Food and Agriculture Organization
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MEDSUDMED - TECHNICAL DOCUMENTS

Synthesis of information on some demersal Crustaceans relevant for fisheries in the South central Mediterranean Sea

SYNTHESIS OF INFORMATION ON SOME DEMERSAL CRUSTACEANS RELEVANT FOR FISHERIES IN THE SOUTH-CENTRAL MEDITERRANEAN SEA

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 2013

The conclusions and recommendations given in this and in other documents in the Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily Project series are those considered appropriate at the time of preparation. They may be modified in the light of further knowledge gained in subsequent stages of the Project.

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 has been cofunded 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 FAO Code of Conduct for Responsible Fisheries and 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.

FAO MedSudMed Project
FAO-FIRF Room C350-353
Viale delle Terme di Caracalla
00153 Rome, Italy

TEL: +39 06 570 54492/56092
FAX:+39 06 570 55188
e-mail: medsudmed@faomedsudmed.org
URL: http://www.faomedsudmed.org

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:

FAO MedSudMed Project
FAO-FIRF Room C350-353
Viale delle Terme di Caracalla
00153 Rome
Italy
medsudmed@fao.org

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Preparation of this document

Information on biological and ecological characteristics of marine species is critical to the identification of management strategies for sustainable fisheries. Several studies have been carried out to describe these traits for the main fisheries target species in the entire Mediterranean region.

The countries participating in the FAO Project MedSudMed (Assessment and Monitoring of Fisheries Resources and the Ecosystems in the Straits of Sicily) deemed it necessary and highly desirable to have a scientific review available which should include and compile the large amount of scientific knowledge which has been accrued on some of the main demersal species relevant for fisheries in the south-central Mediterranean Sea.

In 2008 MedSudMed published a scientific review on some target species in the MedSudMed Project area, i.e. "Fiorentino, F., Ben Meriem, S., Bahri, T., Camilleri, M., Dimech, M., Ezzeddine-Naja S., Massa, F., Jarboui, O., Zgozi 2008. Synthesis of information on some target species in the MedSudMed Project area (central Mediterranean). GCP/RER/010/ITA/MSM-TD-15. *MedSudMed Technical Documents*, 15: 67 pp.". The work of the Project continued since then and with the collaboration of several co-authors from four countries it has been possibile to compile a scientific review focusing on the main demersal crustaceans relevant for fisheries in the south-central Mediterranean Sea. In this view, scientific works originally issued in the national languages were retrieved and due attention was paid to the so called grey literature, often of value and relevance but relatively unknown.

This work cannot and does not aim to be exhaustive, either in terms of species coverage or of literature screened. Moreover, recently a considerable amount of relevant scientific literature has been published which could not be represented in this review, periodical updating should be pursued in the future.

This document is one of products of the MedSudMed Project component "Demersal Fisheries Resources". It is primarily intended for scientists and managers within the national fisheries administrations of the south-central Mediterranean Sea; it can also be of interest to students and professional in the field of fisheries research and management in the Mediterranean Sea region.

Acknowledgements

The assistance of Caroline Bennett in the editorial revision of this document is gratefully acknowledged. All the MedSudMed participating institutions are also acknowledged for their contribution to the preparation of this document, i.e. Istituto per l'Ambiente Marino Costiero-Consiglio Nazionale per le Ricerche (IAMC-CNR) of Mazara del Vallo, Italy, the Marine Biology Research Centre (MBRC) of Tajura, Libya, the Ministry for Sustainable Development, the Ecosystem and Climate Changes (MSDEC) of Malta, the Insitut National des Sciences et Technologies de la Mer (INSTM) of Sfax and La Goulette, Tunisia. The assistance of Ms Carolie Bennet is gratefully acknowledged.

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ABSTRACT

This document reviews and compiles the scientific information on some demersal crustaceans relevant for fisheries target species in the south-central Mediterranean Sea: *Aristaeomorpha foliacea; Melicertus (Penaeus) kerathurus; Metapenaeus monoceros; Nephrops norvegicus*; *Palinurus elephas* and *Parapenaeus longirostris*. The document provides a description of each species including bio-ecology, life history parameters, fishery exploitation and fishing gear selectivity information. Scientific information was organized to provide a synthetic outline on each species, including meristic description, ecology (geographical distribution, habitats), biogical information (maximum size, spawning activity, length at first maturity, recruitment at habitat and nurseries, sex ratio, length–weight relationship, maximum age and natural mortality, von bertalanffy growth function, feeding behaviour, stock units). Information on stock status and exploitation when available (abundance indices from trawl surveys, strength of recruitment, stock assessment, fisheries, fishing zones and seasons, yield, fishing and discards) is also provided per species. This work is the result of international scientific cooperation among the fishery research institutions participating in the FAO-MedSudMed Project.

Contents

Synthesis of information on some demersal crustaceans relevant for fisheries target species in the south-central Mediterranean Sea

Background information

Since the first meeting of the MedSudMed Coordination Committee (CC) (GCP/RER/010/ITA/MedSudMed-TD01) the need to improve the available knowledge on the distribution of fishery resources in the area covered by the Project and to identify more accurately the influence of environmental factors on fisheries was emphasized. On that occasion the Project identified a specific project component to be implemented on this issue, together with a number of medium- and long-terms activities.

