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Growth, mortality and yield of the mudprawn *Upogebia pusilla* (Petagna, 1792) (Crustacea: Decapoda: Gebiidea) from western Greece

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The paper presents data on growth, mortality and yield of the mud prawn Upogebia pusilla in western Greece. The species is intensively exploited in the area as live bait for hand lines and long lines both for professional and sport fishermen. The study area is a closed bay in western Greece with a small opening which connects it to the Ionian Sea. Longevity of the species in the study area was found to be 4+ years. Females' total length ranged between 18 and 54 mm; for males it ranged between 16 and 58 mm. The von Bertalanffy parameters for males were L_∞*=60.30 mm, K=0.520 per year and* t_0*=-0.0166 years; for females they were* L_∞*=58.80 mm, K=0.621 per year and* t_0*=-0.1261 years. Overall von Bertalanffy equation parameters were* L_∞*=61.05 mm, K=0.521 per year and* t_0*=0.086 years. Maximum weight was estimated as 3.440 g at* L_∞ *based on the length-weight relationship. Mortality estimates were Z=1.510 per year, M=0.928 per year and F=0.582 per year resulting in an exploitation ratio of E=39%. Using the above values, yield per recruit was estimated at 2.97 g/year at* F_{max} *levels of 0.750 per year and* E_{opt}*=50%. Overall length-weight relationship was estimated as:* $W = 0.01589TL^{2.972}$, $r^2 = 0.886$*. This paper contributes to the knowledge of population dynamics of the species Upogebia pusilla and in particular, growth, mortality and yield.*

Key words: *Upogebia pusilla*, growth, mortality, yield, length-weight relationship, population dynamics

INTRODUCTION

The infraorder of Thalassinidea, in which the family of Upogebiidae belongs, was recently partitioned into 2 separate infraorders, the Axiidea and the Gebiidea (ROBLES *et al.,* 2009; DE GRAVE *et al.,* 2009). According to this new classification scheme, the species *Upogebia pusilla* is classified in the Gebiidea infraorder. This infraorder is composed of ghost-shrimps and mudprawns inhabiting shallow coastal areas and estuaries. Most of the species inhabit burrows which they excavate in the soft sediment (ATKINSON & FROGLIA, 1999; ATKINSON

& TAYLOR, 2005). Recent accounts of thalassinidean diversity (before partitioning into 2 separate infraorders) bring the number of genera to 99 and species to 600 (ROBLES *et al.,* 2009). The species plays an important role as bioturbators and ecosystem engineers as they affect the coastal benthic community structure (POSEY, 1986, POSEY *et al.*, 1991; NATES & FELDER, 1999). Their extensive burrow complexes affect significantly the perturbation of sediments, the coastal nutrient cycles, food availability and the available space for other benthic organisms (ZIEBIS *et al.,* 1996; BERKENBUSCH & ROWDEN, 2000; FELDER, 2001).

Even though there is a wealth of information on the Gebiidea and Axiidea species, most is related to systematics and new species description (NGOC-HO, 2003; SAKAI, 1999, 2006), ecological studies of benthic fauna (ATES & SEZGIN, 1998; WITBAARD & DUINEVELD, 1989), phylogeny (ROBLES *et al.,* 2009; TSANG *et al.,* 2008a, b); biology (DWORSCHAK, 1983, 1987a, 1988a, b; ASTALL *et al*., 1997; HERNAEZ & WEHRTMANN, 2007; BERKENBUSCH & ROWDEN, 2000; BUTLER *et al*., 2009), burrow morphology and flows (DWORSCHAK, 1987b, 1988a,b; GRIFFEN *et al.,* 2004; KOLLER *et al*., 2006). However, only limited information exists on reproduction and mating behavior (CANDISANI *et al*., 2001; FELDER & LOVETT, 1989; FORBES, 1977) or growth (FORBES, 1977; DWORSCHAK, 1988a, KEVREKIDIS *et al.,* 1997; PEZZUTO, 1998; HANEKOM & BAIRD, 1992; KINOSHITA *et al*., 2003; SOUZA *et al.,* 1998; SHIMIZU & RODRIGUES, 2000; BOTTER-CARVALHO *et al.,* 2007).

The *Upogebiidae* family consists of around 139 species. Most of them are benthic and burrow-dwelling organisms while a few species are known for dwelling in corals and sponges (DWORSCHAK, 2000). The species *U. pusilla* is small sized and excavates simple ‘Y’ shaped burrows which may reach a depth of 80 cm into the sediment. The species is well distributed throughout the Mediterranean coastal zone, in the Atlantic coastal zone between the Mauritanian coasts to the south and the south coasts of the UK to the north (HOLTHUIS, 1991; NGOC-HO, 2003) as well as the Black Sea (MAKAROV, 1938). The species is heavily fished as live bait in the area of western Greece for use mainly in recreational fisheries using hand-line and long-line gears.

Regarding the species *U. pusilla*, there is limited information on population dynamics of the species in the area of the east Mediterranean and only two studies provide such information; by DWORSCHAK (1988a) in northern Adriatic lagoons and estuaries and by KEVREKIDIS *et al.* (1997) in the estuarine area of the Evros River, northern Greece. The aim of this paper is to contribute in the knowledge of population dynamics of the species *U. pusilla* and in particular, growth, mortality and yield.

