greece, E. Mediterranean). In addition to this, the relative growth of the length and the maximum width – and consequently the surface - of the appendix masculina of males was also studied. In general, both sexes showed similar patterns of relative growth. However, the females' body appendages were significantly greater than those of the males. A negative allometry of escaping appendages (telson), abdomen (related to the metabolic processes, rapid locomotion and reproduction), rostrum, appendix masculina (related to mating and sperm transfer) and carapace height and width was found in both sexes. The biometric studies in this species in the central and western Mediterranean are in agreement with those from the eastern part of the basin, suggesting that all the populations throughout the Mediterranean could be considered as uniform.*

Keywords: Caramote prawn; Biometry; Relative growth; Western Greece.

Introduction

The caramote prawn *Melicertus kerathurus* (FORSKÅL, 1775) is a native species in the Mediterranean Sea and the East Atlantic, from Portugal to Angola, and lives in sandy-mud bottoms up to depths of about 80 m. It is extensively fished in all the Mediterranean inshore waters and has been considered for aquaculture in the Mediterranean since 1970 (LUMARE, 1976).

In Greece the species is isolated in the Amvrakikos Gulf (Western Greece), while smaller populations insufficient to support a target fishery can be found along the Ionion Sea coast of Greece and the North Aegean Sea (from the Gulf of Thermaikos to Alexandroupolis, ANON, 2001). It is commonly accepted that scientific knowledge of the coastal ecosystems is still limited. In the case of a closed gulf, such as the Amvrakikos Gulf, pollution and the other coastal human activities apply significant stress to the population of the native prawn, *M. kerathurus* (N.C.M.R., 1989). The isolation of the species population in the Amvrakikos Gulf, combined with the fact that this population has been relatively little studied and is considered as the most valuable commercial product in the region, makes the need for a thorough study imperative.

Allometry describes how an animal organism changes in shape and proportion as it grows (PETERS, 1983). The allometric analyses, or relative growth patterns, of various decapod crustaceans have been studied widely and these can provide a good technique to elucidate the relationships between processes of growth and evolution (BLACKSTONE, 1987). Morphological variation studies within and among penaeid species in the wild began only over 35 years ago for purposes of fishery management and taxonomic purposes. Penaeid shrimps differ in a variety of morphological characteristics that are the expression of genetic differences among them (LESTER & PANTE, 1992). Notwithstanding that many biological aspects of this penaeid are already known, data from biometric studies of *M. kerathurus* are scarce, from the Central (SE Italian coast, LUMARE *et al.,* 1993, E. Tunisia, BEN MARIEM, 1995) and Western Mediterranean (RODRÌGUEZ, 1987). The only study concerning its morphometry in the E. Mediterranean refers to the comparative pattern of taxonomic relationships and the morphological divergence of three shrimps, *M. kerathurus* included, in samples collected from Turkey (AKTAS *et al.,* 2006). According to this study *M. kerathurus* is a taxon closer to *Penaeus semisulcatus,* than *Metapenaeus monoceros.*

Despite the fact that the major aspects of the biology of this species in the Amvrakikos Gulf have recently been published (CONIDES *et al.,* 2006; 2008, KEVREKIDES & THESSALOU-LEGAKI, 2006; KARANI *et al.,* 2005), this is the first attempt to study the morphometric profile of both sexes of *M. kerathurus* individuals on a seasonal basis, and to discuss any possible significant differences, comparing the results with similar studies obtained in the Mediterranean basin. Moreover, this is the first study concerning the appendix masculina of the caramote prawn. This is an accessory male organ, fully developed in adult males, located medially on the second pair of pleopods (WILLIAMS, 1984) and, with the petasma, helps in sperm transfer and copulation (BAUER, 1986). Many stock assessment models require the input of morphometric measurements that could play a vital part in fisheries' conservation (PEZZACK & GUTT, 1998). This paper could be an initial hypothesis for further investigation regarding the morphometric structure of the caramote prawn in the Mediterranean basin and aims at elucidating its population structure and management strategies.

