#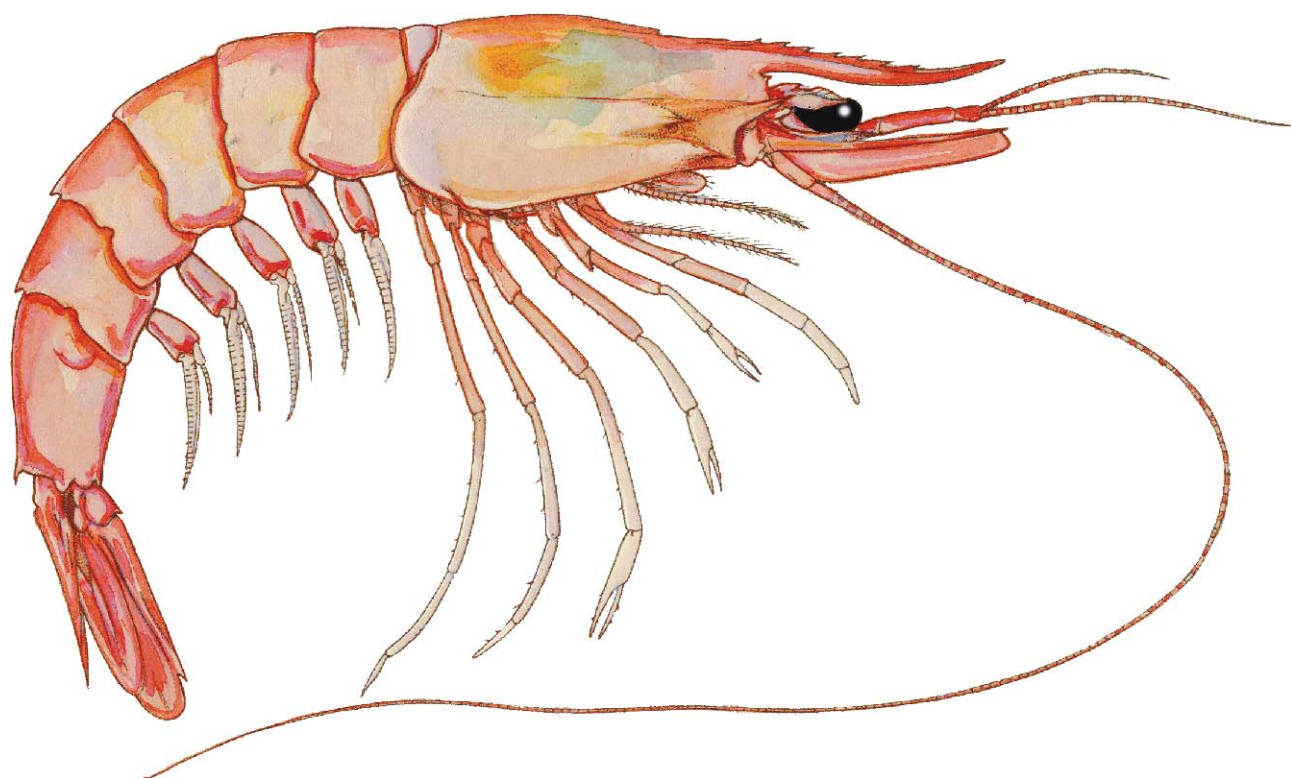 Stock status and potential yield of deep water rose shrimp (*Parapenaeus longirostris*, Lucas 1846) in the south-central Mediterranean Sea

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MedSudMed

Stock status and potential yield of deep water rose shrimp
(*Parapenaeus longirostris*, Lucas 1846)
in the south-central Mediterranean Sea

Preface

The Regional Project "Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily" (MedSudMed) is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Italian Ministry of Agriculture, Food and Forestry Policies (MiPAAF). Since 2012 MedSudMed is cofounded by the Directorate General for Fisheries and Maritime Affairs of the European Commission (DG Mare). The Italian Regione Siciliana funded a project aimed at strengthening MedSudMed's effectiveness on issues related to demersal resources, namely crustaceans, for 18 months, starting from May 2011.

MedSudMed promotes scientific cooperation between research institutions of the four participating countries (Italy, Libya, Malta and Tunisia), for the continuous and dynamic assessment and monitoring of the status of the fisheries resources and the ecosystems in this area of the Mediterranean Sea.

Research activities and training are supported to increase and use knowledge on fisheries ecology and ecosystems, and to create a regional network of expertise. Particular attention is given to the technical coordination of the research activities between the countries, which should contribute to the implementation of the Ecosystem Approach to Fisheries. Consideration is also given to the development of an appropriate tool for the management and processing of data related to fisheries and their ecosystems.

GCP/RER/010/ITA Publications

The MedSudMed Project publications are issued as series of Technical Documents (GCP/RER/010/ITA/MSM-TD-00) and Scientific Reports (GCP/RER/010/ITA/MSM/SR-00) related to meetings, missions and research organized by or conducted within the framework of the Project.

Comments on this document would be welcomed and should be sent to the Project headquarters:

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Preparation of this document

Information is critical to the identification of fisheries management strategies. The assessment of the state of natural resource and of fisheries exploiting them underpins the formulation of the development of management strategies for fisheries. The identification of the main fisheries target species, their stock status and potential yield provides useful information to manage fisheries in a way that addresses the multiple needs of societies while ensuring the sustainable use of natural resources. The concomitant exploitation of the same natural resource by the fisheries of more than one country adds a further layer of interactions calling for joint cooperative studies and sharing of fishery data.

The experts of the countries participating in the FAO Project MedSudMed (*Assessment and Monitoring of the fisheries Resources and the Ecosystems in the Straits of Sicily*) during the 7th MedSudMed Coordination Committee (Malta, February 2009) deemed necessary to identify the main fishery target species whose stocks are shared in the Project area and initiate the joint analysis of existing data for stock assessment. The overall objective was to produce the necessary scientific information to support the identification of likely consequences of different possible management measures. Accordingly MedSudMed organized, in collaboration with CopeMed II, two Working Groups on "*Parapenaeus longirostris* and related fisheries in the Project area" (Malta, September 2009 and Italy 2010) to support technical discussion on cooperative activities and joint data analysis of *P. longirostris*.

This document provides a description of the outcomes the Working Groups and results achieved from the joint analysis of fishery dependent data on *Parapenaeus longirostris* in the south-central Mediterranean Sea. Experts from the Institut National des Sciences et Technologies de la Mer (INSTM) of Tunisia, of the Ministry for Resources and Rural Affairs (MRRA), Malta, Istituto per l'Ambiente Marino Costiero-Consiglio Nazionale delle Ricerche (IAMC – CNR) of Italy and the MedSudMed Project staff participated to this activity.

This document is one of outcomes of the MedSudMed Project component on "Demersal Fisheries Resources". It is primarily intended for scientists and officers of the national fisheries administrations of the south-central Mediterranean Sea. It can also be of interest for students and professional of fisheries research and management in the Mediterranean region. It is believed to be a contribution to better knowledge on the potential yield and state of the stock of *Parapenaeus longirostris* in an area where this species is one of the main fishery target species.