MATERIALS AND METHODS

Study area

The study area is located along the coastal area of Dioni bay (Prefecture of Etoloakarnania, western Greece) at 38° 23.680 N - 21° 07.054 E; Fig. 1). The area is a shallow bay with a maximum depth of 6 m in the middle. The bay is connected to the open sea (Ionion Sea) through a narrow opening with an approximate width of 1000 m. The land surrounding the bay is extensively cultivated and various channels transfer irrigation water to the sea in the bay through a pumping station built in the early 70s. The use of pumping stations in the region for the avoidance of stagnant irrigation waters is imperative since the land surrounding the area is approximately 1 m below mean sea level. The fishing ground is the north part of Dioni bay down to a depth of 1.5 m (shaded area in Fig.1).

Sampling procedure

Sampling of shrimp was carried out on a monthly basis in 1999 using the standard local fishing technique for live mudprawns for bait. The method involves the enclosing of a sea bottom area of around 25 m^2 with a plastic net from the surface of the water to the bottom. Then with the use of a high pressure gaso-

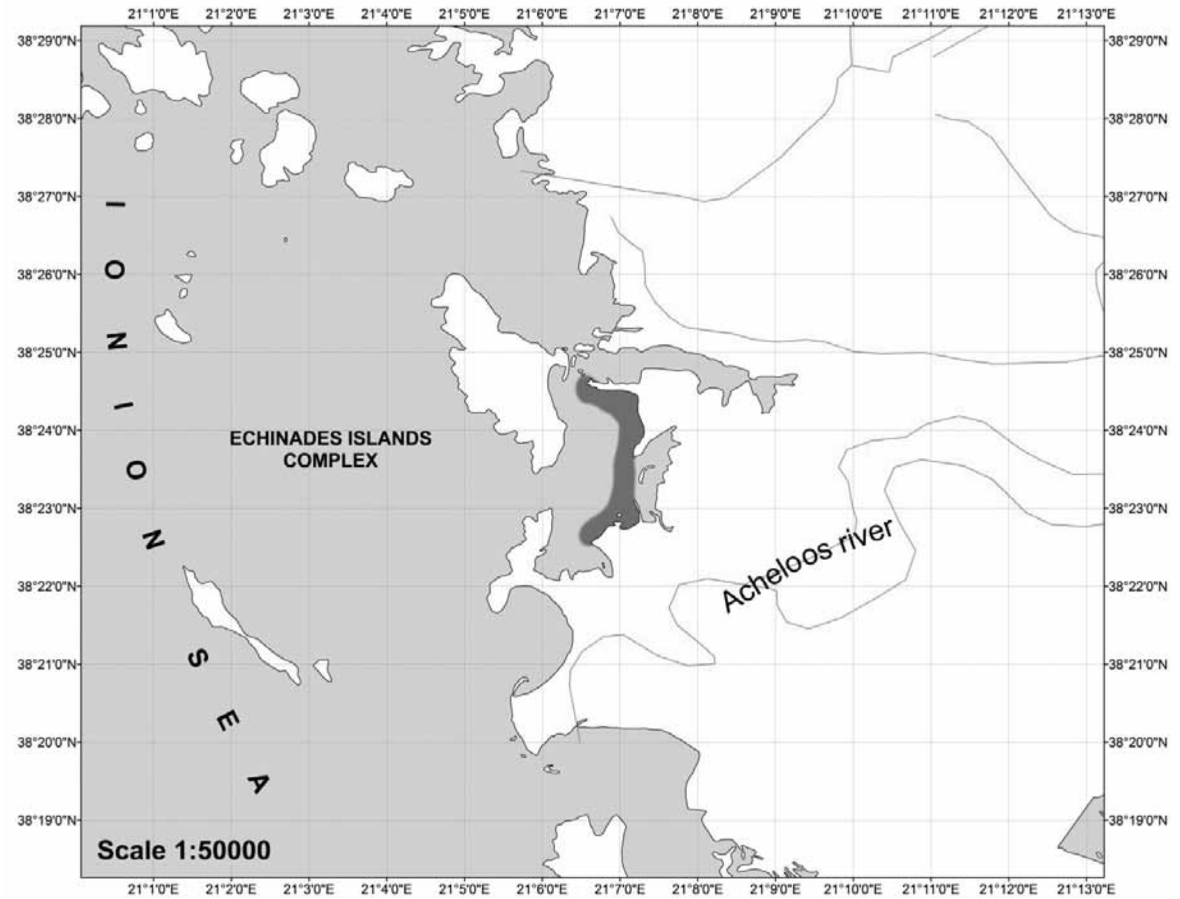


Fig. 1. Map of the study area. Dots indicate shrimp sampling stations

line engine-operated water pump they stir the sediment very deep and destroy the burrows forcing the mudprawns to surface with their subsequent collection using a hand net. Due to the destruction of the sediment the fishermen move the 25 m² - enclosure along the coastal zone. Therefore the sampling stations cannot be fixed. However, the area exploited as a fishing ground is small and can be considered as a single station. For the same reason, the sampled animals were pooled on a monthly basis to provide the monthly samples.

The sampled animals were packaged in a cardboard box and transferred to the laboratory alive for further measurements. In accordance with standard scientific ethics, the prawns were put in a refrigerator in order to die gradually by low temperature before being preserved in 10% formalin solution.