Thenceforth, several research activities were planned and organized according to the needs expressed by the Research Institutions involved in the Project. During the 9th MedSudMed CC (Italy, May 2011), the Project included in the workplan for 2012 the production of concise species sheets for demersal crustaceans that, according to their economic value and commercial catch, have particular relevance for local, national and international fisheries in the south-central Mediterranean Sea. The subdivision of the Mediterranean region in Geographical Sub-areas (GSAs) is reported in Annex A. Throughout the text, reference to Mediterranean sub-regions will be made indifferently using the GSA number or geographical name (e.g. Libyan waters may be referred to either as GSA 21 or Libyan waters).

This document reviews and compiles the scientific information on: *Aristaeomorpha foliacea*; *Melicertus keraturus*, *Metapenaeus monocheros*, *Nephrops norvegicus*, *Palinurus elephas*, and *Parapenaeus longirostris*. A description of each of these target species is provided, including species description (meristics), ecology (geographical distribution, habitats, migrations), biogical information (maximum size, spawning activity, length at first maturity, eggs, larvae and post-larvae, recruitment at habitat and nurseries, sex ratio, length–weight relationship, maximum age and natural mortality, von bertalanffy growth function, feeding behaviour, stock units), evaluation and exploitation (abundance indices from trawl surveys, strength of recruitment, stock assessment, fisheries, fishing zones and seasons, yield, fishing pattern and discards), legislation and management. This work is the result of international scientific cooperation among the fishery research institutions participating in the FAO Project MedSudMed.

Aristaeomorpha foliacea;

Melicertus keraturus,

Metapenaeus monocheros,

Nephrops norvegicus,

Palinurus elephas,

Parapenaeus longirostris.

Aristaeomorpha foliacea (Risso, 1827)

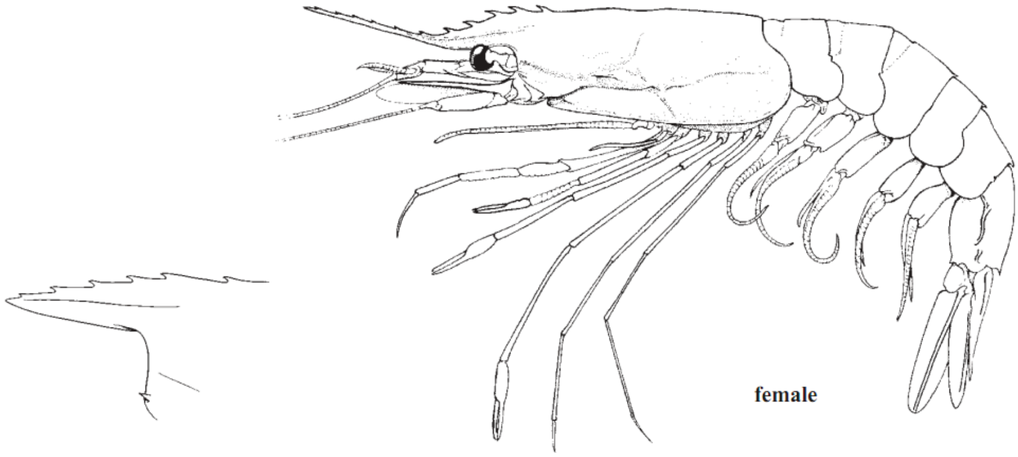


Figure 1. *Aristaeomorpha foliacea* (from Fischer *et al.*, 1987).

Species description

Aristaeomorpha foliacea (giant red shrimp, Figure 1) was first described in the early nineteenth century by Risso in the Ligurian Sea. Together with *Aristeus antennatus* (blue and red shrimp) the two red shrimp are the only species of the family Aristeidae found in the Mediterranean. The systematic classification is: phylum Arthropoda, class Malacostraca, subclass Eumalacostraca, superorder Eucarida, order Decapoda, sub-order Dendrobranchiata, superfamily Penaeoidea (Perez Farfante and Kensley, 1997).

A. foliacea is a large-sized decapod crustacean with a scarlet red coloured, firm though flexible and light exoskeleton and black eyes. In mature females the dorsal part of the abdomen is darker due to the black colour of the mature ovaries. The pleon (abdomen) is slightly keeled along the dorsal midlines of the third segment, becoming pronounced on the following three segments and ending in a sharp posterior point (Bianchini, 1999). Other important morphological characteristics are long pleopods, a carapace with antennal, hepatic and branchiostegal spines, very short upper antennal flagella, strong posteromedian spines on the third to sixth abdominal segments, a telson with four small movable lateral spines, an open telicum and secondary sexual dimorphism with regards to body size and the length of the rostrum. Adult females are larger and have a longer rostrum, which extends far beyond the antennal scale. In males the rostrum is short and does not exceed the tip of the antennular peduncle. The rostrum has 6 to 12 upper teeth, including 2 teeth on the carapace (Fischer *et al.*, 1987; Carpenter and Niem, 1998).