Acknowledgements

ABSTRACT

This document summarises the data used, methods adopted and the results of the joint stock assessment carried out during the MedSudMed and CopeMed II Working Groups on *Parapenaeus longirostris* and related fisheries held in 2009 and 2010 in Malta and Italy respectively. The aim of this document is to describe the state of the stock of *P. longirostris* in the south-central Mediterranean Sea using data from Italy, Tunisia and Malta. The long term objective of this study is to provide the baseline for the establishment of a harmonised management regime for the deep water rose shrimp fishery in the south-central Mediterranean Sea. Overall, fishery dependent data from Italy, Malta and Tunisia for the first time were pooled together and jointly processed. The assessment was performed using length cohort analysis (LCA) and biomass and yield per recruits analyses as implemented in VIT4Win. Current mean fishing mortality and exploitation pattern were assessed using the steady state LCA on length frequency distributions (LFD) of 2007, 2008 and 2009 as well as the average 2007-2009 catches, raised to the total landings. Analyses were performed separately by keeping sex and fleet segments separate (i.e. Italy 12-24; Italy > 24; Tunisia; Malta) as first step. A sensitivity analysis was also carried out as implemented in VIT. The results are discussed in the view of providing robust technical advice for the management of national fisheries exploiting *P. longirostris* in the MedSudMed area taking into account the possible evolution of national fisheries. Some perspective for future joint activities to be carried out within the cooperative framework established by the FAO Projects are also presented.

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Stock status and potential yield of deep water rose shrimp (*Parapenaeus longirostris*, Lucas 1846) in the south-central Mediterranean Sea

1   Introduction

Wild stocks are believed to be fully or over exploited in many oceanic regions (FAO, 2010). In the Mediterranean Sea, about 80 % of the species for which stock assessment has been provided resulted over exploited or depleted, with fishing mortality greatly over a sustainable level (Farrugio *et al*., 1993; Lleonart and Maynou, 2003; FAO, 2010; Barros, 2011). However, scientific information on the state of fish stock in this basin is not complete and the stock assessments provided cover only few areas and species. This situation is further complicated by the occurrence of shared stock and to the consequent need to merge data from different countries and/or collected using different methods for performing stock assessment. Such findings urged national and international bodies involved in fisheries management to encourage the joint assessment of fisheries resources through the establishment of specific working groups and to develop strategies to freeze or significantly reduce the impact of fishing on natural resources. The FAO General Fisheries Commission for the Mediterranean Sea (FAO-GFCM) opted to manage fisheries in the Mediterranean Sea mainly trough managing fishing capacity based on the scientific advice provided by *ad hoc* created specific bodies (i.e. Scientific Advisory Committee and its Sub-committees).

The FAO Project "Assessment and Monitoring of the fisheries Resources and the Ecosystems in the Straits of Sicily" (MedSudMed) aims to support the scientific cooperation and capacity development of participating countries to progress toward a sustainable use of the fisheries resources and the ecosystems. More specifically, MedSudMed seeks to develop a common cognitive basis to support international processes aimed at fisheries management. One of the tools used by the projects in this regard is to further progress in the monitoring of marine stocks and the fishery ecosystem in coherence with the FAO Code of Conduct for Responsible Fisheries and the Ecosystem Approach to Fisheries.

In this framework and according to the recommendation of the Project Coordination Committees (Malta, February 2009, and Libya, May 2010), MedSudMed organised a working group to support technical discussion on cooperative activities and joint data analysis. The first meeting of the working Group was held in Malta on October 2009 and was aimed, *inter alia*, at initiating the sharing and joint of fishery data for the appraisal of the state of the stock of *Parapenaeus longirostris* in the south-central Mediterranean Sea. The work was completed during the second meeting of the MedSudMed and CopeMed II[1] Working Group held in Italy on September 2010. The results of the joint analysis have been presented during the Working Group for Stock Assessment of Demersal Species of the Scientific Advisory Committee (SAC) of the FAO General Fishery Commission for the Mediterranean Sea (FAO GFCM).

In this document the data used, methods adopted and the results of the joint stock assessment carried out during the MedSudMed and CopeMed II Working Groups on demersal fishery resources are presented. The aim is to describe the state of the stock of *P. longirostris* in the shout-central Mediterranean Sea using data from the neighbouring jurisdictions Italy, Tunisia and Malta. The long term objective of this work is to provide the baseline for the establishment of a harmonised management regime for the deep water rose shrimp fishery in the south-central Mediterranean Sea.

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[1] FAO Project "Coordination to Support Fisheries Management in the Western and Central Mediterranean"

Parapenaeus longirostris

The deep water rose shrimp *Parapenaeus longirostris* (Lucas 1846) is distributed throughout the eastern Atlantic Ocean and the Mediterranean basin. Information on the species' ecology however mainly comes from the eastern and central Mediterranean basins, where the species is more abundant than in the western Mediterranean. *P. longirostris* is a short-lived species characterized by high growth and mortality rates (Abellò *et al*., 2002) which reproduces throughout the year (Levi *et al.*, 1995; Ben Mariem *et al.,* 2001). Individuals are mainly found in epibenthic habitats characterised by sandy to muddy bottoms between 100 and 400m, although the species has a bathymetric distribution range of 20 – 750 m. Deep water rose shrimp has a size-dependent depth distribution, with the highest concentration of small individuals found at the edge of the continental shelf (Lembo *et al.*, 1999). This size related depth segregation is reflected in commercial catches, where smallest specimens are caught mainly on the outer continental shelf (50–200 m), and larger specimens along the slope (> 200 m) (Tursi *et al.*, 1999).

In terms of biomass the deep water rose shrimp was the most important crustacean species landed by Mediterranean trawl fisheries in 2000-2008, constituting 23% of total crustacean landings (FAO FishStat Plus, 2010).

Fishery exploitation

Several fishing fleets targeting *P. longirostris* exist throughout the species distribution range, for instance in the eastern Atlantic (Politou, 2008), around the Balearic Islands (Guijarro, 2009) and Greece (Kapiris *et al.,* 2007). However by far, in terms of total yield, the most productive fleet targeting *P. longirostris* is that of the central Mediterranean Sea (Figure 1).
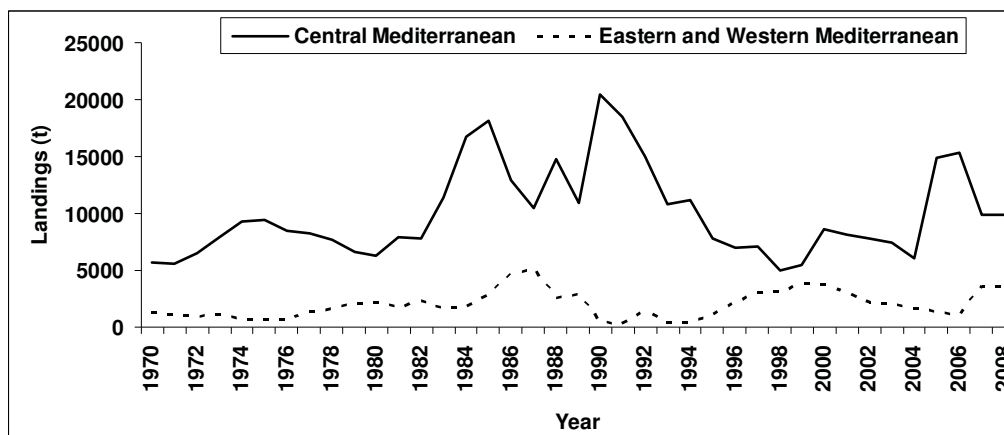
Figure 1. Capture production of *Parapenaeus longirostris* in the Mediterranean Sea from 1970 to 2008 (FAO FishStat Plus, 2010).