Analysis of data

The sex of each individual was determined and its total length and weight measured using a digital caliper to the nearest 0.1 mm and a digital OHAUS balance to the nearest 0.001g after gently drying the animal on paper tissue to remove excess moisture. The measurements taken from each individual were rostrum length (RL), carapace length (CL), abdomen length (AL), telson length (TeL) and wet weight (WW). Total length (TL) was calculated by adding the different body lengths.

Length-frequency histograms were analyzed using the MIX algorithm (R-language environment version 2.7.2; MACDONALD & GREEN, 1988) which are based on the calculation of the density function:

$$g(TL,mm)=\underset{i=1}{\overset{k}{\varepsilon}}\ p_i\,f_i(TL|m_i,s$$

where k is the number of age classes, π is the number of individuals in the class, μ is the average length of the class and σ the standard deviation of μ. Length-based methods are often considered as the only available for the estimation of growth and mortality of decapods as hard parts are lost during molting or not existent, tagging in most cases is not feasible due to the size (for example mudprawns) or distribution of the species (for example deep red shrimps), and in many cases rearing experiments in the laboratory are non-existent or extremely difficult to conduct (SARDA, 1986; RAGONESE & BIANCHINI, 1996). However, variations in growth rates and molt frequency can result in overlapping cohorts within an age class, making size a poor predictor of true age (BOSLEY & DUMBAULD, 2011). Other alternatives include the measurement of lipofuscin concentration in nerve tissue of decapods as an indicator of age which produces more accurate results regarding the estimation of age (BOSLEY & DUMBAULD, 2011). Although the growth process in decapods shows discontinuities due to moulting, the application of continuous asymptotic models such as the von Bertalanffy growth equation is considered acceptable (PAULY *et al.,* 1984; GARCIA, 1985; RAGONESE & BIANCHINI, 1996).

Based on the age cohorts data calculated from the length-frequency distributions the parameters of the von Bertalanffy growth equation (VBGF) were estimated for males, females and the overall population separately using a non-linear regression algorithm (NLreg version 6.3; SHERROD, 1995). Cross examination of the growth results was carried out using the empirical equation by FROESE & BINOHLAN (2000): $\log(L_\infty) = 0.044 + 0.9841 * \log(L_{max})$, where L_{max} is the largest individual in the samples.

$$L_{opt}=\frac{3\cdot L\infty}{3+\frac{M}{K}}$$

In addition, L_{opt} was estimated using the FROESE & BINOHLAN (2000) empirical formula

Optimum length is an estimate of the minimum capture length in order for the population to perform at Maximum Sustainable Yield levels.

Total mortality was estimated using the length-converted catch curve method (RICKER, 1975). Natural mortality was estimated using the Pauly equation (PAULY, 1980). In addition, natural mortality per age class was estimated using the CHEN & WATANABE (1989) equation:

$$M_i=\frac{K}{1-e^{-K(t_i-t_o)}} \qquad ,$$

where *i*, is the age class (1, 2…, t_{max}).

Overall natural mortality was estimated as the average of the 2 approaches. Fishing mortality was estimated as Z-M while the exploitation ratio, E, was estimated as E=F/Z.

Yield per recruit was estimated based on the standard Beverton-Holt model (BEVERTON & HOLT, 1966; PAULY, 1984; PAULY & SORIANO, 1986; SILVESTRE *et al.*, 1991) related to the fishing mortality. The application of yield-per-recruit procedures is common for fishery assessment and the estimation of reference points for stock management (PEREIRO, 1992), and provides a model which can reflect the responses of an exploited population to various levels of fishing mortality and age-at-first-capture.

Morphometric relationships were investigated using linear ($Y=a+bX$) and power models ($Y=aX^b$). For the purposes of the study, the best models based on the correlation coefficient were reported below.

RESULTS

Length-frequency distributions

In total, 9036 *U. pusilla* individuals were collected of which 4756 were females and 4280 were males. According to the length-frequency distribution histograms (Fig. 2), the females total length classes range between 18 and 54 mm and between 16 and 58 mm for the males. The average total length of the females was estimated at 35.08±5.28 mm while for the males was estimated at 35.34±6.72 mm. The analysis of the length-frequency histograms produced 4 major length cohorts for each sex. The data are summarized in Table 1.

Table 1. Length cohorts of the population of Upogebia pusilla in western Greece

	Females	Males	Overall Population
Cohorts	Mean TL (mm±SD)	Mean TL (mm±SD)	Mean TL (mm±SD)
1	23.03±2.15	24.22±2.04	25.10±3.53
2	29.89±2.79	30.93±2.60	30.14±4.35
3	36.62±3.42	37.69±3.17	36.32±5.11
4	44.40±4.14	45.05±3.79	47.56±6.69

Length frequency distributions show that young individuals enter the population in 3 stages during the year: in February-March at sizes 15-20 mm TL, in August at sizes 20-22 mm TL and in the October-December period at sizes 22-24 mm. Large animals appear in the samples only during late winter and early spring and disappear afterwards.

According to RICKER (1979), the inflation point of the VBGF curve (point when growth rate is 0) was estimated to be 2.18 years of age when the individuals have a total length of 40 mm and weight of 1.02 g.

Age and growth

The longevity of the species *U. pusilla* in the study area was estimated at 5.9 years. The parameters of the von Bertalanffy growth equation for males, females and overall population are summarized in Table 2. The corresponding L_∞ values from the empirical equations by FROESE & BINOHLAN (2000) are:

Males: L_∞=61.90 mm (52.2-73.3 mm)
Females: L_∞=61.10 mm (51.5-72.4 mm)
Overall Population: L_∞=61.90 mm (52.2-73.3 mm)

The parameter L_{opt} was found to be 38 mm. The von Bertalanffy growth curves for males and females are illustrated in Figure 3.