Ecology

Geographical distribution – formatting of sections and subsections will be defined at a later stage

The giant red shrimp *Aristaeomorpha foliacea* has a wide geographic distribution. The species has been reported to occur in the Mediterranean, the Atlantic, the Indian Ocean, the western Pacific (Perez Farfante and Kensley, 1997) and South Africa (Bianchini, 1999). Historically red shrimp were found in the Mesozoic basin of Tethys, which extended from the Indian Ocean to the present day Caribbean Sea, including areas which became the Mediterranean Sea (Cau *et al.*, 2002). In the Mediterranean Sea the distribution of giant red shrimp is patchy in nature, with the highest abundances found in the central-eastern basins (Politou *et al.*, 2004).

In the Central Mediterranean there is a longitudinal segregation between the two species of red shrimp: *A. antennatus* decreases in abundance from the western to the eastern Mediterranean whilst the opposite is true for *A. foliacea* (Bianchini and Ragonese, 1994; Cau *et al.*, 2002; D'Onghia *et al*., 1998; Company *et al.*, 2004; Guillen, 2012). In Tunisian waters the relative abundance of the two species has been reported to be 50% *A. foliacea* and 50% *A. antennatus* at La Galite and 80% *A. foliacea* and 20% *A. antennatus* on the nearby Sentinelle Bank (Ben Meriem, 1994). In Spanish waters, the Gulf of Lions and the Ligurian Sea *A. antennatus* outnumbers individuals of *A. foliacea* (Cau *et al.*, 2002); in the Central Mediterranean, eastern Ionian Sea and waters around Greece *A. foliacea* is dominant (Politou *et al.*, 2004; Ragonese, 1995; Cau *et al.*, 2002). A number of hypotheses have been proposed to explain this pattern, including differences in hydrological conditions (Ghidalia and Bourgeois, 1961; Orsi and Relini, 1985; Bianchini, 1999; Politou *et al.*, 2004), differences in productivity between the Mediterranean basins (Politou *et al.*, 2004) and different levels of fishing pressure being exerted across the Mediterranean; *A. antennatus* is more resilient to overfishing than *A. foliacea* (Matarese *et al*., 1997; D'Onghia *et al.*, 2003; Politou *et al.*, 2004).

Habitats

A. foliacea is a deep-water benthopelagic shrimp with a reported depth distribution of 120-1300 m, generally on muddy bottoms (Fischer *et al.*, 1987). The species aggregates in submarine trenches and canyons along the continental slope (Ragonese *et al.,* 1997; Bianchini, 1999) and peaks in abundance at 300-800 m depths (Ragonese *et al.*, 1997 and references therein; Politou *et al.*, 2004) (Figures 2-3). In the Sicilian Channel the species has been reported to have a marked preference for habitats between 500-700 m. More specifically, off the coast of Tunisia the depth distribution of *A. foliacea* increases gradually from the Sisters' Rock located off Tabarka to the Skerki Channel (Ben Meriem, 1994) and the Pantelleria Channel, where it is only found consistently below 600 m depth (Bianchini, 1999).

Based on the bathymetry of the region, it is likely that giant red shrimp have two main distribution zones, one on the eastern side and one on the western side of the Sicilian Channel. The eastern pocket is in addition separated by the Pantelleria and Malta troughs, and the regional distribution of *A. foliacea* can, as a result, be divided into 3-4 areas of greater importance. The eastern and western sides of the channel are however connected by a narrow passage deep enough (200-400 m) to allow the migration of individuals (Bianchini, 1999).

Migrations
A. foliacea migrates nocturnally into the water column in the Strait of Sicily and as a result fishers using bottom trawl gear prefer to target the species in daylight (Bianchini *et al.*, 1998; Bianchini, 1999). These daily vertical migrations of up to 200-300 m from the bottom (Maurin and Carries, 1968) are related to the feeding behaviour of this species, which feeds both on benthic and pelagic organisms (Rainer, 1992; Pipitone *et al.*, 1994; Bello and Pipitone, 2002). Bianchini *et al.* (1998) reported a size-dependent difference in the diel behaviour of *A. foliacea*, with small-sized shrimp seeming to undergo more pronounced migrations into the water column during the night-time.

In addition to such diel migrations, evidence for season movements related to reproductive behaviour has been recorded. An increased abundance of males prior to the spawning season on the upper slope has been attributed to the movement of mature individuals from deep canyons in order to mate (D'Onghia *et al.*, 1998; Belcari *et al.*, 2003). Once spawning has taken place, males are once again displaced to deeper waters (Cau *et al.*, 1987).

Biological information

Maximum size
The maximum body length of females according to FAO species identification guides is 225 mm (59 mm carapace length) and that of males 170 mm (45 mm carapace length). Females commonly measure 170-200 mm body length and males 130-140 mm (Fischer *et al.*, 1987; Carpenter and Niem, 1998). For the Strait of Sicily a length range of 16-74 mm and a median carapace length of 36 mm has been reported (Cau *et al.*, 2002; Ragonese *et al.*, 2004).