P. longirostris is exploited almost exclusively through bottom trawlers that operate on the outer continental shelf and upper slope of the south-central Mediterranean throughout the year, and catches often include Norway lobster (*Nephrops norvegicus*), giant red shrimp (*Aristaeomorpha foliacea*), hake (*Merluccius merluccius*), violet shrimp (*Aristeus antennatus*), scorpionfish (*Helicolenus dactylopterus*), greater forkbeard (*Phicys blennioides*), red Pandora (*Pagellus bogaraveo),* common Pandora (*Pagellus erythrinus*) and monkfish (*Lophius* spp.). Scientific data available indicates that exploitation by the fishing fleets of Tunisia, Malta, Libya and Italy is targeting a single shared stock of deep water rose shrimp (Levi *et al.*, 1994; Camilleri *et al.*, 2007; Fiorentino *et al.*, 2008). Four fishing fleets

exploiting *P. longirostris* can be discerned in the south-central Mediterranean Sea each with specific characteristics: i) Italian or Sicilian small trawlers, with length overall (LOA) included between 12 and 24 m (Italy 12-24); ii) Italian or Sicilian large trawlers with LOA > 24 m (Italy > 24); iii) Tunisian trawlers of about 24 m LOA (Tunisia); and iv) Maltese trawlers with LOA included between 12 and 24 m (Malta).

Sicilian (Italy) trawlers between 12 and 24 m LOA targeting deep water rose shrimp are based in seven harbours along the southern coasts of Sicily. These trawlers operate mainly on short-distance fishing trips, which range from 1 to 2 days at sea, and fishing taking place on the outer shelf and upper slope. With 250 registered vessels, this is the largest component of the fleet targeting deep water rose shrimp in 2009. In more recent years the dynamic of this fleet component evolved resulting in a shift of fishing grounds to deeper waters. Italian trawlers which measure over 24 m LOA have longer fishing trips, which may have a duration of up to 4 weeks and are mostly based in Mazara del Vallo (south-west Sicily). These vessels operate offshore, in both Italian and international waters of the south-central Mediterranean Sea (Figure 2) at depth generally ranging from 200 to 400 m. In 2009, 140 such vessels were active.

In the Maltese Islands small vessels measuring 12 to 24 m LOA target deep water rose shrimp at depths of about 600 m. Fishing grounds for Maltese vessels are located to the north and north-west of Gozo, as well as to the west and south-west of Malta. Catches are primarily destined for the local market. The number of trawlers targeting deep water rose shrimp increased from 7 in 2005 to 12 in 2009, with some vessels fishing in international waters.

Tunisian trawl vessels which target deep water rose shrimp measure around 24 m LOA, and operate primarily in Northern Tunisia where 90% of the country's total *P. longirostris* catches originate. The great majority of these catches are landed in the town of Bizerte and Kelibia. The number of Tunisian trawlers targeting deep water rose shrimp has increased from 40 in 1996 to around 70 in 2009.
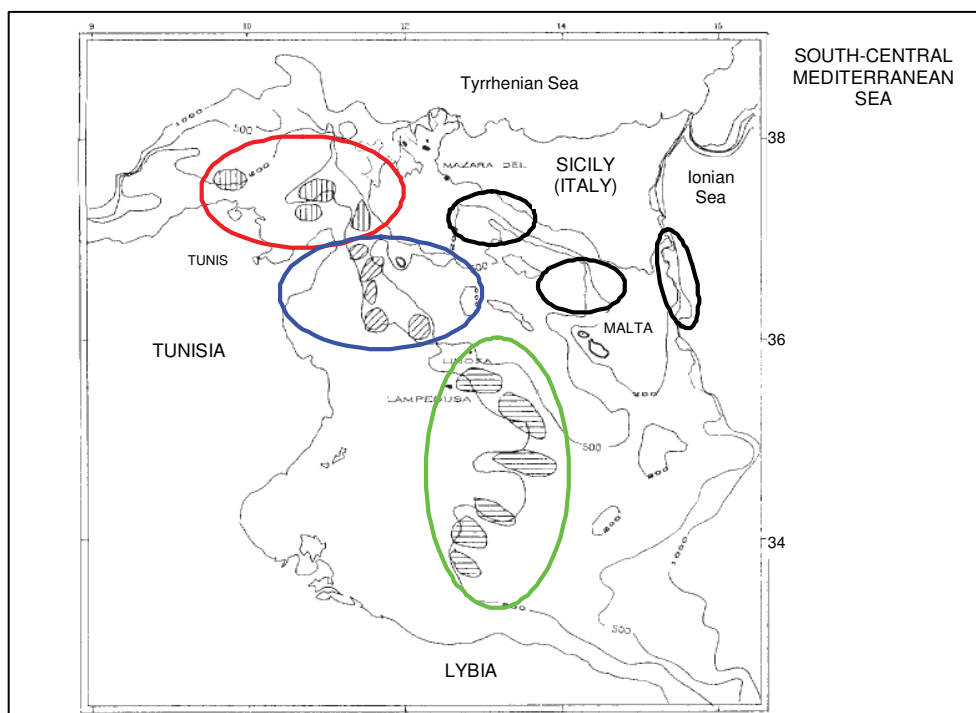

Figure 2. The main fishing areas of *Parapenaeus longirostris* for large (> 24m length overall, coloured lines) and small (12-24 m length overall, black lines) Sicilian trawlers in the south-central Mediterranean (modified from Levi *et al.,* 1995).

In terms of recorded landings, a total of 8,806 t of deep water rose shrimp were landed in the south-central Mediterranean in 2009 (Table 1). The proportion of landings which can be attributed to Italy, Tunisia and Malta reflects the number of vessels targeting this species in the south-central Mediterranean; 82.6 % of the catches were landed by the Sicilian fleet, 17.2% by Tunisian fishermen, and 0.2% by the Maltese trawlers. Despite Malta's very small contribution to regional catches, *P. longirostris* is an important commercial species for Maltese fishermen.

Table 1. Landings (t) of *Parapenaeus longirostris* in 2007 - 2009 by fleet segment for Malta, Italy and Tunisia.