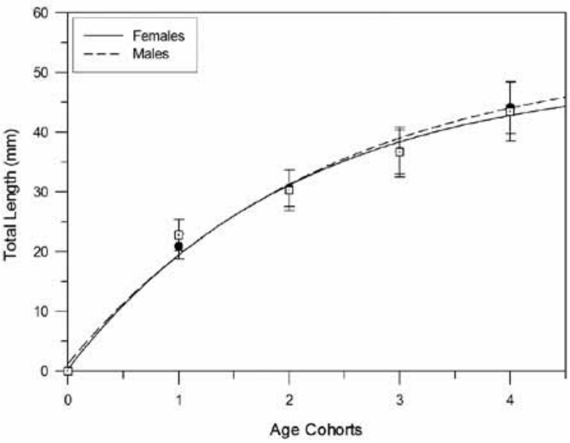
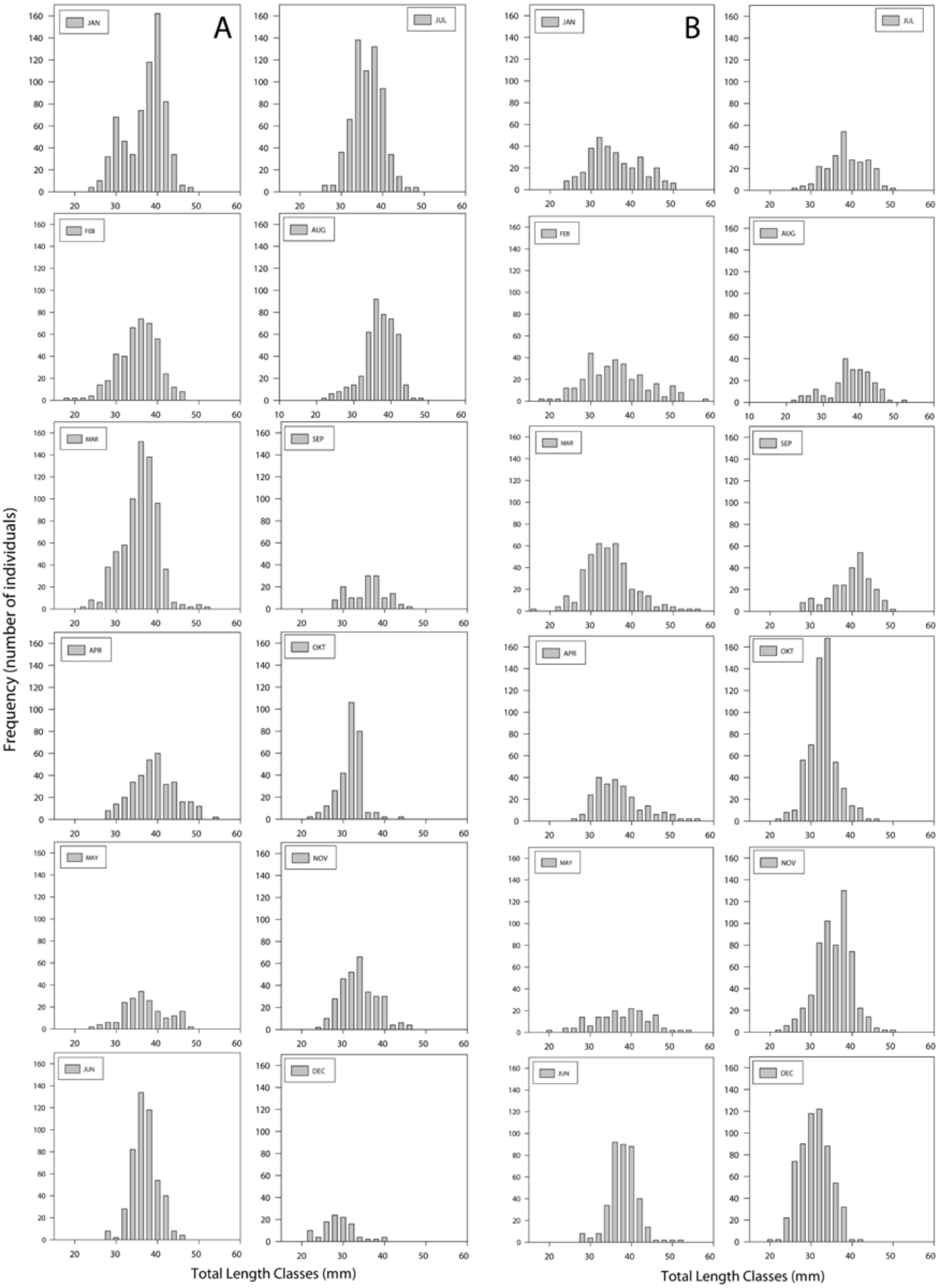


Fig. 3. Growth curves of male and female Upogebia pusilla *from western Greece*

Table 2. Parameters of the von Bertalanffy growth equation form males, females and overall population of Upogebia pusilla in western Greece