Material and Methods

The Amvrakikos Gulf is located on the west coast of Central Greece between 38°55' and 39°05' N and 20°45' and 21°10' E. It covers an area of 530 km^2 with a maximum length of 35 km and maximum width of 20 km. The maximum depth of the gulf is approximately 58 m and is connected with the open sea (the Ionian Sea) through a narrow channel located on the west side. There are 2 rivers; the Louros and Arachthos, which outflow into the gulf area from the north, creating a complex habitat that sustains aquatic ecosystems locally. Most of the fisheries' production of the Amvrakikos area originates from four lagoons in the northern part (ANANIADIS, 1984) but pollution (agriculture chemicals) and the management of freshwater flows for irrigation have caused a dramatic deterioration in water quality and decrease in landings.

Individuals of *M. kerathurus* were collected in the frame of an experimental fishery project organized on a monthly basis during the period 2000-2001 (11 monthly samplings, there is a month's closure for the fishery during July) from the Amvrakikos Gulf (Western Greece, Fig. 1). The prawns were caught using traditional, static bottom trammel nets, with 22 mm internal mesh and 110 mm external mesh. The length of the net averaged 1000 m (800-1500 m), and the height was about 1.2 m (0.8-2 m). Nets were deployed at depths ranging from 1 to 15 m at angles in relation to the coastline, depending on the local morphology and recommendations from experienced fishermen. Specimens were kept on ice until transported to the laboratory. There they were stored in a freezer at -20°C until they were measured.

A total of 2264 females and 3295 males were measured using calipers to the nearest 0.01 mm. To avoid bias due to measuring procedures, the same person always took the measurements. Eight morphometric characteristics were measured on each specimen (Fig. 2). They were: carapace length (CL), carapace height (CH), carapace width (CW), abdominal length, height and width (AL, AH, AW, respectively), rostral length (R) and telson length (T). In addition to this,

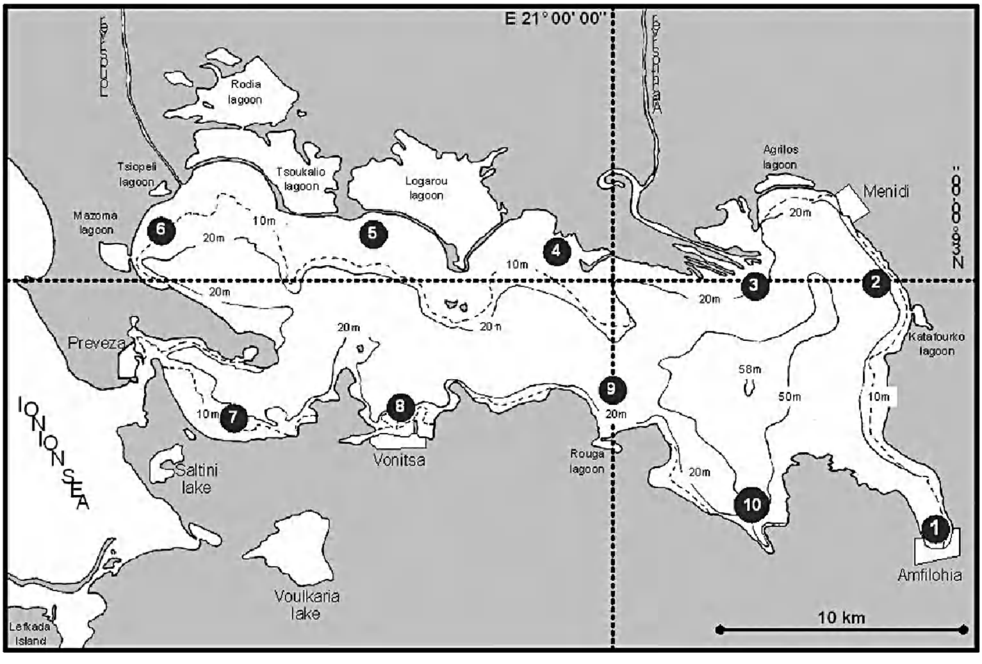

Fig. 1: Map of the sampling area and the depth range of the sampling stations of *M. kerathurus* in the Amvrakikos Gulf.