Spawning
The young of the year recruiting in spring are immature, with only a few individuals reproducing during their first year. Gonadic development begins in winter and individuals become sexually mature in the second summer (Bianchini, 1999; Politou *et al.*, 2004). Once they have reached maturity male giant red shrimp have a protracted reproductive capacity and are ready to mate throughout the year, whilst females mature seasonally (Bianchini, 1999; Perdichizzi *et al.*, 2012). In the Strait of Sicily maturation of female *A. foliacea* and subsequent spawning occurs from spring until autumn, with a marked maturity peak in summer-autumn (Ragonese *et al.*, 2004).
A. foliacea gather in shoals during the mating and spawning season (Bianchini, 1999), however only very limited information on the location of such spawning areas is available. Ragonese and Bianchini (1995) collected samples over a wide area of the Strait of Sicily and found mature females to be concentrated in the deeper waters between the Malta and Adventure banks and in particular to the west of the Maltese Islands (GSA 15). An analysis of 2003-2007 Maltese MEDITS data confirmed that the highest concentrations both by number and by weight of mature *A. foliacea* individuals was found to the North of Gozo at

a depth of ~400-600 m and to the west of the Maltese Islands at a depth of 600-800 m (Knittweis and Dimech, 2009).

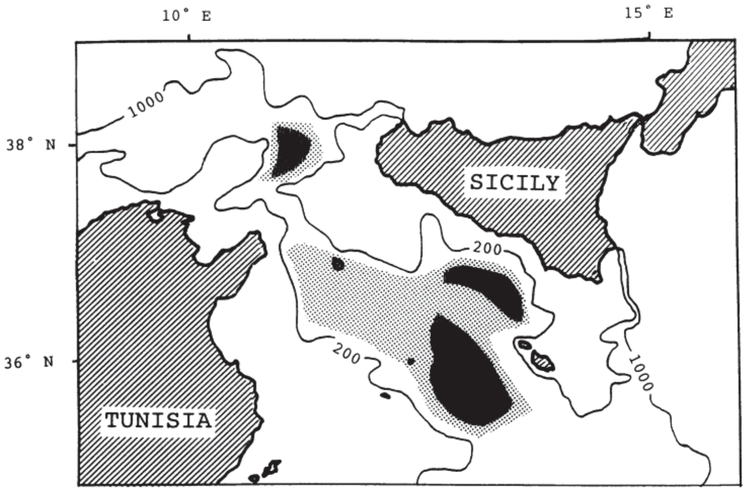


Figure 2. Occurrence of mature *Aristaeomorpha foliacea* females; light shading indicates the study area and dark shading the presence of 'ready to spawn' females (from Ragonese and Bianchini, 1995).

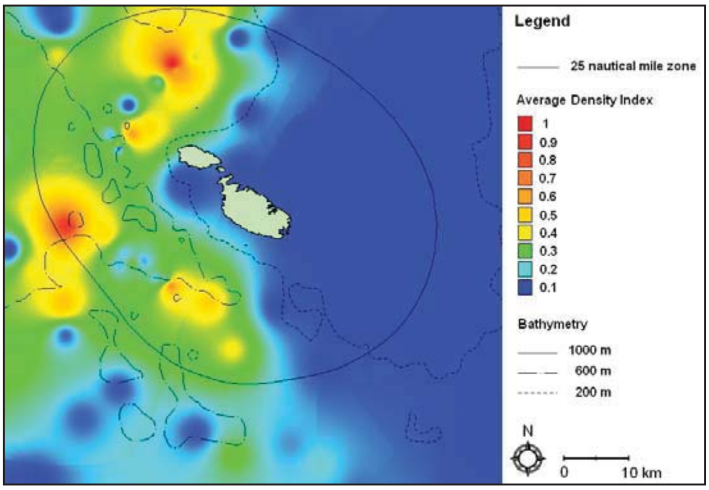


Figure 3. Normalised average density indices of mature giant red shrimp in GSA 15 (Knittweis and Dimech, 2009)

Length at first maturity

Giant red shrimp are dioecious animals and no systematic cases of hermaphroditism have been described. The colour, size and structure of the ovary is used to assess the maturity of female *A. foliacea* (Levi and Vacchi, 1988), whilst fused petasma, a shortened rostrum, and the presence of emi-spermatophores inside the terminal ampullae are the macroscopic features which distinguish a mature male individual (Bianchini, 1999).

Levi and Vacchi (1988) found the smallest female with ripe ovaries caught in the Strait of Sicily to measure 42 mm length. Bianchini (1999) reported males reaching maturity at 30-33 mm carapace length and undergoing the transition between a long and short rostrum in the 31-32 mm length range; females developed spermatophores in the 30 mm size class and all females larger than 40 mm carapace length had spermatophores. However, although spermatophores are present in all large females, the proportion of mature individuals in a given size class never reaches 100%, even during the reproductive periods (Bianchini, 1999). Ragonese *et al.* (2004) report a length at 50% maturity of 30-33 mm carapace length for males and of 42 mm for females. The most recent maturity ogive available was estimated by CNR-IAMC based on 2009 data, with a length at 50% maturity for females of 37.17 mm carapace length / a slope g of 0.541 and a length at 50% maturity of 27.41 mm carapace length / a slope g of 0.988 in males (STECF 11-14, 2011).