Parameters	Males		Females		Overall Population	
	Value	Correlation coefficient	Value	Correlation coefficient	Value	Correlation coefficient
$L\infty$	60.30 mm	0.9584	58.80 mm	0.9745	61.05 mm	0.9080
K	0.520 year^{-1}		0.621 year^{-1}		0.521 year^{-1}	
t_o	-0.0166 year		-0.1261 year		0.086 year	
$W\infty$					3.440 g	

Fig. 2. Length frequency distributions of female (A) and male (B) Upogebia pusilla *in western Greece*



Mortality

Total mortality based on the length-converted catch curve was estimated at 1.510 year^{-1}. Overall natural mortality was estimated at 0.928±0.140 year^{-1}. In addition, natural mortality per age class was estimated at 1.375 year^{-1} for age class I, 0.826 year^{-1} for age class II, 0.667 year^{-1} for age class III and 0.599 year^{-1} for age class IV. Overall average natural mortality was estimated at 0.928±0.140 year^{-1}. Overall fishing mortality was estimated at 0.582 year^{-1}. Using as natural mortality values the values per age class, fishing mortality per age class is estimated at 0.134 year^{-1} for age class I, 0.684 year^{-1} for age class II, 0.843 year^{-1} for age class III and 0.911 year^{-1} for age class IV ($F_{terminal}$). Finally, the exploitation ratio was estimated at 39%.

Yield

Yield per recruit analysis was based on the following data: Length at first capture, 15.61 mm; L_∞, 61.05 mm (from VBGF); K, 0.521 year^{-1} (from VBGF); M=0.928 year^{-1}; Z=1.510 year^{-1} while F was kept variable between 0 and 3 year^{-1}. The results are illustrated in Fig. 4. The results show that MSY can be around 2.97 g/year per recruit at an optimum F of 0.75 year^{-1}. At those levels, E equals 50%.

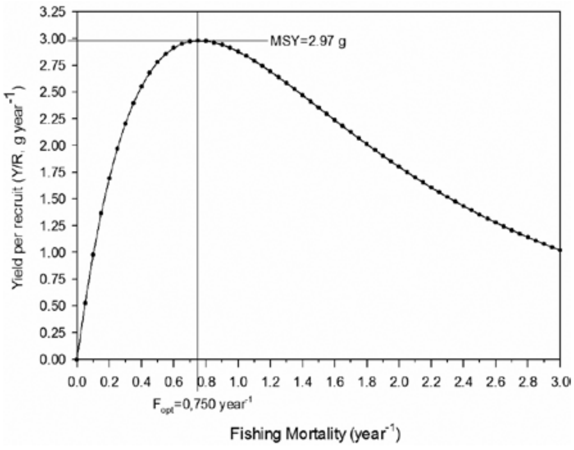


Fig. 4. Yield per recruit analysis of the population of Upogebia pusilla *in western Greece*

Morphometric relationship

The results on the morphometric relationships of *U. pusilla* in western Greece are summarized in Table 3. In Table 3, there are included 2 equations describing the relationship between carapace length and total length: the first is between total length and carapace length excluding the rostrum and the second is based on the carapace length including the rostrum. This was required for comparison purposes since two regional reports on growth of the species (DWORSCHAK 1988a; KEVREKIDIS *et al.*, 1997) used as carapace length the length of the carapace with the rostrum. Male and female length-weight relationships are illustrated in Fig. 5. The overall length-weight relationship was found as:

$$W = 0.01589(TL^{2.972}),\ r^2 = 0.886,\ SE = \pm 0.153$$

Analysis of covariance between the length-weight equations of males and females showed that their difference is statistically significant ($P<0.05$).

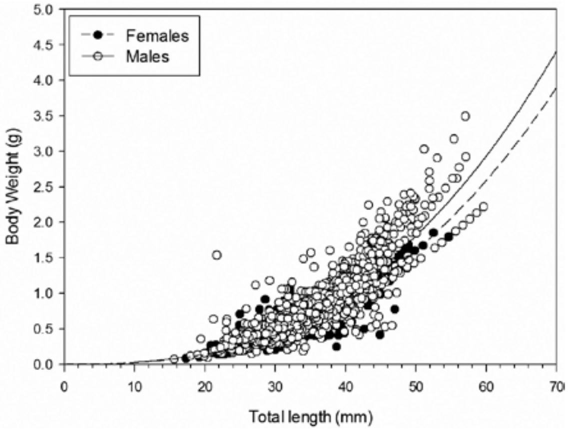


Fig. 5. Length-weight relationships of male and female Upogebia pusilla *in western Greece*

DISCUSSION

Length frequency distributions and growth

From Fig. 1 it is evident that young individuals appear in the population of *U. pusilla* during 3

Table 3. Summary of the morphometric relationships of males and females of Upogebia pusilla in western Greece

MALES				
	a	b	r^2	Standard Error
CL/TL (mm; mm)	0.291	0.257	0.872	± 0.0976
CL+Rostrum/TL (mm; mm)	0.851	0.325	0.915	±0.0840
W/TL (g; mm)	0.0000162	2.985	0.834	± 0.188
FEMALES				
	a	b	r^2	SE
CL/TL (mm; mm)	0.387	0.245	0.871	± 0.0734
CL+Rostrum/TL (mm; mm)	1.194	0.302	0.894	± 0.0964
W/TL (g; mm)	0.000027	2.818	0.824	± 0.126

CL/TL equation is linear ($L_1=a+bL_2$) while W/TL follows the power model ($W=aTL^b$)

different periods of the year. The individuals which enter the population during the first 2 stages (Feb-March and August) belong to the juveniles which were produced from the reproduction of the same year and are small-sized (up to 22 mm TL). The young individuals which appear during Oct-Dec exhibit larger average TL (>25 mm) and originate from the late reproduction of the population in the previous year.

