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Population Structure, Growth, Mortality and Fecundity of *Palaemon adspersus* (Rathke 1837; Decapoda: *Palaemonidae*) in the Parila Lagoon (Croatia, SE Adriatic Sea) with Notes on the Population Management

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Abstract

Baltic prawn, *Palaemon adspersus* population from the Parila lagoon (SE Adriatic Sea, Croatia) was studied between 2010-2011. Specimens were collected monthly in order to determine population structure, growth, mortality and reproduction of this important decapods species. The von Bertalanffy growth function parameters were found $L\infty$=58.98 mm, K=0.975 year^{-1} and t_o=-0.0046 years for males and $L\infty$=72.45 mm, K=1.058 year^{-1} and t_o=-0.0005 years for females. Growth performance (Φ') for females was higher (3.229) than that of males (3.121). Maximum calculated age was 3.07 and 2.83 years for males and females, respectively, while total mortality was estimated as 3.72 per year for males and 3.79 per year for females. The females carried on average 2157 eyed eggs per 1g of total body weight, but exhibited a high variability of fecundity. The results show overexploitation of the resource and therefore management rules based on the precautionary approach are proposed. These rules are based on the limitation of the fishing effort and the establishment of 'no-take' periods during the year as well as the proposal of two biological reference points based on a minimum landing size related to the size-at-maturity and the fishing mortality at Maximum Sustainable Yield.

Keywords: Growth, mortality, length-weight relationship, fecundity, Baltic prawn, reference points, fisheries management.

Introduction

Baltic prawn, *Palaemon adspersus* is a common inhabitant of the Mediterranean coasts, lagoons and estuaries with mediocre tolerance to temperature and salinity extremes (Berglund, 1980, 1982, 1985; Berglund and Bengtsson, 1981). Moreover, it has been demonstrated that the species can maintain its metabolic rates stable in coastal environments independently from salinity (von Oertzen, 1984).The adults are known to be able to survive salinities down to 5 (Berglund, 1980; Barnes, 1994; Hansen *et al*., 2012) and maintain populations in coastal brackish estuaries (Berglund, 1985). Eventhough it is edible, this shrimp is mainly exploited as a live bait for commercial and sport-fishing (Smaldon, 1979; Holthuis, 1980; Guerao *et al*., 1994; Manent and Abella-Gutierrez, 2006). The distribution of this species along the coastal waters is associated with phanerogam meadows and especially *Posidonia*, *Zostera* and *Cymodocea* (Manent and Abella-Gutierrez, 2006; Schaffmeister *et al*., 2006; Bilgin *et al*., 2008). The species is known as omnivorous feeding on small crustaceans, polychaetes, algae and detritus (Bilgin *et al*., 2009). Conversely, the species is essential prey for various coastal and estuarine predators such as the European seabass (*Dicentrarchus labrax*, Cabral and Costa, 2001), the gilthead seabream *Sparus aurata*, the European eel *Anguilla anguilla,* the Atlantic cod *Gadus morrhua* (Janas and Bruska, 2010), as well as cephalopods such as *Sepia* sp. (Blanc and Daguzan, 2000). Due to its preference by the local artisanal fishermen and sport fishermen as fishing bait for hand gear and longlines, the prawn is heavily exploited in the Neretva Estuary and the adjacent areas.

The growth and biology of coastal population of *P. adspersus* has been studied only in the North and Baltic Seas (Berglund, 1984; von Oertzen, 1984; Berglund and Rosenqvist, 1986; Westin and Aneer, 1987), the Mediterranean (Conides *et al*.,1992a,b; Guerao *et al*., 1992; Guerao and Ribera, 1995; Manent and Abella-Gutierrez, 2006), and the European Atlantic coast (Ivleva, 1980; Figueras, 1984, 1986). In addition, much interest has been shown to the ecological importance of the species (Wlodarska-Kowalczuk *et al*., 2010), its distribution (Rufino *et al*., 2006) and its importance for marine coastal communities (Mogias and Kevrekidis, 2005; Gallmetzer *et al*., 2005; Cuesta *et al*., 2006; Barausse *et al*., 2011). However, such studies are lacking in the Adriatic Sea and therefore information on exploitation level and impact on population structure is unknown.

The aim of this paper is to fill this gap in knowledge and to investigate and describe the population structure, growth, mortality, reproduction and length – weight relationships of the *P. adspersus* population in the Parila lagoon (Neretva river delta, Croatia). The results may contribute to the establishment of a management plan for this species.

Materials and Methods

Study Area

The study area was Parila lagoon in the SE Adriatic Sea (Figure 1). The lagoon is located north of the Neretva river mouth, between the river estuary and the city of Ploče (N 34°01'49.1", E 17°26'59.4"; Figure 1). The lagoon is characterized with muddy bottom, *Cymodocea nodosa* patches and the maximum depth of lagoon of 50 cm. Average annual temperature in the lagoon is 17.61±6.7°C (*in-situ* measurements).

Sampling and Measurements

Sampling was carried out on a monthly basis during 2010 and 2011 using a net (mesh size diameter 4 mm), mounted on a small hand dredge. The dredge opening was 1 meter in length and 40 cm in width, while sac with net was 2 m long. The dredge was pulled by walking or from the boat. A total number of 4125 shrimps were collected. The shrimps were put on ice immediately after collection and transfer to the laboratory for further analysis. The use of formalin was avoided since it hardens the body of the shrimp, resulting in difficulty to extend it for length measurements, and it affects the total weight of the shrimp. The samples were separately maintained in a freezer at -18°C until analysis. The length was measured to the nearest 0.1 mm using a digital caliper, and weight using a KERN digital balance (±0.001 g). Each specimen was sexed based on both appendix masculine presence and the exit of the genital pore position under microscope. Egg mass was removed from female abdomen using a painting brush and weighted. The number of eggs was counted on three 0.01 g subsamples of the whole egg mass.

Calculations

The von Bertalanffy growth parameters were obtained from monthly length frequency distributions according to the function (VBGF; Bertalanffy, 1938):

$$Lt = L\infty\,(1 - e^{-K(t-t_0)})$$

where, Lt is the total length (from the tip of the rostrum to the tip of the telson; in mm), L_∞ is the maximum length, K is the growth coefficient (year^{-1}) and t_o is the age at which the length of the organism is zero (years). The inflection point of the growth equation is the point at which growth rate is maximum. For standard VBGF equation, the inflection point is calculated as (Ricker, 1979):

$$i.p. = t_o + \frac{\ln(3)}{K}$$

Maximum life span was estimated according to Taylor (1958):

$$t_{max} = t_0 + \frac{2.996}{K}$$

where, t_{max} is a life span to attain 95% of Lt, t_0 is the length at time zero, 0.95 is 95% and K is the VBGF growth coefficient.