	Malta	**Italy**	**Italy**	**Tunisia**
	12-24 m	**12-24 m**	**>24 m**	**> 24m**
2007	8	3248	2097	1030
2008	22	3734	2207	992
2009	18	5496	1777	1515

2   Materials and Methods

Data source

Data used in this study were derived from catch sampling. In Italy and Malta, data is collected based on the provisions of the European Union Data Collection Regime (DCR)/Framework (DCF; EC 93/2010). Italian data were collected monthly during the biological sampling of landings from commercial trawlers. In Malta, the length frequency distributions of *P. longirostris* caught by bottom otter trawlers are monitored through monthly on board observations, and information of total landings is available from fish market sales vouchers as well as logbook data since all vessels over 10 m LOA record all catches in the latter. Length frequency distributions of catches from Tunisia and Sicily were raised to total landings recorded by fleet segment in the respective countries for the years 2007, 2008 and 2009 and used in the assessment (Figure 3). Data and information from Italian catch derives from commercial landings in GSA 16 (Italian National DCR/DCF Programmes). Maltese data on landings was available for 2007, 2008 and 2009, but length frequency distributions of catches made by Maltese vessels were only available since the start of the EU DCF in 2009. The Tunisian data in terms of capture production and length frequency distribution of the commercial catch are collected twice per month by fishery observer on board of fishing vessels. The number and type of vessels that host observers are defined on sampling basis in order to cover all the fleet components. Samples are also gathered to further define the biological characteristics of the catch. The value of total annual capture production for Tunisia is provided by the statistic office of the General Directorate for Fisheries.

The growth parameters used (Table 2) were those reported by SAMED (2002) and Ben Meriem (unpublished), and are based on the analysis of the modal components of the length frequency distributions of the commercial catch or are derived from studies based on experimental surveys at sea. Weight length relationships coefficients were obtained by national data collection programmes and natural mortality was estimated by the Beverton and Holt Invariant approach (Ragonese *et al.,* 2006). Since very little differences were found between estimates and under the assumption of a unique stock, average values were used in the analyses.
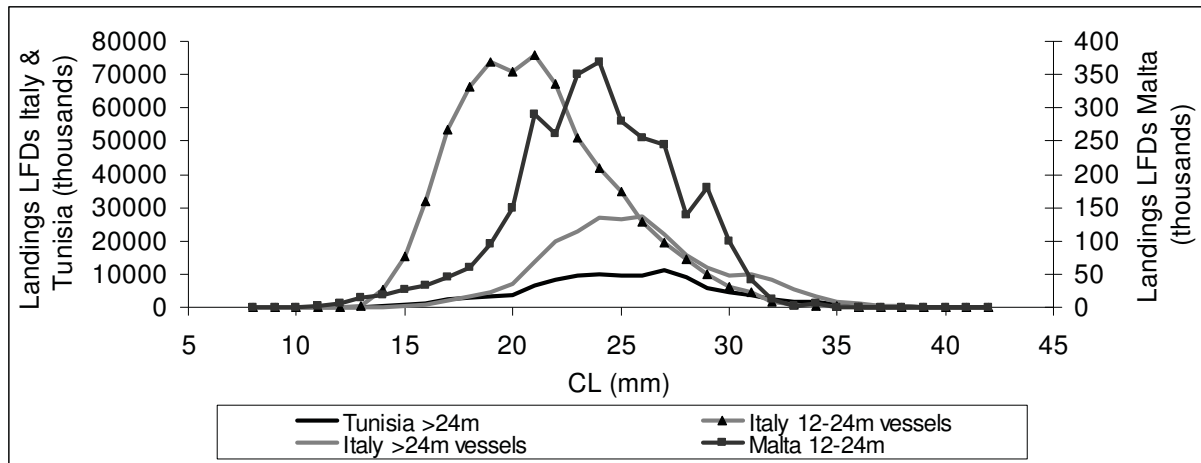
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Figure 3. Overview of average length frequency distribution (LFD) of landings (2007-2009 for Italy and Tunisia; only 2009 for Malta) by the fleet segments exploiting *Parapenaeus longirostris* in the Central Mediterranean.

Table 2. Summary stock assessment parameter estimates for *Parapenaeus longirostris* males and females from Sicily (SAMED, 2002), Tunisia (Ben Meriem, unpublished) and averages used in assessment. L_∞ = asymptotic length, K = growth coefficient, t_0 = age at time zero, a/b = length weight relationship parameters, M = natural mortality rate.

Parameter	Units	Females			Males		
		Sicily	Tunisia	Average	Sicily	Tunisia	Average
L_∞	mm	43	42.41	42.71	34.3	32.82	33.56
K		0.68	0.66	0.67	0.73	0.73	0.73
t_0	year	-0.2	-0.216	-0.21	-0.2	-0.13	-0.15
a		0.0035	0.0023	0.0029	0.0038	0.0031	0.0035
b		2.4457	2.518	2.4819	2.4090	2.4101	2.4096
M		1.07	1.03	1.05	1.53	0.86	1.20

Data analysis

The assessment was performed using length cohort analysis (LCA) as implemented in the VIT4Win (version 1.3) software package (Maynou, 1999-2011; Lleonart and Salat, 1997). Current mean F and exploitation pattern were assessed using the steady state LCA on length frequency distributions (LFD) of 2007, 2008 and 2009 as well as the average 2007-2009 catches, raised to the total landings. Analyses were performed separately on length frequency distributions of females and males and by keeping fleet segments separate (i.e. Italy 12-24; Italy > 24; Tunisia; Malta). Length frequency distributions rather than age frequency distributions were used as the basis of the assessment. The length-based approach was preferred because the biological characteristics such as growth by moulting makes age determination in crustaceans difficult, rendering age-based finfish stock assessment techniques unsuitable for crustaceans (Smith and Addison, 2003). The values of F_{term} were assumed equal to M.

The F values by size and year for combined sex were obtained as ratio of the sum of the catch of females and males to the sum of mean number at sea of females and males respectively. This approach was adopted to smooth the effect of differences between sexes and have more realistic assessment of current F. Indeed, the estimation of current F using sex

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combined parameters is driven by sex reaching largest size, thus providing relatively high values. The VIT package was also used to run a biomass and yield per recruit analysis by sex. The latter was done in order to analyse the stock production per recruit that enters the fishery when varying fishing mortality under equilibrium conditions. To verify if the steady state assumption can be suitable to describe the evolution of *P. longirsotris* stock, the size distribution of the catch were analyzed keeping years separate according to Rätz and al. (2010). However, to give a more synthetic picture of the analyses, average catch data from 2007-2009 was also used. The biomass and yield per recruit values by sex were finally combined to obtain a single value for both the sexes by using an average, weighed by sex ratio (0.57 females/females + males).

In order to investigate the robustness of the LCA estimates, a sensitivity analysis was carried out as implemented in VIT. This routine allows for the estimation of the effects of errors in the precisions of parameters and their potential effects on the results of the yield per recruit analysis. Of the parameters listed in Table 2, the von Bertalanffy growth equation parameters k and natural morality (M) were tested for females. Indeed females are known to be the most critical in estimation of yield per recruit curves, due to their faster growth with respect to males.

3 Results

The results of the calculations performed for the separate years 2007, 2008, 2009 and then for average catches 2007-2009 were in all instances similar. The reconstructed yields obtained by applying the VIT package are virtually equal to the observed ones, thus confirming the consistency of the analytic procedures. Absolute estimation of recruitment and other main results of VIT, including the current mortality rates, are listed in Table 3 below. Population at sea in 2007-2009 in terms of average biomass and numbers of individuals for combined sexes as reconstructed with the VIT length cohort analysis are shown in Figure 4.

Table 3. The main results of the VIT analysis (LCA).