The longevity of crustaceans is difficult to assess because of the difficulties in ageing the animals (XIAO & GREENWOOD, 1993). For this purpose it is common to use the rule of thumb 3/K (PAULY, 1984) for the estimation of longevity of shrimp (BOTTER-CARVALHO *et al.,* 2007; NIAMAIMANDI *et al*., 2007; CHA *et al*., 2004). Previous reports based on laboratory experiments have shown that *U. pusilla* is a species with an intermediate life span compared to other Gebiidea and Axiidea species. Very early studies (TUCKER, 1930; POPOVICI, 1940) reported that the species longevity is more than 3 years. However, CHAUD (1984) reported that its longevity along the French coast of the Atlantic is almost 2 years. The results of the present study show that the species can live more than 5 years since at least 4 age cohorts are evident in the samples. Similar conclusions were reached by DWORSCHAK (1988a) in the north Adriatic (3.5 years) and KEVREKIDIS *et al.,* (1997) at the estuarine area of the Evros River, northern Greece (5 years). Based on the above results, *U. pusilla* exhibits an intermediate life-span in relation to other Gebiidea and Axiidea such as 2 years for *Callianassa kraussi* (FORBES, 1977), *Trypaea australiensis* (HAILSTONE & STEPHENSON, 1961) and *Callianassa japonica* (TAMAKI *et al.*, 1997), 3 years for *Upogebia deltaura* (GUSTAFSON, 1934), 4 years for *Callianassa filholi* (DEVINE, 1966) and *Upogebia africana* (HANEKOM & BAIRD, 1992), 4-5 years for *Upogebia pugettensis* and *Neotrypaea californiensis* (DUMBAULD *et al.*, 1996) and 10 years for *Calocaris macandeae* (BUCHANAN, 1963). Nevertheless, the longevity of *Upogebia major* could not be determined by KINOSHITA *et al.,* (2003) because adult shrimp (> 2 year) could not be separated into yearly cohorts by the size-distribution analysis. Callianassidae species seem to exhibit longer life-spans based on lipofuscin concentration measurements than estimates derived from length measurements (BOSLEY & DUMBAULD, 2011).

Regarding growth rates, the species *U. pusilla* in this study exhibits a very slow rate in relation to other Gebiidea and Axiidea. In Fig. 6, the relationship between the growth rates (based on extrapolations of the reported VBGF equations; from PEZZUTO, 1998; HANEKOM & BAIRD, 1992; KINOSHITA *et al.,* 2003; KEVREKIDIS *et al.*, 1997; SOUZA *et al.*, 1998; BOTTER-CARVALHO *et al.*, 2007) of several Gebiidea and Axiideaas as well as the populations of *U. pusilla* in the Adriatic and the estuarine area of the Evros River are illustrated. On the other hand, a linear relationship between growth and age was reported in *Upogebia pugettensis* (DUMBAULD *et al.*, 1996). In Figure 6, there are included 2 growth curves for the species in western Greece using the carapace length, and the carapace length including the rostrum, respectively, for comparison purposes with the reported growth information for the species populations in north Adriatic Sea and northern Greece (estuarine area of the Evros River). In both cases, *U. pusilla* in western Greece shows low growth rates in relation to other thalassinideans. Intraspecific variations of growth rate have been documented for *Upogebia yokoyai* populations inhabiting two estuaries with differences in organic content. An increase of trophic condition of the habitat resulted in increased growth. In a broader latitudinal sense, a negative relationship between population density and growth was also found, which was explained in terms of reduced survival of recruits in the eutrophicated habitats (YAMASAKI *et al.,* 2010). For *U. pusilla,* DWORSCHAK (1988a) showed that maximum total length of ovigerous females collected from three habitats of the northern Adriatic Sea varied significantly: i.e. while the population of Grado was 50.3–53.3 mm TL, those of Staranzano and Rovinj were smaller at 46.6 mm and 33.1 mm, respectively. The author suggested that the smaller size of females in the Rovinj population was due to a slower growth rate than in the other two populations. In addition, HANEKOM & ERASMUS (1989) concluded that the current and its associated transport of oxygen and food materials strongly influenced the growth of *Upogebia africana*. In general, the main reasons that can explain the lower growth rates of *U. pusilla* in western Greece can be the physical and chemical quality of the water, the existence of suitable food both qualitatively and quantitatively, and the increased consumption of body energy due to the prolonged reproduction period and overfishing which removes the larger individuals from the population. The physical and chemical quality of the water affect the seasonal growth and reproduction cycles of many coastal invertebrates (VERNBERG & VERNBERG 1981; LOCKWOOD 1976; SASTRY 1983). Brackish coastal waters and related habitats (lagoons, etc.) exhibit intensive changes of temperature and salinity and many authors consider those as the major factors which regulate the structure, activity and distribution of the species (VERNBERG 1979). By comparing the annual average temperature values, annual temperatures in western Greece (current study), the estuarine area of the Evros river (North Greece) and the north Adriatic, it is evident that the western Greece area exhibits higher values (20.05, 14.4, and 16.0°C respectively) and therefore, temperature cannot be considered as the primary factor that can explain differences in growth rates. Salinity is a physical quality parameter which is considered as very important for brackish coastal ecosystems (KINNE, 1971). Low salinity levels – common in coastal waters – can cause direct effects on decapods by lowering growth, increasing mortality, reduce oxygen consumption and alter the metabolic rates. Indirectly, low salinity levels affect the organisms by affecting the chemical condition of the seawater, changing the availability of food and its digestibility (BARNES *et al*., 2001; RICHMOND & GOODIN 1996; BOEUF & PAYAN, 2001). Low salinity is also responsible for low growth during the larval stages of decapods, therefore affecting the overall size distribution of a population (RICHMOND & GOODIN, 1996). Furthermore, sediment disturbance due to the fishing method in western Greece could be the reason for lower growth despite the eutrophication of the habitat. Being predominantly a filter-feeder, *U. pusilla* requires stable sediments to construct a semi-permanent burrow. The bait-fishing method employed in the area is based on the disturbance of the sediment using a high pressure water pump which creates a fine sediment cloud on an almost daily basis and which affects the remaining individuals in the adjacent region by clogging the filtering apparatus.