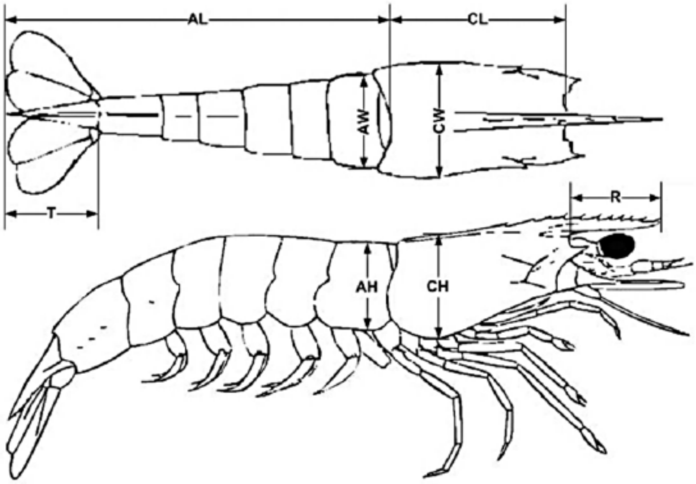

Fig. 2: Morphometric measurements taken on *M. kerathurus* CL: carapace length (CL), carapace height (CH), carapace width (CW), abdominal length, height and width (AL, AH, AW, respectively), rostral length (R) and telson length (T).

the length and the maximum width of the appendix masculina (AMl and AMw respectively) of 682 males were measured under a WILD microscope equipped with a calibrated ocular micrometer. Since their shape is triangular, the formula for the triangle area was used to calculate their surface [AMsu = (AMw x AMl) / 2].

Since carapace length appeared to be minimally affected by growth variations and sexual maturation (LOVETT & FELDER, 1989), this measurement was considered as the independent variable for all relationships performed. The relationship between all measurements vs. CL was investigated for each sex separately using the multiplicative model $Y = aX^b$, where Y and X are the morphological dimensions and a, b the regression constants. The relationships obtained were log-transformed to the form $\log Y = \log a + b \log X$. Log transformation was preferred in order to better satisfy the assumptions of regression analysis (SOKAL & ROHLF, 1981). This allows a single value to be derived from the analysis for the scaling relationship between the two-morphometric parameters. The pattern of allometry for each parameter was established by testing the slope (b) of the obtained regression equations against isometry (Ho: b=1) applying the Student's t-test. The Kruskall-Wallis test (ZAR, 1984) was used to identify possible differences in time, at the 95.0% confidence level. The Mann-Whitney test was applied as a non-parametric test to compare independent samples, at the 95.0% confidence level (SOKAL & ROHLF, 1981).

Results

Mean sizes and standard deviations of all female appendages were larger than those of males throughout the sampling period (Mann–Whitney and Kolmogorov tests, $P<0.0$). The only exception was the rostral length, since no statistically significant difference was observed between the medians of both sexes (Mann-Whitney test, $P>0.05$). In the study area, all the meristic characters proved to be statistically significantly different in both sexes over the seasons (Kruskal-Wallis, in all cases $P<0.01$). All mean values of measurements of females were higher in summer and mainly lower in autumn. Males, by contrast, showed their highest values during autumn and winter (Table 1). The length of the appendix masculina is 1.5 times greater than its width. The main morphometric relationships established for males and females are illustrated in Figure 3. In Figure 4 the morphometric relationships between the carapace length and appendix masculina (length, width, surface) of males are given. The measurements of both sexes showed a single continuous regression line, since juveniles and adults did not show any abrupt change in their morphology. Thus, the regression parameters (Table 2) have been estimated taking into consideration all the monthly measurements.

Table 1
Mean seasonal values (mm) and standard deviation (SD) of *Melicertus kerathurus* (Forskal, 1775) measurements of both sexes in the study area.