Eggs, larvae and post-larvae
Penaeoid shrimps do not brood fertilised eggs and instead release them directly into the sea (Bauer, 1991). Information on larval and postlarval stages is scarce and in particular distribution patterns remain almost completely unknown (Cau *et al.*, 2002). It is likely that larvae develop as epipelagic plankton and that hydrological conditions affect recruitment and thus year class strength in giant red shrimp (Bianchini, 1999).

The only description of *A. foliacea* larval stages is given by Heldt (1955), who was able to identify several morphological characteristics which distinguish *A. foliacea* larvae from *A. antennatus* larvae: a projecting anterior part of the carapace and different relative antenna lengths at Protozoea stages II and III; longer uropods at the Protozoea stage III, absence of pterigistomian spines and a longer A2 endopodite compared to the exopodite and a different telson shape at the Mysis stage (Figure 4).

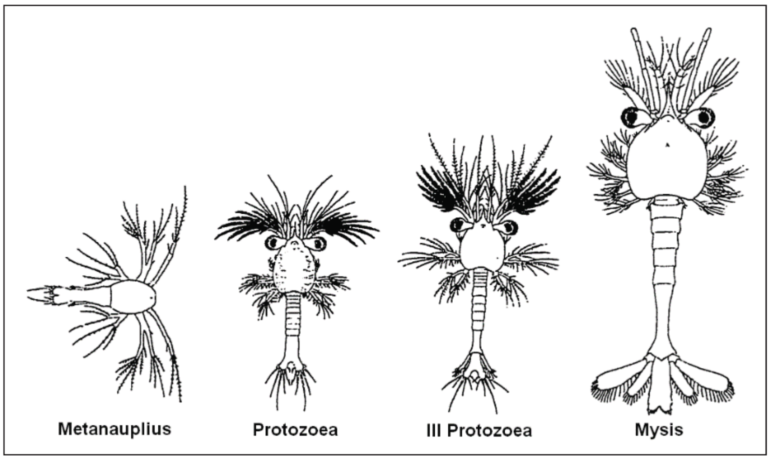


Figure 4. Larval stages of *Aristaeomorpha foliacea* (from Heldt, 1955).

Recruitment and nursery areas
The recruitment of juvenile *A. foliacea* in the Central Mediterranean takes place in spring (Ragonese *et al.*, 2004) when individuals have reached a size of 25-31 mm carapace length (Garofalo *et al.*, 2011; Figure 5).
Giant red shrimp recruits have been found dispersed widely at depths of 500-700 m in the Strait of Sicily: based on 1994-2004 south Sicily (Italy, GSA 16) MEDITS and GRUND data Garofalo *et al.* (2011) carried out a persistence analysis, which found *A. foliacea* recruits were only spatially structured in five years over the eleven year study period. The two stable nursery areas identified are located in the middle of the Strait and on average supported 30% of the total number of juveniles in the years studied.

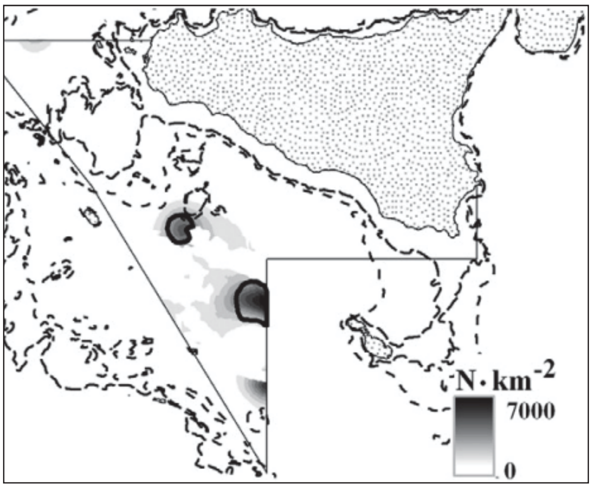


Figure 5. Density map of *Aristaeomorpha foliacea* recruits, showing the location of two persistent nurseries (from Garofalo *et al.*, 2011).

Based on an analysis of 2003-2007 MEDITS data collected in GSA 15, two areas with high densities of juvenile giant red shrimp located at a depth of ~600 m have, in addition, been identified (Figure 6). One area is located within the 25 nautical mile Maltese Fisheries Management Zone and the other right on the border of GSA 15 (Knittweis and Dimech, 2009). An updated, joint analysis of GSA 15 and GSA 16 data is needed in order to improve the available knowledge on the location of *A. foliacea* nursery areas.

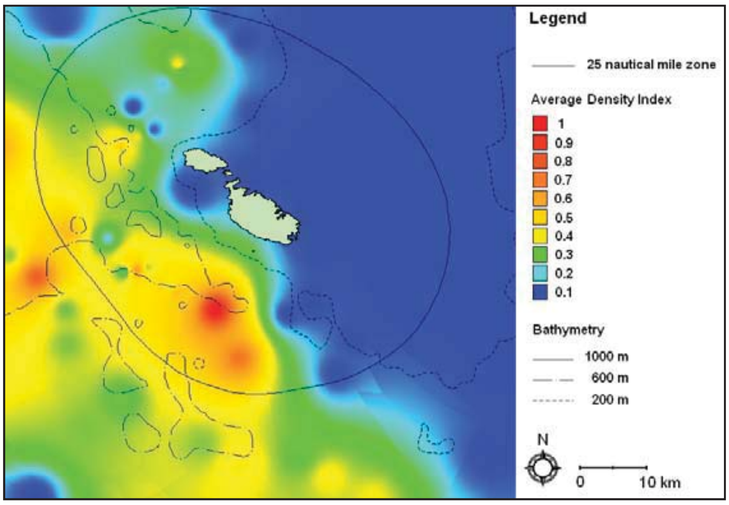


Figure 6. Normalised average density indices of immature giant red shrimp in GSA 15 (Knittweis and Dimech, 2009).