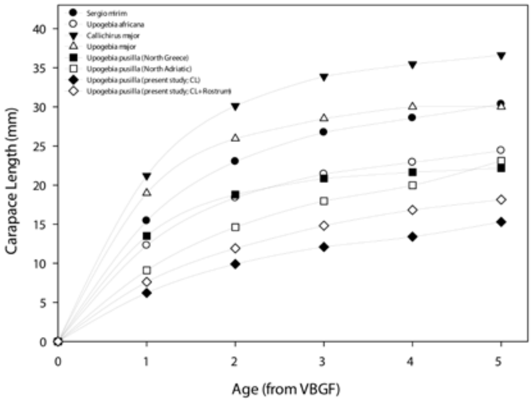


Fig. 6. Comparison of growth between various species of Axiidea and Gebiidea

Mortality

The estimated natural mortality for males was 0.820 per year and for females was 0.927 per year. Overall natural mortality was estimated at 0.928 per year. The results show that the exploitation rate of males is higher than that of females. Sex-differentiated mortality – and exploitation – seems to be related to the size of the individuals as well as their standard behaviour in relation to the fishing activity. Males of *U. pusilla* are statistically larger than females in size and weight. In addition, the females probably spend a large part of their lives in the burrows due to egg-carrying – since the reproduction period in the area is rather long (from Jan to Sept; CONIDES, 2011) - when at the same time the males show normal mobility and therefore their probability of being caught is higher.

Total mortality of *Callichirus major* was found to be around 3 or higher in harvested populations with males being more vulnerable (SOUZA *et al.*, 1998; BOTTER-CARVALHO *et al.*, 2007), while not exploited *Neocallichirus mirim* showed lower values such as 1.53 and 1.27 for males and females, respectively (PEZZUTO 1998). Low mortality and recruitment rates have been reported by BERKENBUSCH & ROWDEN (1998) for *Callianassa filholi* from New Zealand.

The estimated exploitation ratio of 39% for *U. pusilla* is below the 0.5 threshold proposed by GULLAND (1971) for which F=M.

Yields

The results show that under the present exploitation regime, the population shows a yield per recruit figure of 2.97 g/year at an optimum fishing mortality of 0.750 per year and an exploitation rate of 50%, while the current F is 0.582 per year with an exploitation ratio equal to 39%. For management purposes, several reference points have been proposed and all are related to the maximum F derived from the yield-per-recruit diagram (F at MSY) such as F0.1, Fmax, F25% and F40% (SUN *et al.*, 2005). Several authors have supported the use of F0.1 or F40% as target reference points and F25% as a threshold reference point in order to obtain optimal yields (e.g. GULLAND & BOEREMA, 1973; DERISO, 1987; SISSENWINE, 1978; SISSENWINE & SHEPHERD, 1987; MACE & SISSENWINE, 1993; CHEN, 1997). It is obvious from the results that currently the overall levels of F and E are not high enough to create a growth overfishing situation to the population. However, considering the fishing mortalities estimated per cohort, it is evident that for the major cohorts represented in the samples (cohorts 2 and above), the exploitation ratio is equal to, or above, 0.5 per year which is the growth overfishing threshold according to GULLAND (1971). The resilience of the *U. pusilla* population evident from the results in western Greece is owed to the fact that only a part of the area in which the individuals are distributed within the study area, is actually exploited by fishing. Therefore, reproduction occurring at the remaining 'virgin' area produces offspring which could colonize very quickly the exploited area. About 2 million prawns are harvested from six sites of *U. africana* annually, yet they represent about 8.5% of the exploited stocks and only 0.9% of the whole estuary stock which seems not to be over-exploited (HODGSON *et al.*, 2000).