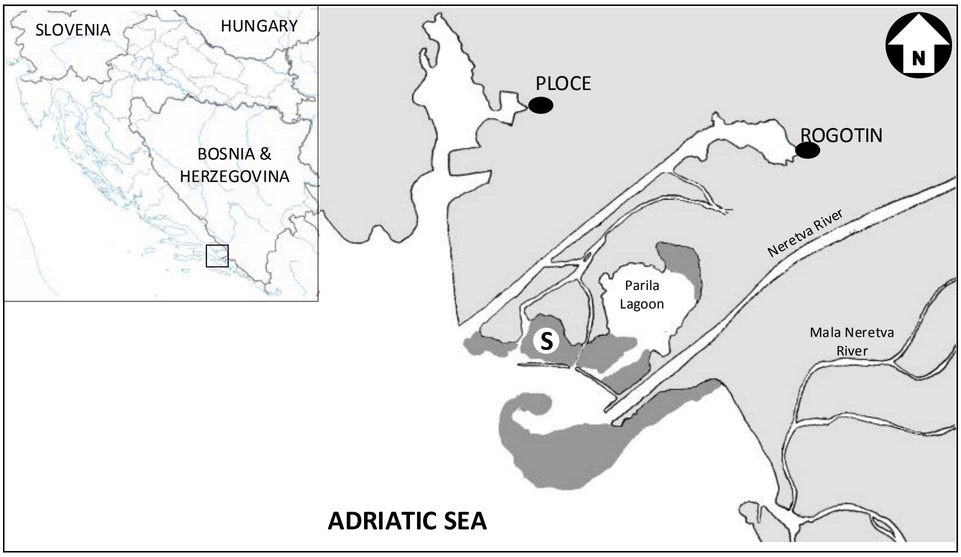

Figure 1. Map of the Parila lagoon study area showing the sampling stations (dark grey areas: shallows; S, sampling station location).

Growth performance was calculated according to Pauly and Munro (1984):

$$\Phi' = log(K) + 2log(L\infty)$$

Where Φ' is the growth performance index, K is the growth coefficient and L∞ is the maximum length.

The length– weight relationship was estimated using log transformed weight and length data as:

$$log(W) = a + b \times log(TL)$$

where, W is the body weight (g), TL is the total length, (from the tip of the rostrum to the tip of the telson; in mm), a is the intercept, and b is the slope of the regression line. Weight measurements for gravid females were carried out after removing the egg mass from the abdomen.

Natural mortality (M) was estimated based on VBGF parameters according to Pauly (1980, 1984; FiSat II software):

$$log(M) = -0.0152 - 0.279\ log(L\infty) + 0.6543\ log(K) + 0.463\ log(T)$$

where, T is the mean environmental temperature (°C). The annual average temperature in the study area was 17.61 °C based on *in-situ* measurements using portable digital instruments (HACH).

Total mortality (Z) was estimated using the length-converted catch curve method (Pauly, 1984). This method was selected as most appropriate to estimate Z since it derives data from the actual length-frequency distributions (raw data) of the population in the given area in relation to other empirical methods which are based on values which are calculated from the length-frequency distributions (for example L∞, K, t_{max} etc.). The exploitation ratio was estimated as Z/M (%).

Fecundity was examined in 180 female individuals covering all length classes in the samples and expressed as the number of eyed eggs per female individual and the number of eyed eggs per 1 g of female individual body weight. Reproductive output (RO) was estimated as the ratio between egg mass weight and total body weight according to Kim *et al*. (2008). Statistical analysis was performed with SPSS v.22 and FiSat II software. All Statistical analyses were considered significant at α=0.05 level.

Results

Population Structure

Monthly distributions of the total body length of all collected samples of *P. adspersus* are illustrated in Figure 2. The results show that for the most part of the year, the population was dynamically changing since both young and old cohorts entered and exited the main population in the lagoon. Young individuals (<30 mm TL class) appeared during fall and winter (mostly December and January) following the reproduction period between late March and late August. As young individuals are considered the age 1 and 1+ individuals considering the growth curve (Figure 3) and the estimated longevity of the species. During summer they disappeared from the lagoon population as they enter the next cohort. During the spawning season, older individuals (>55 mm TL class) disappeared from the population probably due to a migration to the coast in order to release their eggs and then reappeared after August and remained there until January. The increased appearance of young individuals (<30 mm TL) in July is owed to the fact that the adults migrate towards the coast to release their eggs and therefore, only the young individuals remain in the lagoon for food and shelter.

Growth and Mortality

The results show that females grow faster and exhibit larger body size after 1.5-2 years (Figure 3). L∞ was found 58.98 mm for males and 72.45 mm for females. K values are almost similar between sexes (0.975 per year for males and 1.058 per year for females).From the VBGF data, the inflection point was estimated at 1.12 years for males and 1.04 years for females, which can be considered as rather early during their life span. Maximum age was estimated to be 3.07 years for males and 2.83 years for females. Natural mortality was estimated at 2.17 per year for the males and 2.16 for the females. Total mortality was estimated at 3.72 per year for males and 3.79 per year for females. The resulting exploitation ratio (E) is estimated at 58% and 57% for the males and females respectively.

Length–Weight Relationships

The length – weight relationships for males and females were estimated as follows (Figure 4):

$$Females: W(g) = 0.0003[TL,mm]^{2.131}, r^2 = 0.902, std.error = \pm 0.16g$$

$$Males: W(g) = 0.0009[TL,mm]^{1.808}, r^2 = 0.877, std.error = \pm 0.18g$$

Analysis of covariance showed that the two models are statistically different (p=0.01) while the power coefficients were found significantly different from 3 (P<0.01).

Fecundity

Several relationships between female body size and fecundity values were calculated as follows:

Total Length (cm)= -0.364+0.113 [Egg mass (g)], r^2=0.874, std.err. = 0.05 g

Total Weight (g)= 0.055+0.191 [Egg mass (g)], r^2=0.798, std.err. = 0.05 g

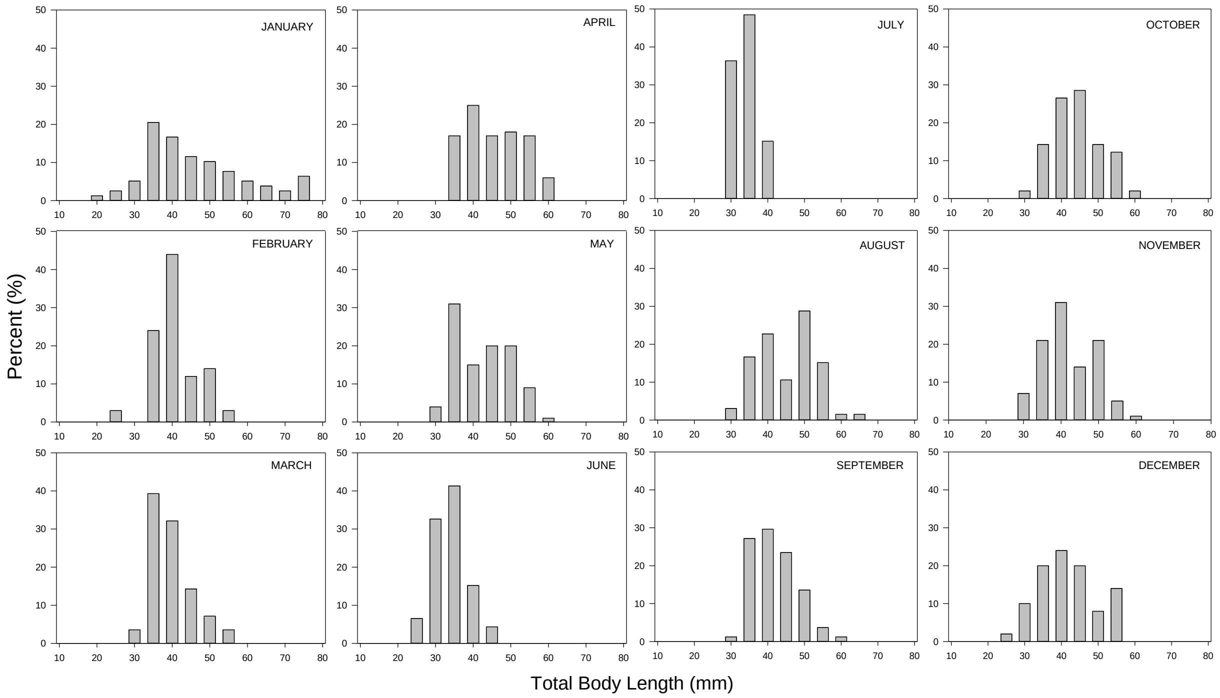

Figure 2. Monthly distributions of the total body length of all collected samples of *Palaemon adspersus* from the Parila lagoon (Croatia).

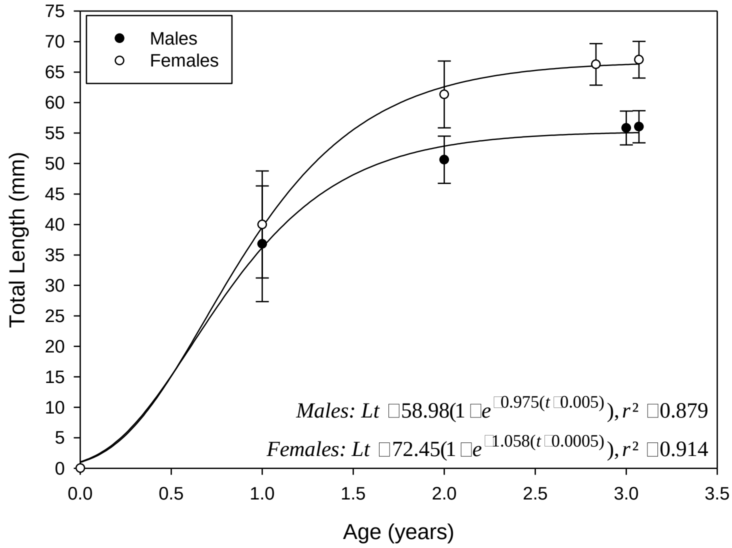

Figure 3. Growth rates of male and female *Palaemon adspersus* from the Parila lagoon (Croatia).

Total Length (cm)= 241.85 [Egg number]$^{1.17}$,
r^2=0.814, std.err. = 176 eggs

Total Weight (g)= 1743.62 [Egg number]$^{0.28}$,
r^2=0.79,5, std.err. = 183 eggs

The relationships between female total length and total weight with fecundity (eyed egg numbers per individual) are illustrated in Figure 5. According to the measurements, the average number of eyed eggs per 1g of total body weight was estimated at 2157±485 eggs or 1540.61±345 eggs (mean ± SD) per individual. The RO value was estimated at 0.28±0.11.

Discussion

Population Structure

The population structure when approached by the length–frequency distributions provides information regarding the movements of the various cohorts both in time (as the individuals grow) as well as in space (in and out of a specific location). The results from the length–frequency analysis presented here showed two main cohort movements: the movement of the adults out of the lagoon during the reproduction period, indicating that egg release is

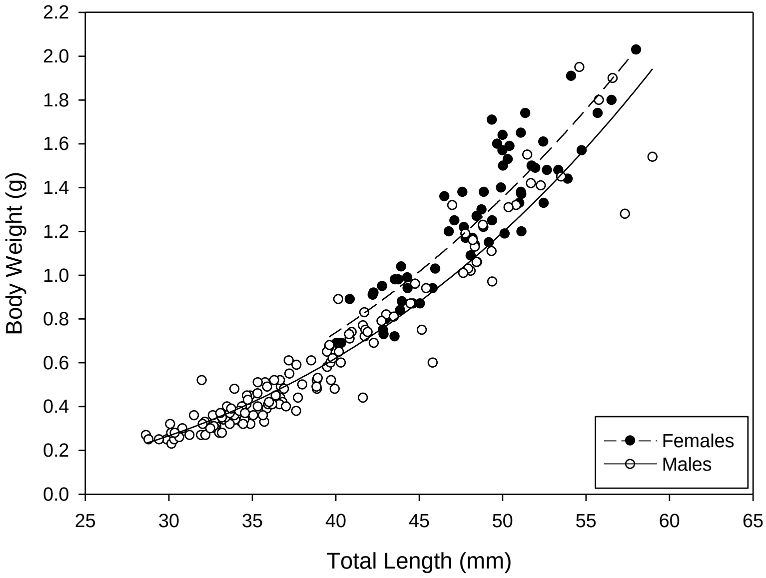

Figure 4. Length – weight relationships of male and female *Palaemon adspersus* from the Parila lagoon (Croatia).