Measure		Season			
		Winter	Spring	Summer	Autumn
	Sex	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
CL	M	35.39 (2.61)	33.77 (2.76)	34.72 (2.36)	35.02 (4.03)
	F	38.47 (4.40)	38.19 (3.62)	43.68 (3.93)	37.22 (6.56)
CH	M	18.45 (2.07)	17.25 (1.97)	16.89 (2.12)	18.90 (2.97)
	F	20.11 (2.84)	20.00 (2.24)	22.68 (2.79)	19.73 (4.31)
CW	M	15.57 (1.63)	14.20 (1.61)	14.51 (1.91)	15.70 (2.39)
	F	17.15 (2.20)	16.21 (2.29)	19.74 (2.59)	16.61 (3.39)
AL	M	71.08 (4.91)	68.26 (4.89)	69.73 (4.69)	70.73 (7.63)
	F	73.75 (7.89)	73.64 (5.71)	79.40 (5.55)	71.76 (10.75)
AH	M	14.78 (1.66)	13.77 (1.54)	13.96 (1.68)	15.43 (2.38)
	F	15.74 (1.81)	15.00 (1.71)	17.04 (2.84)	15.96 (2.89)
AW	M	13.44 (1.62)	12.23 (1.34)	12.75 (1.69)	13.71 (2.01)
	F	14.49 (1.79)	13.46 (1.84)	15.40 (2.25)	14.14 (2.61)
R	M	16.48 (1.73)	14.96 (1.74)	15.09 (1.63)	15.68 (2.25)
(	F	17.97 (8.72)	15.67 (1.71)	17.75 (2.38)	16.08 (3.63)
T	M	21.42 (1.93)	20.30 (1.66)	21.16 (1.54)	20.43 (2.51)
	F	22.13 (2.15)	21.65 (2.17)	23.74 (1.83)	20.54 (3.13)
AMl		0.57 (0.06)	0.54 (0.09)	0.55 (0.08)	0.55 (0.08)
AMw	M	0.41 (0.05)	0.37 (0.06)	0.38 (0.07)	0.39 (0.06)
AMs		0.12 (0.03)	0.10 (0.03)	0.10 (0.03)	0.11 (0.03)

carapace length (CL), carapace height (CH), carapace width (CW), abdominal length (AL), abdominal height (AH), abdominal width (AW), rostral length (R), telson length (T), appendix masculina length (AMl), appendix masculine width (AMw), appendix masculine surface (AMs)

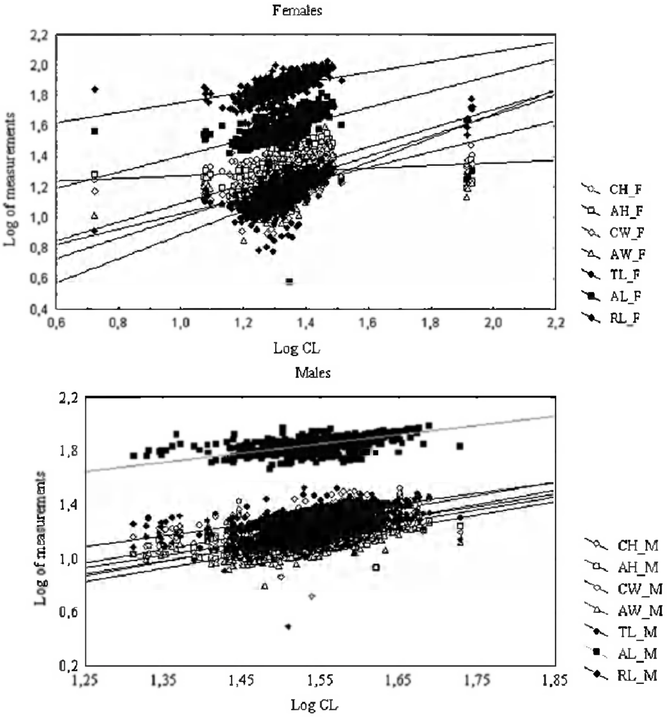

Fig. 3: Relationship between carapace length and other measurements (mm) (logarithmic plots) of *M. kerathurus* females and males in the Amvrakikos Gulf (data pooled for all the sampling periods).

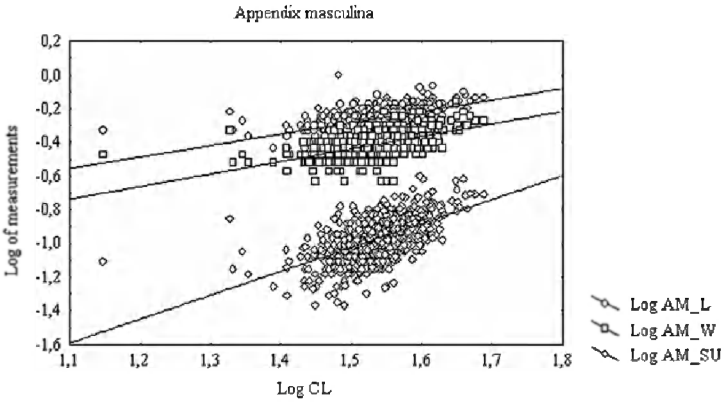

Fig. 4: Relationship between carapace length and appendix masculina measurements (mm, mm^2) (logarithmic plots) of *M. kerathurus* males in the Amvrakikos Gulf (data pooled for all the sampling periods).