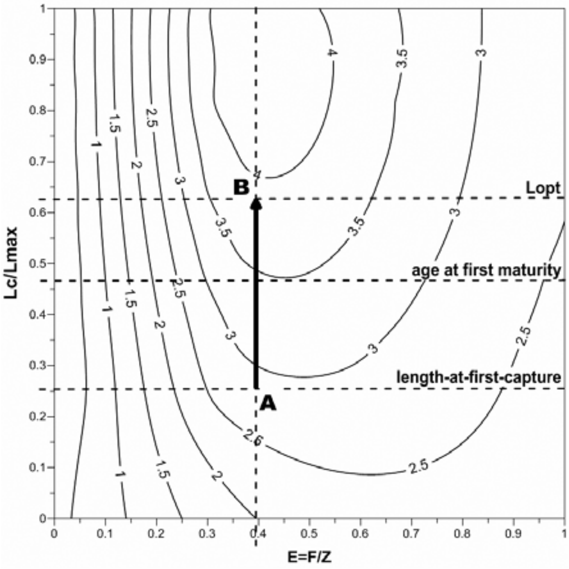


Fig. 7. Isopleth diagram for the population of Upogebia pusilla *in western Greece*

This resilience profile is similar to the case of other species such as the deep-water red shrimps for which only the parts of the population inhabiting the shallower range of their depth distribution (between 400-800 m) are trawled (RAGONESE & BIANCHINI, 1996; DEMESTRE & LLEONART, 1993; DEMESTRE & MARTIN, 1993; SARDA *et al.,* 1993).

Sensitivity analysis of the yield per recruit curve changing the age-at-first-capture from 0.66 years (which is the current age at first capture) to 1 year results in an increase of MSY by about 8% from 2.97 g/year to 3.21 g/year. However, changing the natural mortality from 0.928 per year (present levels) to 0.8 per year and keeping the age-at-first-capture at the current levels (0.66 years) results to an increase of MSY by 24.8%. On the contrary, an increase of the natural mortality from 0.928 per year to 1.2 per year results in an increase of MSY by 34.3%.

In Fig. 7, the isopleth diagram of the population of *U. pusilla* in western Greece is illustrated. It is clearly seen that at the current levels of exploitation and fishing technique selectivity (Fig.7, point A) the yields produced are much lower than the yields which could be produced if management measures were adopted in order to allow small individuals to escape and increase the size-at-first-capture to levels close to L_{opt} (Fig.7, point B) without changing the current exploitation patterns. Considering that the species is fished to be used as bait for hand lines and long lines, it is evident that sizes which are equal to 20 mm total length or more are more suitable for this purpose considering the average size of the hooks for such fishing purposes.

CONCLUSIONS

Upogebia pusilla is an important economic resource in western Greece exploited for bait for sport fishing. The local population is composed of individuals belonging to 4 age classes. Growth estimates showed that the species in western Greece exhibits lower growth rates than other Thalassinidea as well as from other populations of the same species in northern Greece and the north Adriatic Sea. The main reason for this seems to be the low and sharply fluctuating salinity of the coastal waters which affects growth. Natural mortality values were found to be rather high indicating that the environmental quality of the target area in western Greece is degraded and affecting negatively the local population. Yield analysis indicates the current level of exploitation (39%) is not high enough to indicate overfishing. However, economic and production benefits can be gained if certain management measures are taken for the conservation of the resource. The main measure which needs to be taken is to increase the minimum landing size of the species, maintaining the current levels of exploitation and fishing technique selectivity and which will allow an increase of MSY by 8%. In addition, any further measures which will lead to an improvement of the environmental quality of the water may increase MSY up to 24%.

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Rast, smrtnost i prinos po novačenju dekapodnog raka karlića, *Upogebia pusilla* (Petagna, 1792) (Crustacea: Decapoda: Gebiede), u zapadnom dijelu Grčke

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SAŽETAK

U ovom radu izneseni su podaci o rastu, smrtnosti i prinosu dekapodnog raka karlića *Upogebia pusilla* u zapadnoj Grčkoj. Vrsta se intenzivno iskorištava u području kao živi mamac za ručne linije i duge linije, te je koriste profesionalni i sportski ribolovci. Istraživano područje je zatvorena uvala u zapadnoj Grčkoj s malim otvorom koji je povezuje s Jonskom morem. Dugovječnost vrsta u istraživanom području inosila je 4 + godine. Ukupna dužina ženki se kretala između 18 i 54 mm, a mužjaka između 16 i 58 mm. Dobivene vrijednosti izračunate su prema jednadžbi von Bertalanffy-a, te su za mužjake iznosile: L_∞ = 60,30 mm, K = 0,520 i t_0 = -0.0166, dok su za ženke iznosile: L_∞ = 58,80 mm, K = 0,621 i t_0 = -0.1261. Ukupni parameteri dobiveni prema jednadžbi von Bertalanffy-a su iznosili: L_∞=61.05 mm, K=0.521 i t_0=0.086 years. Maksimalna procijenjena masa je iznosila 3.440 g na temelju dužinsko-masenog odnosa. Procjene smrtnosti bile su: Z = 1,510 godišnje, M = 0,928 godišnje, a F = 0,582 godišnje, što je rezultiralo eksploatacijskim omjerom E = 39%. Koristeći gore navedene vrijednosti, prinos po novačenju je iznosio 2.97 g/godišnje na F_{max} nivoima od 0.750 godišnje i E_{opt}=50%. Ukupni dužinsko-maseni odnos iznosi: $W = 0.01589TL^{2.972}$, r^2 = 0.886. Ovaj rad pridonosi poznavanju dinamike populacije vrste dekapodnog raka karlića, a posebice njegovog rasta, smrtnosti i prinosa po novačenju.

Ključne riječi: *Upogebia pusilla*, rast, smrtnost, prinos po novačenju, dužinsko-maseni odnos, dinamika populacije