Sex ratio

Giant red shrimp sex ratios can vary between areas, seasons and depending on the depth sampled (D'Onghia *et al.*, 1998; Bianchini, 1999; Belcari *et al.*, 2003). For the Mediterranean as a whole, females have been reported to be slightly more abundant than males (Cau *et al.*, 2002; Belcari *et al.*, 2003; Can and Aktas, 2005), although a dominance of males has been reported from Greek waters (Cau *et al.*, 2002; Papaconstantinou and Kapiris, 2003; Politou *et al.*, 2004).

Based on data from eight seasonal trawl surveys carried out in 1985-1987 a sex ratio of 53% females was reported for giant red shrimp in the Strait of Sicily (Ragonese and Bianchini, 1995). An analysis of GRUND and MEDITS survey data collected in the Central Mediterranean in 1994-2002 revealed a proportion of giant red shrimp females in the whole population of 0.43-0.49 (Ragonese *et al.*, 2004) and a later analysis of 1994-2004 GRUND and MEDITS survey data showed that sex ratios oscillated without any apparent pattern around the expected value of 0.5 during this period (Ragonese *et al.*, 2012). A more recent estimate based on an analysis of Maltese 2009-2011 commercial fisheries monitoring data from GSA 15 gave an average overall catch (including both landings and discards) sex ratio of 0.46 (MRRA, unpublished data).

With regards to sex ratio by size, there is an almost complete separation of sexes for mature individuals, with females being more abundant in the large size classes and males being more abundant in the middle size classes (Bianchini, 1999; Politou *et al.*, 2004; Ragonese *et al.*, 2012; Figure 7).

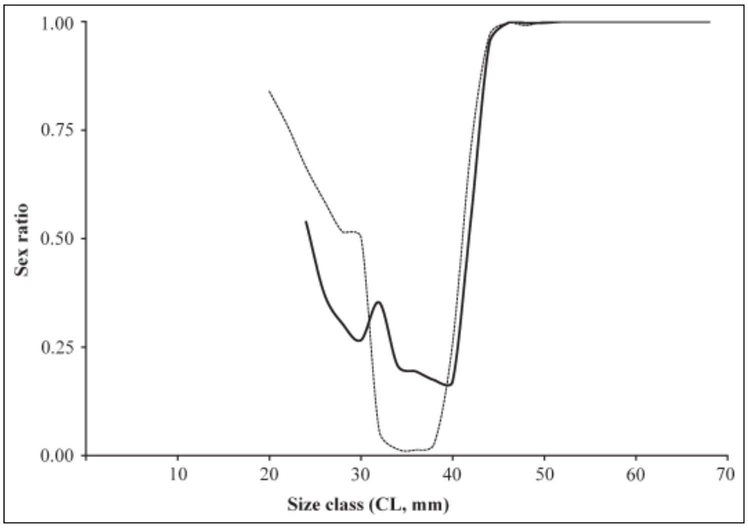


Figure 7. *Aristaeomorpha foliacea* sex ratio by size class in the South of Sicily and the Maltese Islands; dotted and solid lines represent MEDITS and GRUND interpolated values respectively (from Ragonese *et al.*, 2012).

Although no relationship between sex ratio and depth has been found for the Strait of Sicily (Bianchini, 1999; Ragonese *et al.*, 2012), it has been hypothesised that males become more abundant with depth and that during the mating season males migrate from the deeper canyons to shallower depths (D'Onghia *et al.*, 1998; Belcari *et al.*, 2003).

Length-weight relationships

The available parameters of allometric length-weight relationships measured in the Central Mediterranean are reported in Table 1.

Table 1. Length-weight parameters of *Aristaeomorpha foliacea* in the Strait of Sicily (GSA 15 and GSA 16); model: W = a CL^b.

Author	GSA	Period	Data Type	Sex	a	b
Ragonese *et al*. (1997)	16	1985-1987, 1993	Commercial	F	0.0013	2.64
Ragonese *et al*. (2004)	16	1994-2002	Survey	F	0.00176-0.00210	2.51-2.56
Ragonese *et al*. (2004)	16	1994-2002	Survey	M	0.00116-0.00135	2.65-2.56
MRRA (2009)	15	2006-2008	Survey	M	0.00153	2.59
MRRA (2009)	15	2006-2008	Survey	F	0.00104	2.68
CNR-IAMC (2009)*	16	/	/	F	0.0016	2.5884
CNR-IAMC (2009)*	16	/	/	M	0.001	2.7456
Gancitano *et al.* (2011)	16	/	/	F	0.0013	2.636
MRRA (2012)	15	2009-2011	Commercial	M	0.00635	2.2129
MRRA (2012)	15	2009-2011	Commercial	F	0.00146	2.6065

*In STECF EWG report 11-14 (2011)

Maximum age and natural mortality

Ragonese *et al.* (1994) used Bhattacharya's method as implemented in the COMPLEAT ELEFAN package (Gayanilo *et al.*, 1988; 1994), complemented with information on survey season and reproductive patterns to estimate a maximum age of 4 years for female and 5 years for male giant red shrimp.