The pooled equation parameters representing the relative growth of each parameter in relation to carapace length, after log transformation, of both sexes is given in Table 2. In the same table the correlation coefficient and the type of allometry are included as well as a comparison of the slopes of the regression lines. In all cases, for both sexes, a negative allometry was shown for all the measurements. In females, higher correlation coefficients were usually observed. On the other hand, the slopes (b) in females were more isometric than in males, indicating significant sexual dimorphism. For all the variables, with the exception of the rostrum of males, regressions were statistically significant (ANOVA, P<0.05).

Discussion

The *M. kerathurus* population in the Amvrakikos Gulf belongs to the 0 and 1 year classes only (maximum 1+) and only a very small number of individuals were found belonging to 2 and 2+ classes (CONIDES *et al.,* 2006). Earlier studies in the Amvrakikos Gulf from 1980 to 1984

Table 2
Allometry of the measured appendages in *M. kerathurus* in samples caught in the Amvrakikos Gulf, where n: number of measurements; a: y-intercept; b: slope; r: correlation coefficient; t: Student's t-test statistic. In all cases P<0.05. Carapace length (CL), carapace height (CH), carapace width (CW), abdominal length (AL), abdominal height (AH), abdominal width (AW), rostral length (R), telson length (T), appendix masculina length (AMl), appendix masculina width (AMw), appendix masculina surface (AMs).

Dimension Measured/CL	Sex	n	a	b	r	t-test	Allometry
CH	M	3295	0.87	0.24	0.38	-76.52	Negative
	F	2264	0.80	0.31	0.46	-57.59	Negative
CW	M	3294	0.86	0.21	0.33	-79.16	Negative
	F	2264	0.75	0.30	0.44	-59.26	Negative
AL	M	3237	4.07	-1.45	-0.77	-122.27	Negative
	F	2207	3.72	-1.19	-0.62	-70.46	Negative
AH	M	3295	0.86	0.19	0.31	-81.57	Negative
	F	2263	0.77	0.26	0.46	-74.90	Negative
AW	M	3294	0.85	0.17	0.30	-83.57	Negative
	F	2264	0.77	0.24	0.37	-63.44	Negative
R	M	2665	0.08	0.72	0.83	-31.42	Negative
	F	1785	-0.07	0.81	0.73	-10.56	Negative
T	M	2680	0.14	0.76	0.93	-40.07	Negative
	F	1809	0.03	0.83	0.92	-22.51	Negative
AMl	M	682	1.66	0.47	0.65	-26.61	Negative
AMw	M	682	1.72	0.44	0.67	-56.24	Negative
AMs	M	682	1.80	0.26	0.70	-74.32	Negative

combined with culture experiments in the laboratory showed that the prawn's longevity can be as long as 36 months in this area (KLAOUDATOS 1984). This fact could be attributed to the negative effect of e intensive fishery on the population, causing a decline in the production from the above area (ANON., 2001). Unfortunately, the protection schemes and the management of this protected area are of very low quality. Thus, additional, drastic measures must be applied.

A clear sexual dimorphism size was found for *M. kerathurus:* females reached larger sizes than males during the whole study period. However, it is worth noting that females were much less abundant than males in almost all the sampling months (CONIDES *et al.,* 2008). The obtained allometric equations in the present study showed that the increase in size of all the morphometric characters (carapace height, carapace width, abdominal length, height and width, rostrum and telson) in relation to carapace length is almost the same in both sexes of *M. kerathurus* and expressed by a negative allometry. That means that the carapace length is growing slightly faster than the measured appendages. Similarly, the same growth pattern has been shown for the appendix masculina of males. The higher slope (b) values in females suggest that females grow faster than males. This fact must be taken into account for feature management purposes in the area. All the slight, observed morphological variations between the sexes could be attributed to the marked differences in growth pattern of males (much lower maximum carapace length, greater growth rate values) compared to females (RODRIGUEZ, 1987).