Variables	2007	2008	2009	2007-2009
Observed Yield (tons)	6383	6955	8806	7381
Reconstructed Yield (tons)	6375	6933	8806	7383
Recruits at 11 mm CL (millions)	3167	2731	3374	3064
Mean F	1.00	1.02	1.38	1.16
Current critical length (mm)	18.3	18.3	18.7	18.3
Virgin critical length (mm)	22.0	22.0	22.0	22.0
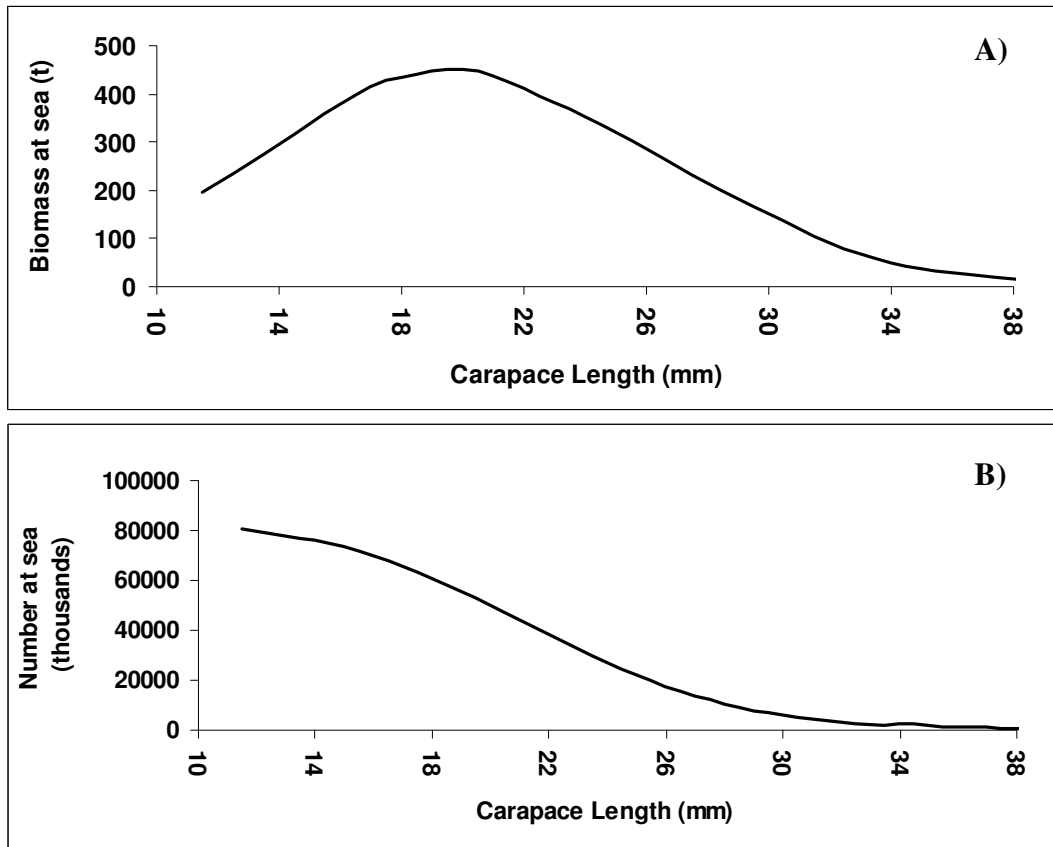
Figure 4. Average population at sea in 2007-2009 in terms of A) biomass and B) number of individuals for combined sexes as reconstructed with the VIT length cohort analysis.

The analysis of fishing mortality rates (F) by size mirrored the catch length frequency distributions: Italian 12-24 m LOA fleet segment exerted the highest fishing mortality rates on juvenile deep water rose shrimp (Figure 5). Total F (all fleet segments combined) was exerted on size classes 11.5 mm – 40.5 mm, with a peak at 31.5 mm (CL).
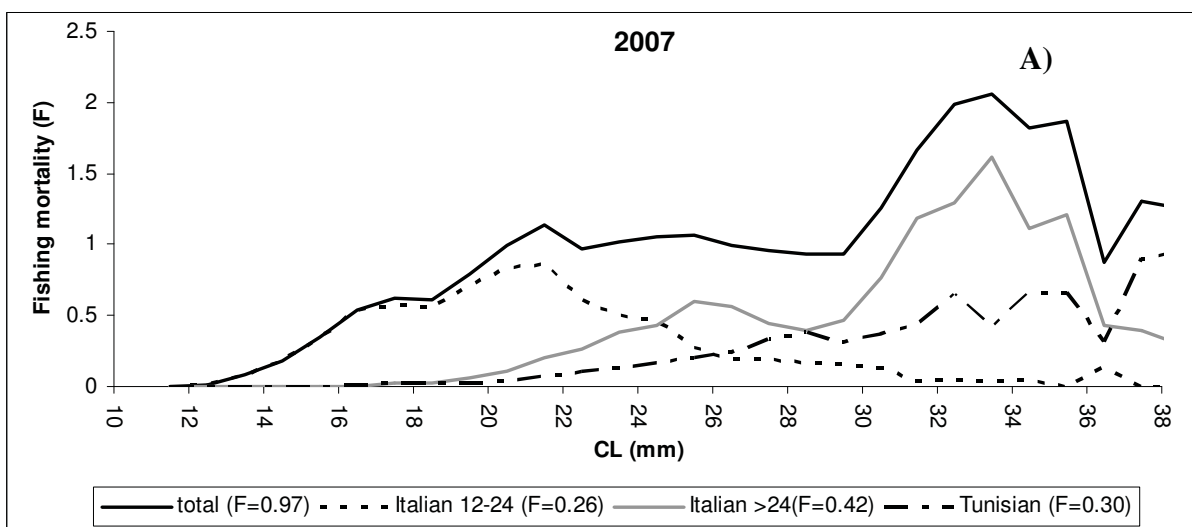
Figure 5. *P. longirostris* fishing mortality rates (F) by size and bottom otter trawling fleet segments in GSAs 12-16; A) 2007, B) 2008, C) 2009, D) average 2007-2009.