Cau *et al.* (2002) calculated growth curves for females based on 1994-1999 MEDITS data using Modal class Progression Analysis (MPA) as implemented in the FAO FiSAT software, and estimated a maximum age of 5 years for individuals from the Strait of Sicily.

Based on age slicing using the LFDA routine with growth parameters estimated by CNR-IAMC (2009), the maximum estimated age in the exploited female *A. foliacea* standing stock during the period 2006-2009 estimated by STECF 11-14 (2011) was 6 years.

More recently, Ragonese *et al.* (2012) hypothesized that the longevity parameters for males estimated by classic length frequency distribution analysis may have been underestimated due to reduced growth and an aggregation of older individuals in the larger size classes after the onset of sexual maturity. Based on the Author's analyses a higher maximum age of 7-10 years for adult male giant red shrimps in the Central Mediterranean was proposed.

Ragonese *et al.* (1994) analysed a two year time series of *A. foliacea* length frequency distributions from the Strait of Sicily and estimated an annual instantaneous natural mortality (M) of 0.4 for females. Although the authors stated that values for males are likely to be similar, no estimate was given for males. Other estimates of natural mortality over the species lifespan in the Central Mediterranean are 0.5 for females (Bianchini, 1999), 0.4 for females (Ragonese *et al.*, 2004) and 0.4-0.6 for males (Ragonese *et al.*, 2012).

Natural mortality rates by age were calculated according to the ProdBiom model developed by Abella *et al.* (1997) by STECF 11-14 (2011) as reported in Table 2.

Table 2. Natural mortality at age for *Aristaeomorpha foliacea* in GSA 15 and 16 as estimated by STECF 11-14 (2011).

Age	0	1	2	3	4	5+
Natural mortality at age	0.62	0.30	0.23	0.19	0.17	0.16

Von Bertalanffy growth function (VBGF)

Von Bertalanffy growth parameters estimated to date for the Strait of Sicily are reported in Table 3 for comparative purposes.

Table 3. Von Bertalanffy growth function estimated for the Strait of Sicily (GSA 15 and 16); L∞, k and t0 refer to the asymptotic carapace length (CL; mm), the curvature coefficient (year^{-1}) and the theoretical age at size 0.

Author	Sex	L∞	K	t_0	Remarks
Ragonese *et al.* (1994)	F	65.5	0.67	0.28	
Ragonese *et al.* (1994)	M	41.5	0.96	0.28	
Bianchini (1999)	M	40-41	1.08	/	
Cau *et al.* (2002)	F	65.5	0.67	/	
Bianchini and Ragonese (2002)	F	60 - 61	0.63 - 0.66	/	
Ragonese *et al.* (2004)	F	65.8	0.52	-0.23	
AAVV (2008); Red's Project	F	62.24	0.65	0.05	
AAVV (2008); Red's Project	M	40.31	0.79	-0.44	
CNR-IAMC (2009)	F	61.66	0.78	-0.22	
CNR-IAMC (2009)	M	41.95	0.7	-0.18	
SGMED 02-09 (2009)	F	68.9	0.61	-0.2	
Ragonese *et al.* (2012)	M	41.9	1.40 / 0.56	0.2 / -0.99	Double phase VBGF: coefficients before / after transitional age

Feeding behaviour

Giant red shrimp are opportunistic carnivores and scavengers (Bianchini, 1999). The first study on the feeding behaviour of *A. foliacea* found a high diversity in consumed prey types, including pelagic, benthic and benthopelagic organisms in the Ligurian Sea (Brian, 1931). This pattern was later confirmed for the Central Mediterranean: stomach content analysis of giant red shrimp found both strictly benthic and pelagic prey (Bello and Pipitone, 2002). The most widely accepted explanation is that *A. foliacea* undergoes diel migrations related to its feeding behaviour, feeding on benthic organisms during the day and preying in the water column at night (Bianchini, 1999; Rainer, 1992; Bello and Pipitone, 2002).

The most important food sources of giant red shrimp in the Strait of Sicily are crustaceans (49%), bony fish (21%), cephalopods (9%), siphonophores (5%), gastropods (5%), bivalves (3%), polychaetes (1%), unidentified prey (7%) and foraminiferans (Bello and Pipitone, 2002). The precise dietary importance of the latter is difficult to estimate because foraminiferans may be unintentionally ingested when feeding on benthic prey (Rainer, 1992; Cartes, 1995). Common benthopelagic decapods ingested by *A. foliacea* in the Strait of Sicily are *Plesionika* and *Pasiphaea* spp., in particular *Pasiphaea sivado* (Bianchini, 1999). Cephalopods have a higher relative importance in the diet of *A. foliacea* compared to giant red shrimp from other areas and as a result it is likely that *A. foliacea* contributes significantly to the mortality of juvenile cephalopods of species such as *Heteroteuthis dispar* in Central Mediterranean food webs (Bello and Pipitone, 2002).

