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

L. Glamuzina¹, A. Conides², I. Prusina², M. Ćuktera³, D. Klaoudatos³, P. Zacharakís⁴, B. Glamuzina³

¹ University of Split, Center for Marine Studies, Livannjska 5/I1II, 21 000, Split, Croatia.
² Hellenic Centre for Marine Research, Institute for Marine Biological Resources and Inland Waters, 46.7 km Athens-Sounion Avenue, 19013 Anavyssos Attikis, Greece.
³ University of Dubrovnik, Cira Carica 4, 20000, Dubrovnik, Croatia.
⁴ Institute of Geological and Mineral Research, Sp. Loui 1, 17677 Acharnes, Athens, Greece.

* Corresponding Author: Tel.: +30-22940 77190; Fax: +30-22940 77190;
E-mail: akoni@tee.gr

Received 9 April 2014
Accepted 16 July 2014

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 $t_\infty = 0.0046$ years for males and $L_\infty = 72.45$ mm, $K = 1.058$ year⁻¹ and $t_\infty = 0.0005$ years for females. Growth performance ($\Phi'$) 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; Guerard 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; Guerard et al., 1992; Guerard 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-Kowalczyk 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., 2007).
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):

\[
L_t = L_\infty \left( 1 - e^{-K(t-t_0)} \right)
\]

where, \(L_t\) is the total length (from the tip of the rostrum to the tip of the telson; in mm), \(L_\infty\) is the maximum length, \(K\) is the growth coefficient (year\(^{-1}\)) and \(t_0\) 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):

\[
i.p. = t_0 + \frac{\ln(3)}{K}
\]

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

\[
t_{\text{max}} = t_0 + \frac{2.996}{K}
\]

where, \(t_{\text{max}}\) is a life span to attain 95% of \(L_t\), \(t_0\) is the length at time zero, 0.95 is 95% and \(K\) is the VBGF growth coefficient.
Growth performance was calculated according to Pauly and Munro (1984):

\[ \Phi' = \log(K) + 2\log(L) \]

Where \( \Phi' \) is the growth performance index, \( K \) is the growth coefficient and \( L_x \) 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):

\[ \log(M) = -0.0152 - 0.279 \log(L) + 0.6543 \log(K) + 0.463 \log(T) \]

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 \( L_x \), \( K \), \( t_{\max} \) 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 \( \alpha=0.05 \) 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). \( L_x \) 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:**

\[ W(g) = 0.0003(TL,mm)^{2.131} \]

\( r^2 = 0.902, \text{ std.err.} = \pm 0.16g \)

**Males:**

\[ W(g) = 0.0009(TL,mm)^{1.308} \]

\( r^2 = 0.877, \text{ std.err.} = \pm 0.18g \)

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):**

\( r^2=0.874, \text{ std.err.} = \pm 0.05 \)

**Total Weight (g):**

\( r^2=0.798, \text{ std.err.} = \pm 0.05 \)
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 Gosseleck, 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 |
|                                                 | \(L_\infty\) | \(K\)    | \(\Phi'\) | \(L_\infty\) | \(K\)    | \(\Phi'\) |          |
| \(P. adspersus\)                                | 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 |
|                                                 | 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 |
| \(P. gravieri\)                                 | 22.20     | 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     | Guerao et al., 1994 |
| \(Eopalaemon modestus\)                         | 21.39     | 0.58      | 2.42      | 18.40     | 0.62      | 0.62     | Oh et al., 2002 |

\(\Phi'\) 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 ($\Phi'$; 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 $P. \text{adspersus}$ 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 (Novel van Rysselberge, 1937; Forster, 1951; Desbrosses, 1951; Cole, 1958; Rodriguez, 1981, Figueras, 1986; Guero 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 $P. \text{adspersus}$. 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

<table>
<thead>
<tr>
<th>Area</th>
<th>Sex</th>
<th>Parameter a</th>
<th>Parameter b</th>
<th>Parameter a</th>
<th>Parameter b</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parila lagoon, Neretva</td>
<td>M</td>
<td>0.0009</td>
<td>1.81</td>
<td>0.0119</td>
<td>3.15</td>
<td>Present study</td>
</tr>
<tr>
<td>River delta, Croatia</td>
<td>F</td>
<td>0.0003</td>
<td>2.13</td>
<td>0.0044</td>
<td>2.83</td>
<td></td>
</tr>
<tr>
<td>Balearic Islands, Spain</td>
<td>M</td>
<td></td>
<td></td>
<td>0.0160</td>
<td>3.01</td>
<td>Manent and Abella-Gutierrez, 2006</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td></td>
<td></td>
<td>0.0186</td>
<td>2.96</td>
<td>Mohammad Khani et al., 2004</td>
</tr>
<tr>
<td>Balearic Islands, Spain</td>
<td>M</td>
<td></td>
<td></td>
<td>0.0007</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td></td>
<td></td>
<td>0.0014</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>Caspian Sea, Iran</td>
<td>M</td>
<td></td>
<td></td>
<td>0.0044</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td></td>
<td></td>
<td>0.0066</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Messolonghi lagoon, Greece</td>
<td>M</td>
<td>0.000004</td>
<td>3.20</td>
<td>0.00019</td>
<td>2.92</td>
<td>Conides et al., 1992</td>
</tr>
<tr>
<td>Gulf of Gdansk, Poland</td>
<td>F</td>
<td>0.000005</td>
<td>3.11</td>
<td>0.00014</td>
<td>3.01</td>
<td>Lapinska and Szańawska, 2006</td>
</tr>
<tr>
<td>Black Sea (Turkish coast)</td>
<td>M</td>
<td>0.000002</td>
<td>2.93</td>
<td>0.000007</td>
<td>3.25</td>
<td>Bilgin et al., 2009</td>
</tr>
</tbody>
</table>

TL, total length; CL, carapace length; W, weight
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 this way we may allow the prawns to reproduce at least once during their life. Using the formulas of Froese and Binohlan (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.

Acknowledgments

We would like to thank the two anonymous referees for their valuable comments which improved this paper. We also would like to thank Dr Christos Maravelias for his thorough review of the draft manuscript and his valuable comments.

References


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.