The absolute estimations of spawning stock biomass (SSB) for combined sexes in the 2007-2009 were: 5,679 t in 2007; 4,673 t in 2008; and 4,630 t in 2009. The estimates of absolute recruitment in thousands of individuals from VIT analysis for GSAs 12-16 in 2007-
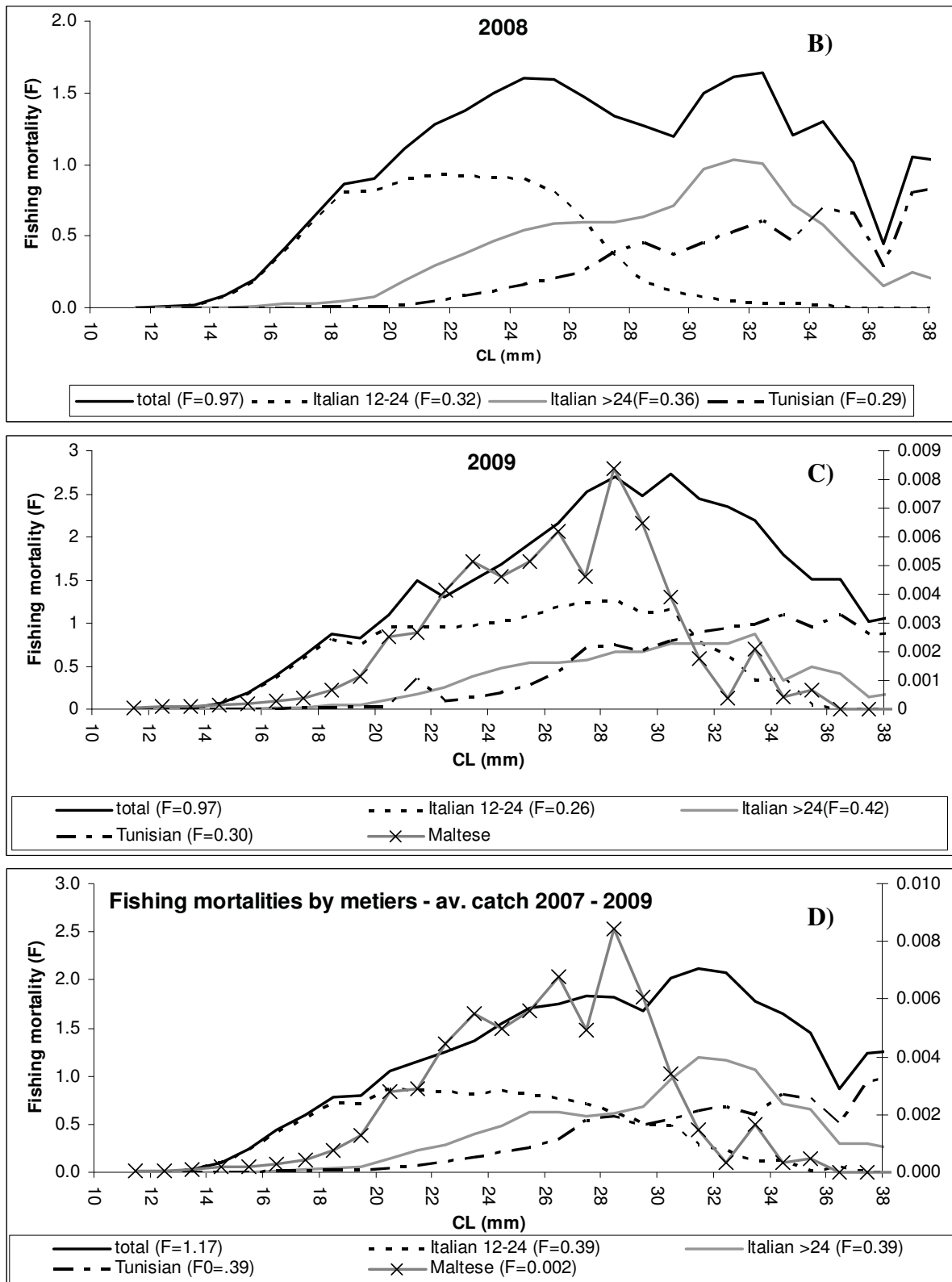
2009 were: 3,167,792 in 2007; 2,731,346 in 2008; and 3,374,713 in 2009. Thus both the SSB and the recruitment levels remained stable over the assessment period.

Assuming no variation in the exploitation pattern, the main results of the Y/R analysis are reported in Table 4 below. The results of estimating spawning stock biomass as well as biomass and yield per recruit, by varying current fishing mortality (F_c) through a multiplicative factor for average catches recorded in the Central Mediterranean for 2007-2009, are reported in Figure 6. Overall, results showed that current values of fishing mortality F are higher than $F_{0.1}$, suggesting a state of overexploitation for this stock. According to the analysis, to reach $F_{0.1}$ a reduction ranging between 20 and 30% of the current fishing mortality on the stock of *P. longirostris* is advisable.

Table 4. Estimation of yield (Y in g), biomass (B in g) and spawning stock biomass (SSB in g) per recruit (R), varying current fishing mortality by a multiplicative factor in VIT analysis. The factor corresponding to the target reference point $F_{0.1}$ is marked in bold.

Year	Factor	F	Y/R	B/R	SSB/R
	0	0	0	6.46	5.5
2007	**0.79**	**0.79**	**2.12**	**3.03**	**2.17**
	1	1	2.25	2.55	1.74
	0	0	0	6.68	5.77
2008	**0.94**	**0.95**	**2.46**	**2.72**	**1.89**
	1	1.02	2.51	2.52	1.71
	0	0	0	6.46	5.5
2009	**0.73**	**0.98**	**2.41**	**2.76**	**1.85**
	1	1.35	2.57	2.24	1.37
Average	0	0	0	6.46	5.5
catch	**0.77**	**0.89**	**2.31**	**2.86**	**1.97**
2007-2009	1	1.16	2.46	2.41	1.55

Results of the sensitivity analysis (Table 5) showed that changing M and k has a pronounced effect on yield per recruit estimates when the variation is in the opposite direction. Biomass per recruit and spawning stock biomass per recruit in contrast are strongly affected when the change is in the same direction. Results are only shown for females since the yield per recruit for deep water rose shrimp females is more important than that for males (3 g and 1.8 g respectively) and the contribution of females to the total SSB by far exceeds that of males (Figure 6).

Table 5. Results of the sensitivity analysis performed for the k of VBGF and M (natural mortality) used in the VIT analysis. Variations of 10%, 20% and 40% (↓ decrease and ↑ increase) were tested on yield per recruit (Y/R), biomass per recruit (B/R) and spawning stock biomass per recruit (SSB/R) estimates (in g per recruit). Dark shading represents changes in Y/R when k and M are changed; light shading represents changes in B/R and SSB/R. Only results of females are presented.