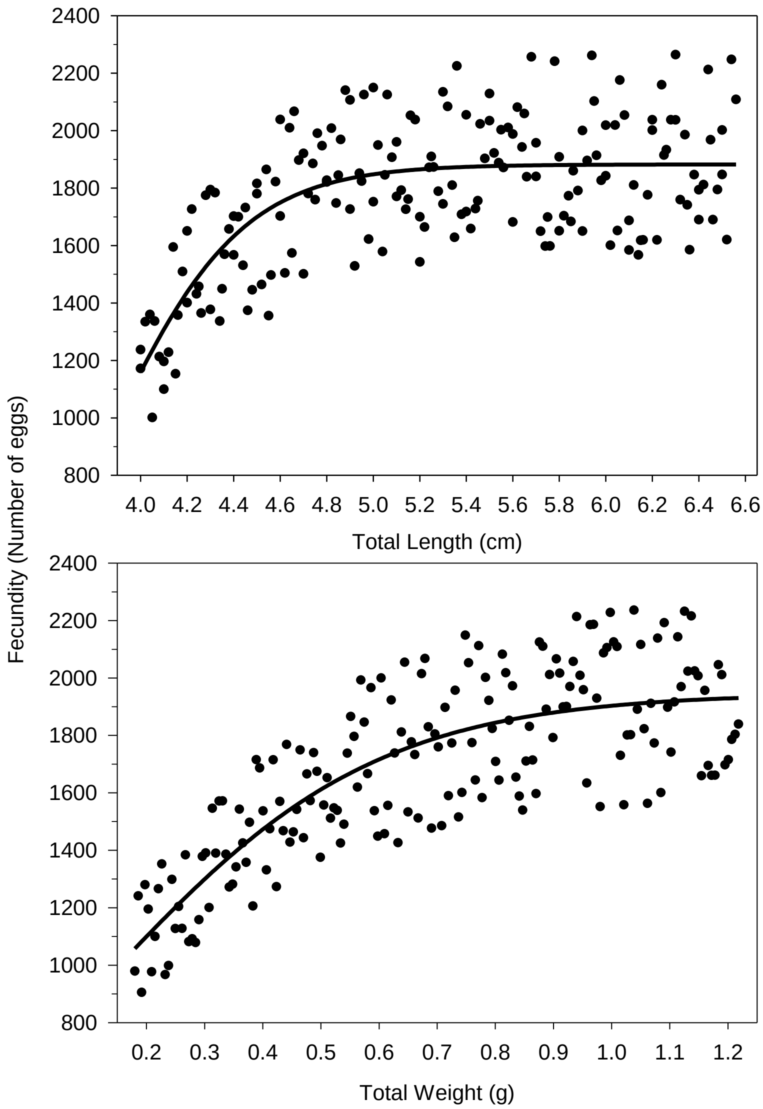

Figure 5. The relationships between *Palaemon adspersus* female total length and total weight with fecundity (egg number per individual) from Parila lagoon (Croatia).

carried out along the coast and not in the lagoon, and their later return for feeding and energy replenishment), as well as the movement of the juveniles after reproduction for recruitment in the lagoon population, obviously for feeding and protection from predators in the *Cymodocea* beds. Such migration for recruitment in estuaries has been also observed in Ebro river delta (Guerao and Ribeira, 1995).

Coastal populations of this species are shown to exhibit depth related migration movements from shallow waters to deep waters in winter and back (Hagerman and Østrup, 1980; Barnes, 1994; Jazdzewski and Konopacka, 1995). Such a migration owed to temperature regime was not detected in this study as the older cohorts are present during winter in the lagoon. This is in accordance with the observations made at south Black Sea coasts (Turkey; Bilgin *et al*., 2009) as well as the European Atlantic coast (Berglund, 1982). According to Berglund (1982) *P. adspersus* is sensitive to environmental salinity, temperature and oxygen and for this reason it inhabits mainly non-tidal areas. This concurs with the observations in the present study since the temperature variation in the Parila lagoon is between 9.16°C and 26.53°C which can be considered as favorable for the presence of this species year round.

Our results and observations support that Parila lagoon is a suitable environment for the species. The benthos of the lagoon is characterized by soft bottom rich with phanerogam beds. Most authors have reported association of this species with phanerogam beds which are considered as soft bottom habitats (Berglund, 1980, 1982; Köhn and Gosselck, 1989; Conides *et al*., 1992a, 1992b; Guerao and Ribera, 1995; Guerao, 1994; Jazdzewski and Konopacka, 1995; Manent and Abella-Gutierrez, 2006; Schaffmeister *et al*., 2006; Bilgin *et al*., 2008). On the contrary, according to Gallmetzer *et al*. (2005) and Orav-Kotta (2004) the usual habitat of the species is hard bottom. These authors, however, reported that the species can be found in detritus accumulations on hard bottoms related to *Posidonia* beds and it can be assumed that the species may move between the beds (soft-bottom) to adjacent detritus accumulation and back for feeding and refuge respectively, forming a mobile macrofauna community (Kikuchi 1980; Mazzella *et al*., 1989; Gambi *et al*., 1992; Sanchez-Jerez *et al*., 1999; Jazdzewski and Konopacka (1995).

Growth and Mortality

The population of *P. adspersus* in Parila lagoon seems to be related to the Messolonghi–Etolikon lagoon population (West Greece) based on the VBGF parameters (Table 1). It can be assumed that the geographical relation of these two locations (Ionion Sea is the natural extension of the Adriatic Sea towards the Mediterranean), as well as the similarities in environmental conditions, indicate the possibility that these two populations share the same ancestry. Obviously, a genetic study is required to prove this statement.

Growth seasonality has been reported as a common characteristic of the species (Bilgin *et al*., 2009) also in relation to recruitment variations (Bilgin *et al*., 2009; Chatzinikolaou and Richardson, 2008). However, the situation in semi-closed environments, like the lagoons and estuaries is different than along the coastline. These habitats exhibit high influence from the weather conditions due to shallow depths and the constant mixing of fresh and sea water. At the same time the shrimps constantly move in and out of the lagoons (adults for reproduction and juveniles for

Table 1. Comparison of growth equation variables and growth performance of various *Palaemon* id prawns

Species	Females			Males			Reference
	L_∞	K	Φ'	L_∞	K	Φ'	
P. adspersus	72.45	1.058	3.229	58.98	0.975	3.12	Present study
	62.99	1.19	3.67	49.63	1.09	3.43	Bilgin *et al.*,2009
	78.66	0.17	3.01	64.68	0.17	2.84	Conides *et al.*, 1992
	47.80	2.07	3.67	34.14	1.08	3.10	Manent and Abella-Gutierrez, 2006
		1.90			1.80		Gueаro and Ribera, 1995
	68.19	1.07	3.70	44.91	1.67	3.52	Figueras, 1986
	87.52			81.69			Nouvel van Risselberge, 1937
	104.65						Desbrosses, 1951
	104.22			84.54			Campillo, 1979
	106.12			87.28			Figueras, 1984
P. gravieri	23.20	0.80	2.63	18.59	0.70	2.39	Kim, 2005*
P. longirostris	16.32	0.51	2.13	11.68	0.62	1.93	Cartaxana, 2003*
P. serratus	137.40	0.48	3.96	97.84	0.73	0.73	Figueras, 1986
	90.73			79.55			Forster, 1951
	69.75			64.41			Cole, 1958
	80.03			68.00			Rodriguez, 1981
P. xiphias	70.00	1.92	3.97	50.00	1.57	1.57	Guerrao *et al.*, 1994
Exopalaemonmodestus	21.39	0.58	2.42	18.40	0.62	0.62	Oh *et al.*, 2002

(*) length measured from Carapace.

food and shelter) within a year. Furthermore our observations show that the intensive fishing of this species can cause irregular recruitment patterns since it is obvious that the females are mostly targeted due to their larger size.