The negative allometry of the escaping appendages (telson) has also been observed in other shrimps, such as *Aristaeomorpha foliacea* (KAPIRIS, 2005) and *Aristeus antennatus* (KAPIRIS & KAVADAS, in press) and was obvious since decapods, while growing, are more in contact with the substratum and, thus, their ability to swim and escape decreases. The higher slope (b) of the regression line for females' telson could indicate their possible greater escaping, and consequently, swimming ability compared to males. Similarly, the observed negative allometry of the abdomen (directly related to overall metabolic process, primarily reproduction, rapid locomotion) is in accordance with the above observation. Thus, the reduction in the ability to move rapidly with increasing size is in agreement with the above reduction in escaping and swimming ability. The same negative allometry of telson and abdomen length was also observed in *M. kerathurus* samples caught in Tunisia (BEN MARIEM, 1995; MUSTAFA, 1962) and in the Acquatina and Lesina lagoons in SE Italy (LUMARE *et al.,* 1993). A negative allometry of abdomen length was observed, in relation to the total length, in both sexes of the caramote prawn collected in the Gulf of Cadiz (Spain) (RODRÌGUEZ, 1987). A similar growth pattern of the rostrum (an organ possibly related to mating and swimming behavior, sexual segregation and feeding), in relation to carapace length, was reported by BEN MARIEM (1995).

The maximum mean value of the appendix masculina's length and width, and consequently of its surface, was in winter. Such a seasonal growth pattern was not expected, since the copulation of this species begins in spring (CONIDES *et al.,* 2008). A deeper study on the possible role of the appendix masculina in *M. kerathurus* must be carried out.

To summarize, the present study reinforces the view that its growth is continuous, and the studied characteristics could explain the harmony which has been statistically observed in both sexes. The analyses of the allometric characters of *M. kerathurus* could confirm the genetic uniformity of most of its Mediterranean (Tyrrhenian, Adriatic, Ionian and Tunisian Seas) populations, as MATTOCCIA *et al.* (1987) have pointed out.

Acknowledgements

The data used to prepare this paper originate from the research project 'Study of the current state of the fishery of the native prawn *Penaeus kerathurus* population in the north Mediterranean' number 037/98 funded by EU/DG XIV Fisheries within the framework of the Biological Studies for the Support of the Common Fishery Policy 1998. The authors wish to express their appreciation to Mr. G. Christides for his technical assistance.

References

AKTAS. M., TURAN, C. & BOZKURT, A., 2006. Taxonomic description of three species (*Melicertus kerathurus, Metapenaeus monoceros, Penaeus semisulcatus*) using multivariate morphometric analyses. *Journal of Animal and Veterinary* Advances 5(3):172-175.

ANANIADIS, C., 1984. Aspects of coastal lagoons and pond fishery management problems in Greece. *GFCM Studies and Reviews*, 61(1):477-520.

ANONYMOUS, 2001. Study of the current state of the fishery of the native prawn *Penaeus kerathurus* population in the north Mediterranean. Number 037/98, EU/DG XIV Fisheries.

BAUER, R.T., 1986. Phylogenetic trends in sperm transfer and storage complexity in decapod crustaceans. *Journal of Crustacean Biology,* 6:315-325.

BEN MARIEM, S., 1995. Caractères biométriques de Penaeus kerathurus (Forskål, 1775) du Golfe de Gabès, Tunisie (Decapoda, Penaeidae). Crustaceana, 68(5):583-596.

BLACKSTONE N.W, 1987. Allometry and relative pattern and process in evolutionary studies. *Systematic Zoology,* 36:76-78.

CONIDES, A., GLAMUZINA, B., PAPACONSTANTINOU, C. & KAPIRIS K., 2006. Age, growth, and mortality of the karamote shrimp, *Penaeus (Melicertus) kerathurus* (Forskål, 1775) in the East Ionian Sea (Western Greece). *Crustaceana,* 79(1):33-52.

CONIDES, A., GLAMUZINA, B., JUKDUJAKOVIC, J., KAPIRIS, K., PAPACONSTANTINOU, C. & HUNTER, S., 2008. Study of the reproduction of the karamote shrimp Penaeus (*Melicertus*) *kerathurus* in the Amvrakikos Gulf, Western Greece. Acta Adriatica, 49(2):97-106.