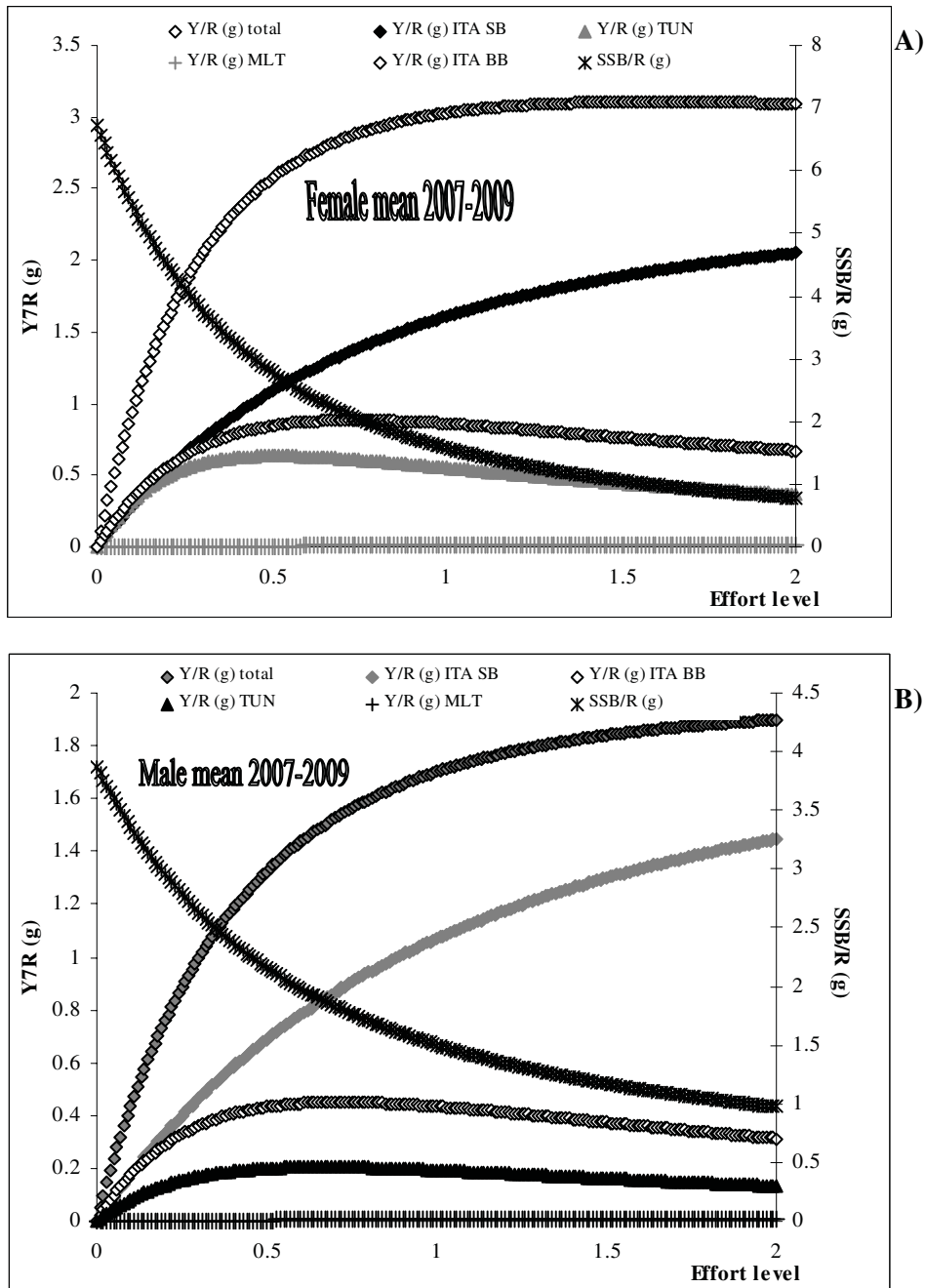|	Variations tested								
	10%			20%			40%		
Parameters altered	Y/R	B/R	SSB/R	Y/R	B/R	SSB/R	Y/R	B/R	SSB/R
No variation	2.36	2.44	1.66	2.36	2.44	1.66	2.36	2.44	1.66
↓ k and ↓ M	2.37	2.71	1.84	2.37	3.04	2.06	2.38	4.04	2.73
↓ k and ↑ M	1.77	2.48	1.67	1.17	2.48	1.63	0.23	2.19	1.29
↑k and ↓ M	2.94	2.39	1.64	3.47	2.33	1.61	4.44	2.20	1.54
↑ k and ↑ M	2.36	2.23	1.52	2.36	2.05	1.40	2.35	1.76	1.21

Figure 6. A) Spawning Stock Biomass (SSB) and B)Yield per recruit (Y/R) varying current fishing mortality (F_c) for male and female pink shrimp by a multiplicative factor.

4 Discussion

The stock assessment for *P. longirostris* in the Central Mediterranean carried out in this study is the first assessment which makes use of commercial data from Italy, Tunisia and Malta to perform a joint assessment. *P. longirostris* in the south-central Mediterranean is exploited by Italy, Tunisia and Malta and almost certainly consists of a single shared stock (Levi *et al.,* 1994; Camilleri *et al*., 2007; Fiorentino *et al.,* 2008). As a consequence, a joint assessment is the only way to obtain an accurate reflection of stock status for this species in the area. Moreover, the joint analysis of stock status is essential for scientists from

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neighbouring countries to exchange expertise, discuss and agree on potentially harmonised data collection systems, assessment methods, and management recommendations for their respective governments and the FAO General Fisheries Commission of the Mediterranean (GFCM). Such an initiative is thus a necessary precursor for the eventual development of a long term management plan for the deep water rose shrimp fishery in the south-central Mediterranean, agreed by countries that shared the stock in the area.

The main assumption underlying the VIT model is that the population which is being assessed is in a steady state since the program works with pseudo-cohorts when long time series of data are not available. The VIT analysis thus assumes that the population being assessed is in equilibrium, including constant growth, recruitment and mortality rates over time. In order to test this assumption, calculations were performed first for the separate years 2007, 2008, 2009 and then for the average catch of 2007-2009. Since all analyses gave similar results, we concluded that the VIT analysis was suitable to carry out a stock assessment of *P. longirostris* in the 2007 -2009 period, despite the restrictive hypothesis assumptions underlying the model.

The sensitivity analysis carried out underlines the importance of using reliable growth and mortality parameters. However, testing the effect of growth rate parameter (k) and natural mortality (M) on the Yield per Recruit estimates, minor variations of Y/R changing parameters in the same direction were found. This is in line with the well known positive correlation between k and M (Ragonese *et al.,* 2006).

Based on average catches in 2007-2009, the results of the stock assessment showed that fishing mortality should be reduced by 23% for deep water rose shrimp in the south-central Mediterranean to reach the target reference point $F_{0.1}$. If fishing mortality rates of 2009 are taken as a baseline, the necessary reduction to reach $F_{0.1}$ is 27%. A comparison of the catch length frequency distributions from Maltese, Tunisian and Sicilian vessels reveals that a large number of juvenile shrimp are caught by Italian vessels with a length of 12-24m, fishing mainly on shrimps nurseries on the Sicilian-Maltese shelf (Fortibuoni *et al.,* 2010), that contribute to set at a low level the value of $F_{0.1}$.

Although the diagnosis of growth overfishing for the stock of deep water rose shrimp in the south-central Mediterranean, no formal international management objectives were identified for fisheries concerned. Similar to other areas in the Mediterranean, the management of the trawl fishery in general is based on control of fishing capacity (licenses), fishing effort (fishing activity), and technical measures such as mesh size restrictions and area/season closures.

Concerning the regulation of fishing capacity, a reduction of the Italian trawl fleet by 25%, as vessels number, from the 2008 level is currently underway. The Maltese Islands are surrounded by a 25 nautical miles fisheries management zone, where fishing effort and capacity are being managed by limiting vessel sizes, as well as total vessel engine powers (see European Commission Council Regulation 1967/2006). Trawling is allowed within this designated conservation area, however only by vessels not exceeding an overall length of 24 m, and only within designated areas.

Regarding technical measures, the European Commission regulation EC 1967/2006 fixed a minimum mesh size of 40 mm square or 50 mm diamond for bottom trawling of EU fishing vessels. The same measure has been adopted by the GFCM in 2009 (REC.CM-GFCM/33/2009/2, FAO GFCM, 2009). This measure was implemented on Italian and Maltese trawlers in June 2010. The same measure has been adopted by the GFCM in 2009 (REC.CM-GFCM/33/2009/2, FAO GFCM, 2009) for the entire Mediterranean region and will become mandatory starting from 31 January 2012. This measure should modify the exploitation pattern of *P. longirostris* fisheries. In Tunisia the technical measures include a

minimum legal mesh size of 40 mm. In Sicily (south-Italy) an annual trawling ban of 30 days is currently in place, usually implemented from August to September.