The Growth Performance Index (Φ'; Sparre and Venema, 1992) can be used for comparison purposes especially under environmental stress. In addition, it is preferred for growth comparison between sexes of a species, and between species rather than comparison of $L\infty$ and K, as these two parameters are inherently negatively correlated (Pauly and Munro, 1984). From Table 1 it is visible that females grow faster and reach larger $L\infty$ values in relation to males. In addition, the estimated growth performance values of this population (both males and females) are intermediate when the other populations are either above 3.5 or below 3. There seems to exist a similarity only with the males from the Balearic Islands in the West Mediterranean (Spain; Table 1).The statistically significant effect of geographic latitude to male growth performance index has been reported in many previous studies (Figueras, 1986; Guerao and Ribera, 1995; Manent and Abella-Gutierrez, 2006; Bilgin *et al* 2009). However, these results were obtained from few different studies and should be interpreted with caution.

Longevity of *P. adspersus* in the Parila lagoon was estimated to be 3.07 years (37 months) for the males and 2.83 years (34 months) for the females. This is in accordance with the results reported by Campillo (1975), though most authors report smaller longevity estimates between 1 and 2 years (Nouvel van Rysselberge, 1937; Forster, 1951; Desbrosses, 1951; Cole, 1958; Rodriguez, 1981, Figueras, 1986; Guerao and Ribera, 1995; Manent and Abella-Gutierrez, 2006; Bilgin *et al*., 2009). Smaller longevity for the females is more or less expected because they are mostly targeted by fishing due to their bigger size. Longevity is affected, among others, also by geographic latitude (Bilgin *et al*., 2009; Guerao *et al*., 1994; Oh *et al*., 2002, Oh and Hartnoll, 2004) which is not evident here.

Length–Weight Relationships

Limited information exists on the length – weight relationships of the species *P. adspersus*. The results showed significant differences of the length – weight equation parameters in various regions (Table 2). Allometry is better described by the carapace length (CL) to weight (W) relationship rather than the total length (Lt) to weight relationship, as it can be seen from the power coefficients in Table 2. The data from the study by Mohammad Khani *et al*. (2004), although included in Table 2, cannot be considered as valid due to the inadequately reported power (b) coefficient of the CL-W relationship as they appear in FAO-AGRIS online database.

A principal component analysis (PCA) on the coefficients of the CL-W relationship (data from Table 2), reveals that the males and females from the Parila lagoon have significant difference (Figure 6). This clearly indicates that the population structure of the two sexes in terms of body size is different in Parila lagoon. Furthermore it indicates that size-related migrations of the sexes are different so that the cohorts present in the lagoon throughout the year are different. Such differences between length and weight of males and females have been observed in *Palaemon elegans* along the Polish coastal waters of south Baltic Sea (Vistula lagoon, Puck Bay and Vistula river delta; Janas and Mańkucka, 2010). Furthermore, the same authors reported that males showed greater variability in length which is in full accordance with this study. The Mediterranean populations of the species *Palaemon elegans* tend to have uniform populations in terms of body proportions between sexes while as we move to northern latitudes (South Black Sea, Caspian Sea and Baltic Sea), the variability of body proportions between sexes is increasing indicating large intrapopulation differences (Janas and Mańkucka, 2010).

Table 2. Comparison of length – weight relationships of *Palaemon adspersus* from various geographic locations

Area	Sex	based on TL-W relationship		based on CL-W relationship		Reference
		Parameter a	Parameter b	Parameter a	Parameter b	
Parila lagoon, Neretva	M	0.0009	1.81	0.0119	3.15	Present study
River delta, Croatia	F	0.0003	2.13	0.0044	2.83	
Balearic Islands, Spain	M			0.0160	3.01	Manent and Abella-
	F			0.0186	2.96	Gutiérrez, 2006
Caspian Sea, Iran	M			0.0007	0.84	Mohammad Khani *et al.*,
	F			0.0014	0.59	2004
	M			0.0044	0.29	
	F			0.0066	0.19	
Messolonghi lagoon,	M	0.000004	3.20	0.00019	2.92	Conides *et al.*, 1992
Greece	F	0.000005	3.11	0.00014	3.01	
Gulf of Gdansk, Poland	Both	0.000004	3.17			Lapinska and Szaniawska, 2006
Black Sea (Turkish	M	0.00002	2.93			Bilgin *et al.*, 2009
coast)	F	0.000007	3.25			

TL, total length; CL, carapace length; W, weight

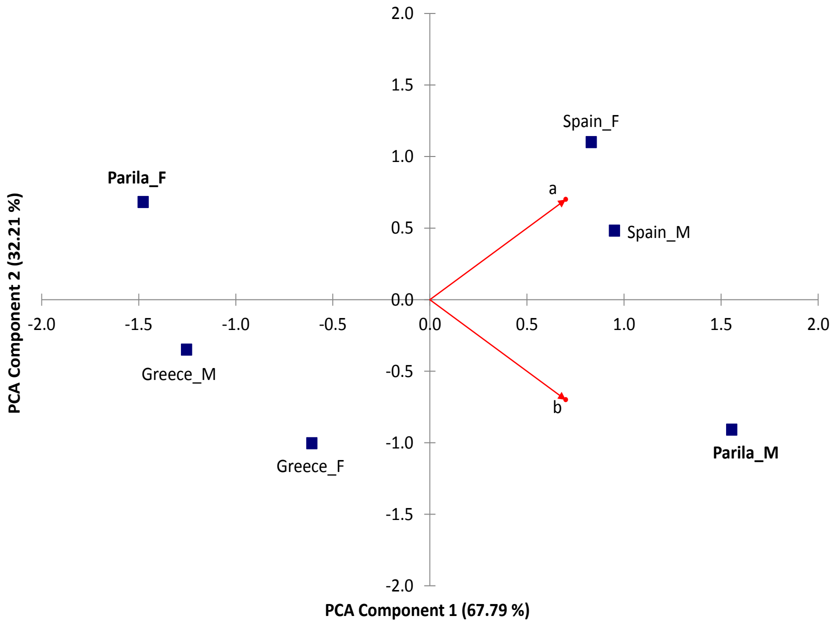

Figure 6. Principal Components Analysis (PCA) biplot of the three *Palaemon adspersus* populations (Greece, Spain and Croatia) based on the coefficients of the carapace length – weight relationship (parameters a, b see from Table 2; the notation F denotes females and _M, the males).