KAPIRIS, K., 2005. Morphometric structure and allometry profiles of the giant red shrimp *Aristaeomorpha foliacea* (Risso, 1827) in the Eastern Mediterranean. *Journal of Natural History,* 39(17):1347-1357.

KAPIRIS, K., KAVVADAS, S. Morphometric structure and allometry profiles of the red shrimp *Aristeus antennatus* (Risso, 1816) in the Eastern Mediterranean. *Aquatic Ecology* (in press).

KARANI, I., KITSOS, M.S., CHARTOSIA, N., KOUKOURAS, A., 2005. Diet composition of the penaeid shrimp Melicertus kerathurus (Forskå l, 1775) (Decapoda, Penaeidae) in the Aegean Sea., 78(4):385-396.

KEVREKIDIS, K. & THESSALOU-

LEGAKI, M., 2006. Catch rates, size structure and sex ratio of *Melicertus kerathurus* (Decapoda: Penaeidae) from an Aegean Sea trawl fishery *Fisheries Research,* 80 (2-3):270-279.

KLAOUDATOS, S.D., 1984. Contribution to the biology of the shrimp *Penaeus kerathurus* reared under controlled conditions. PhD Thesis, university of Patras, Greece, 135 pp.

LESTER, L.J & PANTE, M.L.R., 1992. Genetics of Penaeus species. In: Marine Shrimp Culture: Principles and Practices, A.W. Fast and L.J. LESTER (eds), Elsevier Science Publishers B.V.:29-52.

LOVETT, D.L., FELDER. D.L., 1989. Application of regression techniques to studies of relative growth in crustaceans. *Journal of Crustacean Biology,* 9:529-539.

LUMARE, F., 1976. Research on the reproduction and culture of the prawn *M. kerathurus* in Italy. *General Fisheries Council for the Mediterranean. Studies and Reviews* 55:35-48.

LUMARE, F., SCORDELLA, G. & ZONNO, 1993. Morphometric study of the wild populations of *Penaeus kerathurus,* Forskål 1775, from the Acquatina and Lesina lagoons (South-East Italian coast). *Oebalia,* XXIV:57-64.

MATTOCCIA, M., LA ROSA, G., DE MATTHAEIS, E., COBOLLI SBORDONI, M. & SBORDONI, V., 1987. Patterns of genetic variability and differentiation in a Mediterranean population of *Peaneus kerathurus* (Crustacea, Decapoda). In: Proc. Word Shimp. on selection, Hybridization, and Genetic Engineering in Aquaculture, 1. Triwes, K. (editor), H. Heenemann GMBH, Berlin:131-141.

MUSTAFA, B., 1962. Observations biologiques sur *Penaeus kerathurus* Forskål et étude biométrique. Annales XIII, Institute de Naturelles Sciences et Technologie Océanographique et Pêche Salammbô, République Tunisienne: 101 pp.

N.C.M.R., 1989. Oceanographic study of the Amvrakikos Gulf. Part 6. Aquaculture, NCMR Technical Survey, 97 pp.

PEZZACK, D.S. & GUTT, I.M., 1998. Background Document on Length-Cohort Analysis (LCA) and Egg per Recruit (e/r) Determinations Used in Lobster RAP 1998. Marine Invertebrate Fisheries Division Science Branch, Department of Fisheries and Oceans, Maritimes Region, Reference Document.

PETERS, R.H., 1983. The Ecological Implications of Body Size. Cambridge University Press, United Kingdom.

RODRIGUEZ, A., 1987. Biologia del langostino *Penaeus kerathurus* (Forskål, 1775) del Golfo de Cadiz. III. Biometria edad y crecimiento. *Investigaciones Pesqueras* 51(1):23-37

SOKAL, R.R & ROHLF, F.J., 1981. Biometria, (Madrid: H. Blume Ediciones), 832 pp.

WILLIAMS, G.D F., 1984. Shrimps, lobsters, and crabs of the Atlantic coast of the eastern United States, Maine to Florida *in* Decapod Crustacea, east coast U.S. Smithsonian Institution Press, Washington.

ZAR, J.H., 1984. Biostatistical Analysis, 2nd ed. (Englewood Cliffs, N. J.: Prentice-Hall), 662 pp.

Submitted: April 2009
Accepted: May 2009
Published on line: June 2009