The closed seasons which are already in place in Sicily at the end of summer could allow to reduce fishing mortality on juvenile *P. longirostris*. However the temporary or permanent closure to fisheries over critical areas (e.g. nurseries) could further improve the exploitation pattern and stock status of deep water rose shrimp in the south-central Mediterranean Sea. These measures could be put in place through the establishment of fishing restricted areas FRAs (permanent closure) or closed season for fisheries (temporary). Stable nurseries of this species have in recently been identified in the south-central Mediterranean on the Adventure as well as Malta Banks (Figure 7). Fortibuoni *et al.* (2010) found that *P. longirostris* young-of-the-year as well as mature females aggregate in areas where enrichment and retention processes occur, which are linked to oceanographic processes taking place in the south-central Mediterranean. The value of seasonal closures as a management tool however depends on the careful consideration of the dynamics of the fishery as well as the biology of the species (Dinmore *et al.*, 2003). Temporary area closures may lead to effort displacement, with fishing vessels no longer able to operate in a certain area impacting populations and the environment elsewhere, or vessels increasing their fishing effort in the months following the closure (Rinjsdorp *et al.,* 2001, Halpern *et al.*, 2004, Murawski *et al.*, 2001). It is thus necessary to carefully balance the potential benefits of implementing a FRA against the spatial as well as the temporal displacement of fishing effort and to consider the implementation of effective effort controls and monitoring as an complementary measure (Dinmore *et al.,* 2003, Hiddink *et al.,* 2006).
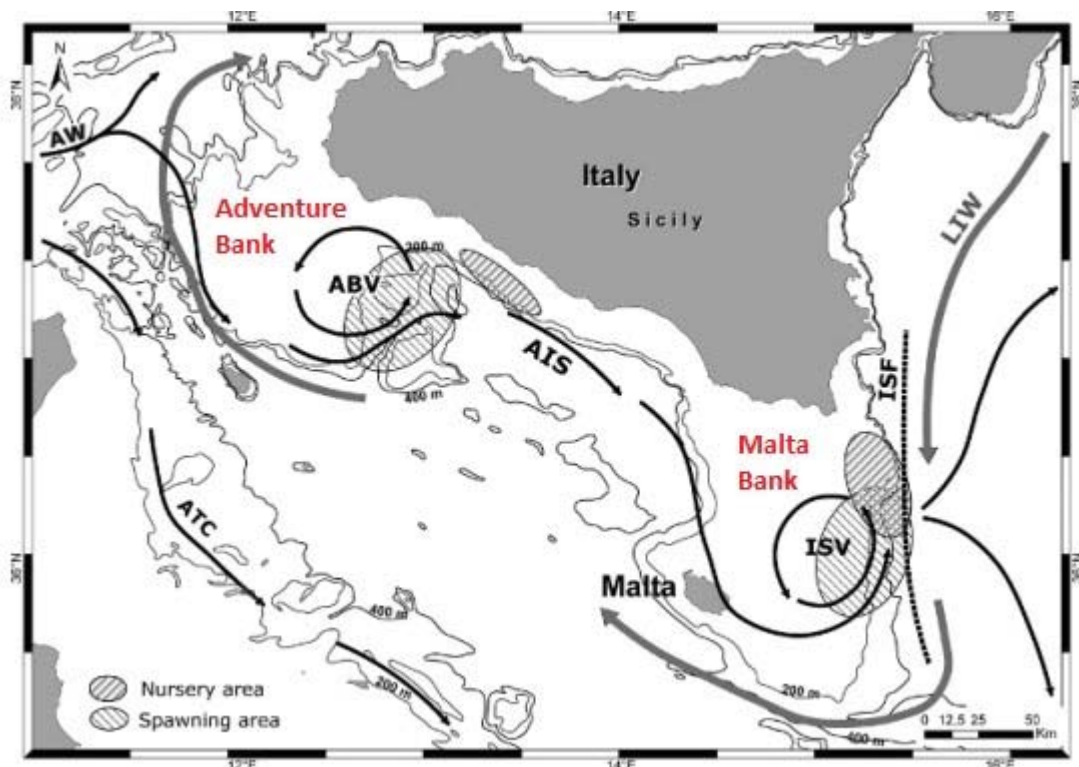

Figure 7. Location of stable nursery and spawning areas of *Parapenaeus longirostris* as well as major oceanographic features in the south-central Mediterranean Sea; ABV: Adventure Bank Vortex; ATC: Atlantic Tunisian Current; AIS: Atlantic Ionian Stream; ISV: Ionian Shelf-break Vortex; ISF: Ionian Slope Front; LIW: Levantine Intermediate Water; AW: Atlantic Water (after Fortibuoni et al., 2010).

A further improvement of the exploitation pattern of the deep water rose shrimp fishery is expected to be due to the already mentioned change in the minimum legal mesh size in the code end, adopted firstly by the European Commission (Reg. EC 1967/2006) and then by the FAO General Fisheries Commission for the Mediterranean (Rec.GFCM/33/2009/2). Scientific evidence suggests that the implementation of such minimum mesh sizes would considerably improve the state of demersal resources. For diamond 40 mm opening mesh size Sobrino *et al.,* (2005) reported a length at 50% capture (L_c) of *P. longirostis,* ranging between 13 and 16 mm CL. Similar values were confirmed after by Ragonese and Bianchini (2006). Guijarro and Massuti (2006) reported an increase in L_c of *P. longirostis* to around 20 mm with a 40 mm square mesh in the Western Mediterranean, and experiments carried out on decapods crustaceans in the Eastern Mediterranean showed a L_c of *P. longirostis* of 18 mm with a 40 mm square mesh (Deval *et al.*, 2009). However the fact that the length at 50% maturity of female deep water rose shrimp is only reached at a size of 24 mm, and that of males 19 mm (Ragonese *et al.,* 2004), further underlines the necessity of simultaneously establishing FRAs in combination with effective effort controls to protect critical life stages.

To improve the robustness of the assessment and thus the technical advice in support of fisheries management, alternative methods such as global production methods and/or age based virtual population approaches should be used once a sufficient time series of data becomes available. In addition, the use of survey data to confirm the trends witnessed in commercial data and tune the matrix of catch at age for VPA approaches should in the future be an important improvement. Scientific surveys are already being carried out in the region with Malta and Sicily participating in the annual Mediterranean International Trawl Survey (MEDITS; Bertrand *et al.,* 2002), and Tunisia carrying out annual scientific trawl surveys with a dedicated research vessel and protocol. However different sampling protocols are in use, so estimates of inter-calibration coefficients are required before the integration of this data into a stock assessment. Finally, to make the analysis more complete, effort should be put in place to gather and incorporate information on possible Libyan fisheries exploiting *P. longirostris*. The cooperative framework established by the FAO Project MedSudMed will be instrumental to pursue this objective.

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