Fecundity

Average number of eggs per 1 g of total body weight (mainly the standard deviation) as well as the profiles of the body size to number of eggs relationships, indicated that there exists a weak relationship between these variables, meaning that this species exhibits a high variability of fecundity. Such increased variations have been reported for this species as well as similar ones such as *Crangon crangon* (Puro, 2010), *Palaemon northropi* (Pralon and Negreiros-Fransozo, 2006; Anger and Moreira, 1998) and *Palaemon pandaliformis* (Day, 2001). The high variability observed in these species can be the result of natural egg loss during incubation as observed in nature. Egg loss may be caused by mechanical stress, parasites and occasionally increase of egg volume during incubation (Bilgin and Samsun, 2006). However this observation is not in accordance to Berglund and Rosenqvist (1986) who reported that fecundity in this and similar species is strongly related to body size (also Emmerson, 1985; Guerao *et al*. 1992, 1994; Anger and Moreira, 1998; Day, 2001).

Conclusions

Lagoon environment is a highly variable and dynamic environment applying pressures to the species which live in or utilise periodically during certain life stages. In the present case of Parila lagoon, the negative externalities on the population of *P. adspersus* prawn are further enhanced due to the intensive fishing of the species for bait. The estimates of mortality indicate that females are more vulnerable to fishing due to relative immobility during egg carrying and due to the high preference by fishermen due to their large size in relation to males (general problems related to the open access regime; Caddy and Cochrane, 2001). In addition to this, females receive more fishing pressure as they spend more time in the lagoon as proven by the length-weight relationships obviously for shelter (during reproduction) and feeding (after reproduction). Considering the species is very important for coastal food chains as the prey of many fish of high market value (for example, European sea bass, Gilthead seabream etc.), it is evident that certain measures are needed to ensure the conservation of the population in the Parila lagoon.

There are several management measures which may be taken to fulfill this goal. We propose a management system based on the precautionary approach composed of fishing effort control measures and limit reference points. The control of fishing effort is based on reducing the fishing period within the year and establish a no-take period around the peak of reproduction (May-June).

The performance of the population can be monitored using biological reference points based on a number of population dynamics parameters such as the minimum landing size of prawns and maximum mortality. The minimum landing size is related to the size-at-maturity size since thisway we may allow the prawns to reproduce at least once during their life. Using the formulas of Froese and Binolhan (2000) the size-at-maturity for males is 29.9 mm and 39.3 mm for females. Therefore, a minimum size limitation of 40 mm for the whole population is a reasonable reference point. Such limitation, could provide an increase to the relative yield per recruit up to +29.5%

(Froese and Binohlan, 2000). However, this measure can be considered as very strict for the fishermen, since according the results of this study, the prawns with a TL less or equal to 40 mm (Fig. 1) represent the 30-50% of the population depending on the month, indicating a significant reduction of the available population for exploitation. This clearly implies that a broad stakeholder participation management scheme is required (Jentoft and McCay, 1995).

In relation to setting of a reference point based on mortality this may follow the assumption of Garcia *et al*. (1989) that fishing mortality at MSY, FMSY, is equal to kM (where, k is a constant and M is the natural mortality, per year). According to several authors, k can be anything between 0.32 and 4, the lowest values being for short-lived species (Beddington and Cooke, 1983; Caddy and Csirke, 1983; Garcia and LeReste, 1981; Patterson, 1992). The life span of the species *P. adspersus* was estimated at 3 years and for this reason we propose an initial value for a reference point of FMSY equal to 1.165 per year (k=1). This equals to a reduction of the current average fishing mortality of 1.59 per year by 27%.

It is obvious that a management plan cannot be static but dynamic in terms of constant monitoring which should include a feedback action to enable the correction and/or adaptation of the reference points on an annual basis in order to achieve an optimum exploitation regime for the population.

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References

Anger, K. and Moreira, G.S. 1998 Morphometric and reproductive traits of tropical caridean shrimps. Journal of Crustacean Biology, 18: 823-838.

Barausse, A., Michieli, A., Riginella, E., Palmeri, L. and Mazzoldi, C. 2011. Long-term changes in community composition and life-history traits in a highly exploited basin (northern Adriatic Sea): the role of environment and anthropogenic pressures. Journal of Fish Biology, 79: 1453-1486.

Barnes, R.S.K. 1994. The brackish-water fauna of northwestern Europe. Cambridge University Press, Cambridge, 287 pp.

Beddington, J.R. and Cooke, J.R. 1983. The potential yield of previously unexploited stocks. FAO Fisheries Technical Paper No: 242, Rome, 47 pp.

Berglund, A. 1980. Niche differentiation between two littoral prawns in Gullmar Fjord, Sweden: *Palaemon adspersus* and *P. squilla*. Holarctic Ecology, 3: 111–115.

Berglund, A. 1982. Coexistence, size overlap and population regulation in tidal vs. non-tidal *Palaemon* prawns. Oecologia, 54: 1–7.

Berglund, A. 1984. Reproductive adaptations in two *Palaemon* prawn species with differing habitat requirements. Marine Ecology Progress Series, 17: 77–83.

Berglund, A. 1985. Different reproductive success at low salinity determines the estuarine distribution of two *Palaemon* prawn species. Holarctic Ecology, 8: 49-52.

Berglund, A. and Bengtsson, J. 1981. Biotic and abiotic factors determining the distribution of two prawn species: *Palaemon adspersus* and *P. squilla*. Oecologia, 49: 300–304

Berglund, A. and Rosenqvist, G. 1986. Reproductive costs in the prawn *Palaemon adspersus*: effects on growth and predator vulnerability. OIKOS, 46: 349-354.

Bertalanffy, L. von 1938. A quantitative theory of organic growth (Inquiries on growth laws. II). Human Biol. 10: 181-213

Bilgin, S. and Samsun, O. 2006. Fecundity and Egg Size of Three Shrimp Species, *Crangon crangon*, *Palaemon adspersus* and *Palaemon elegans* (Crustacea: Decapoda: Caridea), off Sinop Peninsula (Turkey) in the Black Sea. Turkish Journal of Zoology, 30: 413-421.

Bilgin, S., Ozen, O. and Ates, A.S. 2008. Spatial and temporal variation of *Palaemon adspersus* , *Palaemon elegans*, and *Crangon crangon* (Decapoda: Caridea) in the southern Black Sea. Estuarine, Coastal and Shelf Science, 79: 671–678.

Bilgin, S., Samsun, O. and Ozen, O. 2009. Seasonal growth and reproduction biology of the Baltic prawn, *Palaemon adspersus* (Decapoda: *Palaemonidae*), in the southern Black Sea. Journal of the Marine Biological Association of the United Kingdom, 89(3): 509–519.

Blanc, A. and Daguzan, J. 2000. Size selectivity in the diet of the young cuttlefish *Sepia officinalis* (Mollusca: Sepiidae). Journal of the Marine Biological Association of the United Kingdom, 80: 1137–1138.

Cabral, H. and Costa, M.J. 2001. Abundance, feeding ecology and growth of 0-group sea bass, *Dicentrarchus labrax*, within the nursery areas of the Tagus estuary. Journal of the Marine Biological Association of the United Kingdom, 81: 679–682.

Caddy, J.F. and Csirke, J. 1983. Approximations to sustainable yield for exploited and unexploited stocks. Oceanogr. Trop., 18(1): 3-15.

Campillo, A. 1975. Donnees pratiques sur l'élevage au laboratoire de *Palaemon terrains* (Pennant). Revue des Travaux de l'Institut des Peches Maritimes, 39 (4): 395-405.

Cartaxana A. 2003. Growth of the prawn *Palaemon longirostris* (Decapoda, *Palaemonidae*) in Mira River and estuary, SW Portugal. Journal of Crustacean Biology, 23: 251–257.

Chatzinikolaou, E. and Richardson, C.A. 2008. Population dynamics and growth of *Nassarius reticulatus* (Gastropoda: Nassariidae) in Rhosneigr (Anglesey, UK). Marine Biology, 153: 605–619.

Cole, H. 1958. Notes on the biology of the common prawn *Palaemon serratus* (Pennant). Fisheries Investigations, 22: 1-22.

Conides, A., Tsevis, N. and Klaoudatos, S. 1992a. Somatic measures and mortality of the prawn *Palaemon adspersus* (Rathke, 1837) in Messolonghi Lagoon, western Greece. Fresenius Environmental Bulletin, 1:

468–471.

Conides, A., Tsevis, N. and Yannopoulos, C. 1992b. Studies on sex ratios observed on the prawn *Palaemon adspersus* (Rathke, 1837) population at Messolonghi lagoon, Greece. Fresenius Environmental Bulletin, 1: 665–669.

Cuesta, J.A., Gonzalez-Ortegon, E., Rodrıguez, A., Baldo, E., Vilas, C. and Drake, P. 2006. The decapod crustacean community of the Guadalquivir Estuary (SW Spain): seasonal and inter-year changes in community structure. Hydrobiologia, 557: 85–95.

Day, C.A. 2001. An Introduction to the Ecology and Behaviour of the Prawn, *Palaemon affinis* Milne-Edwards, 1837 (Crustacea: Decapoda: Natantia). MSc thesis, Christchurch: University of Canterbury, New Zelland,153 pp.

Dessbrosses, P.C. 1951. Les crevettes roses. Bulletin Informaccion et Doc Off Peches Maritimes, SerB.n.s, 39.

Emmerson, W.D. 1985. Fecundity, larval rearing and laboratory growth of *Palaemon pacificus* (Stimpson) (Decapoda, *Palaemonidae*). Crustaceana, 49 (3): 277-289.

Figueras, A.J. 1984. Biologia y pesca del camaron (*Palaemon adspersus* y *Palaemon serratus*) en la ria de Vigo. PhD thesis: Obradoiro: Universidad de Santiago de Compostela, Spain, 122 pp.

Figueras, A.J. 1986. Crecimiento de *Palaemon adspersus* (Rathke 1837) y *P. serratus* (Pennant 1777) (Decapoda: Natantia) en la ria de Vigo (S) de Espana). Revista de Investigacao Pesqueira (Maputo), 50(1): 117-125.

Forster, O.R. 1951. The biology of the common prawn, *Leander serratus* Pennant. Journal of the Marine Biological Association of the United Kingdom, 30: 333-360.

Froese, R. and Binohlan, C. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology, 56(4): 758–773.

Gallmetzer, I., Pflugfelder, B., Zekely, J. and Ott, J.A. 2005. Macrofauna diversity in *Posidonia oceanic* detritus: distribution and diversity of mobile macrofauna in shallow sublittoral accumulations of *Posidonia oceanica* detritus. Marine Biology, 147: 517–523.

Gambi, M.C., Lorenti, M., Russo, G.F., Scipione, M.B. and Zuppo, V. 1992. Depth and seasonal distribution of some groups of the vagile fauna of the *Posidonia oceanica* leaf stratum: structural and trophic analyses. Marine Ecology, 13: 17–39.

Garcia, S.M., LeReste, L. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. FAO Fisheries Technical Paper No 203, Rome, 215 pp.

Garcia, S.M., Sparre, P. and Csirke, J. 1989. Estimating surplus production and maximum sustainable yield from biomass data when catch and effort time series are not available. Fisheries Research, 8: 13–23.

Guerao, G. 1994. Feeding habits of the prawns *Processa edulis* and *Palaemon adspersus* (Crustacea, Decapoda, Caridea) in the Alfacs Bay, Ebro Delta (NW Mediterranean). The Zoological Miscellany, 17: 115-122.

Guerao, G. and Ribera, C. 1995. Growth and reproductive ecology of *Palaemon adspersus* (Decapoda, *Palaemonidae*) in the western Mediterranean. Ophelia, 43(3): 205-213.

Guerao G., Perez-Baquera J. and Ribera, C. 1994.Growth and reproductive biology of *Palaemon xiphias* Risso, 1816 (Decapoda, Caridea, *Palaemonidae*). Journal of Crustacean Biology, 14: 280–288.

Guerao, G., Ribera, C. And Castello, F. 1992. Biologia de la reproduccion de *Palaemon adspersus* Rathke, 1837 (Crustacea: Decapoda: Caridea) en la bahıa de ElsAlfacs (delta del Ebro). Boletim da Sociedade Portuguesa de Entomologia, 1(3): 171–180.

Hagerman, L. and Østrup, J.1980. Seasonal and diel activity variations in the shrimp *Palaemon adspersus* from a brackish, non-tidal area. Marine Ecology Progress Series, 2: 329-335.

Hansen, J.P., Wikstrom, S.A. and Kautsky, L. 2012. Taxon composition and food-web structure in a morphometric gradient of Baltic Sea land-uplift bays. Boreal Environment Research, 17: 1-20.

Holthuis, L.B. 1980. Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries. FAO Fish. Synopisis, 125(1), Rome, 271 pp.

Ivleva, I.V. 1980. The Dependence of crustacean respiration rate on body mass and habitat temperature. International Review of Hydrobiology, 66(1): 1-47.

Janas, U. and Bruska, O. 2010. Energy values and energy resources of two prawns Baltic coastal waters: the indigenous Palaemon adspersus and the nonindigenous *Palaemon elegans*. Oceanologia, 52(2): 281-297.

Janas, U. and Mańkucka, A. 2010. Body size and reproductive traits of *Palaemon elegans* Rathke, 1837 (Crustacea, Decapoda), a recent colonizer of the Baltic Sea. Oceanol. Hydrobiol. St., 39: 3-24.

Jazdzewski, K. and Konopacka, A. 1995. Pancerzowce prócz równonogów ladowych. Malacostraca except Oniscoidea. Katalog Fauny Polski, Warszawa, 9(1): 1-165.

Jentoft, S. and McCay B.J. 1995. User participation in fisheries management lessons drawn from international experiences. Marine Policy, 19(3): 227-246.

Kikuchi, T. 1980. Faunal relationships in temperate seagrass beds. In: R.C. Phillips and C.P. McRoy (Eds.), Handbook of seagrass biology: an ecosystem perspective. Garland STPM Press, New York: 153–172.

Kim, S. 2005. Population structure, growth, mortality, and size at sexual maturity of *Palaemon gravieri* (Decapoda: Caridea: *Palaemonidae*). Journal of Crustacean Biology, 25: 226-232.

Kim, J.C., Ma, W.M., Oh, C.W. and Paik, S.G. 2008. Reproduction and growth of the freshwater prawn, *Palaemon paucidens* (Decapoda: *Palaemonidae*) in a lake of Korea. Journal of Environmental Biology, 29(2): 163-168.

Köhn, J. and Gosselck, F. 1989. Identification key for the Malacostraca of the Baltic Sea. Mitteilungenausdem Zoologischen Museum in Berlin, 65(1): 3-114.

Lapinska, E. and Szaniawska, A. 2006. Environmental preferences of *Crangon crangon* (Linnaeus 1758), *Palaemon adspersus*, Rathke 1837, and *Palaemon elegans* Rathke 1837, in the littoral zone of the gulf of Gdansk. Crustaceana, 79(6): 649-662.

Manent, P. and Abella-Gutiérrez, J. 2006. Population biology of *Palaemon adspersus* Rathke, 1837 (Decapoda, Caridae) in Fornells Bay, Balearic Islands, Western Mediterranean. Crustaceana 79(11):1297-

1308.

Mazzella, L, Scipione, M.B. and Buia, M.C. 1989. Spatio-temporal distribution of algal and animal communities in a *Posidonia oceanica* meadow. Marine Ecology, 10: 107–129.

Mogias, A. and Kevrekidis, T. 2005. Macrozoobenthic community structure in a poikilohaline Mediterranean lagoon (Laki Lagoon, northern Aegean). Helgoland Marine Research, 59: 167–176.

Mohammad Khani, H., Pursufi, T., Binaei, A.O.-V., Peyghambari, Y., Zamani, A.O.-R., Hoseyni, A., Qadir Nezhad, H. and Khatib, S. 2004. Survey on some biological aspects of the shrimps of the Caspian Sea in the coastal water of the Golestan province. Golestan Agricultural and Natural Resources Research Center, Gorgan (Iran), FAO/AGRIS Database.

Nouvel van Rysselberge, L. 1937. Contribution a l'étude de la mue, de la croissance, el de la régénération chez les Crustaces Natantia. Recueil de l'Institut zoologique Torley-Rousseau, 6: 9-161.

Oh, C.-W. and Hartnoll, R.G. 2004. Reproductive biology of the common shrimp *Crangon crangon* (Decapoda: Crangonidae) in the central Irish sea. Marine Biology, 144: 303-316.

Oh C.W., Suh H.L., Park K.Y., Ma C.W. and Lim H.S. 2002. Growth and reproductive biology of the freshwater shrimp *Exopalaemon modustus* (Decapoda: *Palaemonidae*) in a lake of Korea. Journal of Crustacean Biology, 22: 357–366.

Orav-Kotta, H. 2004. Habitat choice and feeding activity of benthic suspension feeders and mesograzers in the Northern Baltic Sea. PhD thesis: Institute of Zoology and Hydrobiology, Faculty of Biology and Geography, University of Tartu, Estonia, 117 pp.

Patterson, K. 1992. Fisheries for small pelagic species: an empirical approach to management targets. Reviews in Fisheries Biology and Fisheries, 2: 321–338.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil International pour l'Exploration de la Mer, 39(3): 175-192.

Pauly, D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. International Center for Living Aquatic Resources Management (ICLARM), Studies and Reviews, (8): 325 pp.

Pauly, D. and Munro, J.L. 1984. Once more on the comparison of growth in fish and invertebrates. International Center for Living Aquatic Resources Management (ICLARM), Fishbyte, 2: 1-21.

Pralon, B.G.N. and Negreiros-Fransozo, M.L. 2006. Population biology of *Palaemon* (*Palaeander*) *northropi* Rankin, 1898 (Crustacea, Decapoda, *Palaemonidae*) in a tropical South American estuary. Acta Limnologica Brasiliensia, 18(1): 77-87.

Puro, H. 2010. Reproductive biology of a new invader, brown shrimp *Crangon crangon* (L), in Iceland. BSc Thesis, Faculty of Life and Environmental Sciences, Engineering and Natural Sciences, University of Iceland, 38 pp.

Ricker, W.E. 1979. Growth Rates and Models. In: W.S. Hoar, D.J. Randall, J.R. Brett (Eds.), Fish Physiology, Academic Press, New York: 678-742 pp.

Rodriguez, A. 1981. Growth and sexual maturation of *Penaeus kerathurus* (Forskal, 1775) and Palaemon serratus (Pennant) in salt ponds. Aquaculture, 24: 257–266.

Rufino, M.M., Maynou, F., Abello, P. and Sarda, F. 2006. Spatial and environmental factors affecting the distribution of the main decapod crustacean prey species in the NW Mediterranean. Hydrobiologia, 555: 129–141.

Sanchez-Jerez, P., Cebrian, C.B. and Espla, A.A.R. 1999. Comparison of the epifauna spatial distribution in *Posidonia oceanica*, *Cymodocea nodosa* and unvegetated bottoms: importance of meadow edges. Acta Oecologica, 20:391–405.

Schaffmeister, B.E., Hiddink, J.G. and Wolff, W.J. 2006. Habitat use of shrimps in the intertidal and shallow subtidal seagrass beds of the tropical Banc d'Arguin, Mauritania. Journal of Sea Research, 55: 230-243.

Smaldon, G. 1979. British Coastal Shrimps and Prawns: Keys and Notes for the Identification of the Species, Synopses of the British fauna, New Series 15. Academic Press, London, 126 pp.

Sparre, P. and Venema, S.C. 1992. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper 306, Rome, 376 pp.

Taylor, C.C. 1958. Cod growth and temperature. Journal du Conseil International pour l'Exploration de la Mer, 23:366-370.

von Oertzen, A. 1984. Metabolic similarity of *Palaemon* populations from different brackish waters. Short Note. International Review of Hydrobiology, 69(5), 753-755.

Westin, L. and Aneer, G. 1987. Locomotor activity patterns of nineteen fish and five crustacean species from the Baltic Sea. Environmental Biology of Fishes, 20(1): 49-65.

Włodarska-Kowalczuk, M., Jan Marcin Wesławski, J.M., Warzocha, J. and Janas, U. 2010. Habitat loss and possible effects on local species richness in a species-poor system: a case study of southern Baltic Sea macrofauna. Biodiversity and Conservation, 19: 3991–4002.