Diet composition is size related in *A. foliacea*. Significant differences were found with regards to the number of cephalopods eaten by small compared to large-sized giant red shrimp in the Strait of Sicily, only medium and large shrimp were able to prey on larger cephalopods (Bello and Pipitone, 2002). Bianchini (1999) found that larger individuals consumed more cephalopods, shrimps and siphonophores, while small specimens consumed a larger proportion of benthic mollusks and foraminifera. In the Greek Ionian Sea a similar positive trend of ingesting larger prey with increased size has been observed for female giant red shrimp, whilst immature individuals have a higher occurrence of epibenthic prey in their foreguts (Kapiris, 2012). Large shrimp are likely to be more efficient predators because of their increased swimming ability and larger mandibles.

In addition to the influence of somatic growth on feeding habits, giant red shrimp change their feeding behaviour seasonally. In the Strait of Sicily there are seasonal differences in prey type, with siphonophores of the family Diphyidae consumed mainly in spring and benthic gastropods an important food source in autumn (Bianchini, 1999). In the Greek Ionian Sea giant red shrimp have an increased feeding activity in spring-summer, which is likely related to the increased reproductive activity in this season (Kapris, 2012). In winter *A. foliacea* has the highest stomach fullness, but the ingested food has a lower quality (Bianchini, 1999; Kapiris, 2012).

Stock units

Despite the commercial importance of *A. foliacea*, only very little information is available on population structure, larval mixing and migration patterns. Based on the bathymetry of the Strait of Sicily, Bianchini (1999) hypothesized that giant red shrimp in the Strait of Sicily have two main distribution zones, one on the eastern side and one on the western side of the Sicilian Channel, connected with a passage to allow for the movement of individuals. However, Marcias *et al.* (2010) carried out a study on the genetic connectivity between giant red shrimp populations from Sardinia and the Strait of Sicily and found no significant genetic variability between the populations sampled. The Authors thus concluded that *A. foliacea* in the western and central Mediterranean forms one large panmictic stock.

Evaluation and exploitation

Biomass indices from trawl surveys

Fishery independent information regarding the state of the giant red shrimp stock in GSAs 15 and 16 can be derived from the international bottom trawl survey MEDITS, which has been carried out in GSA 16 since 1994 and in GSA 15 since 2002 (Figures 8 and 9). Information presented by STECF 11-14 (2011) shows that patterns recorded in GSA 15 and GSA 16 in 2002- 2010 mirrored one another. The stock declined slightly in 2004-2007, before increasing in 2008 and peaking in 2009. In 2010 the population returned to levels similar to those recorded in 2005-2007. Similar peaks in abundance had previously occurred in 2000 and 2004. The highest number of *A. foliacea* caught per hour in 1994-2010 was 81.3 individuals in GSA 15 in 2004; the lowest number caught per hour 1994-2010 was 1.79 in GSA 15 in 2009. The lowest biomass of *A. foliacea* caught per hour in 1994-2010 was 0.36 kg/hour in GSA 16 in 1997; the highest biomass caught per hour 1994-2010 was 1.79 kg/hour in GSA 15 in 2009.

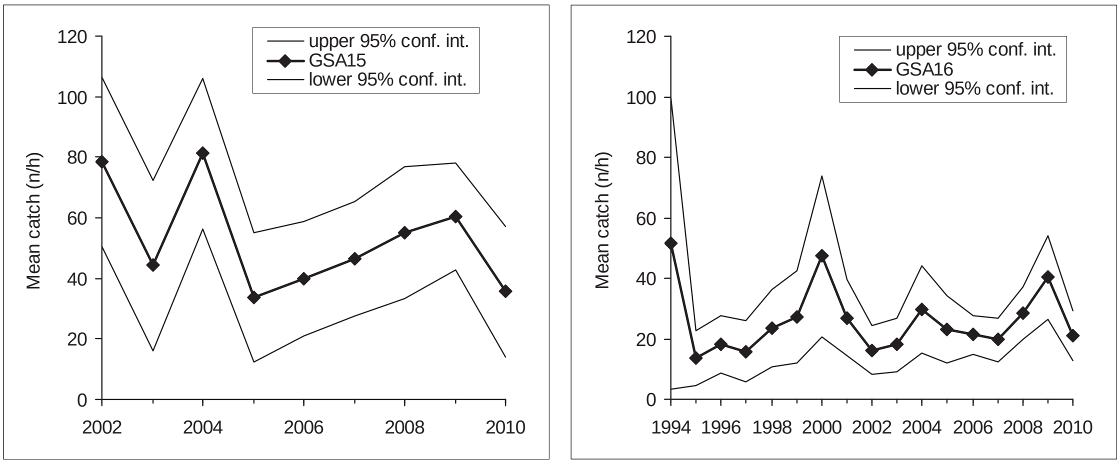


Figure 8. Abundance indices of *Aristaeomorpha foliacea* for the years 2002-2010 in GSA 15 (left) and 1994-2010 in GSA 16 (right).

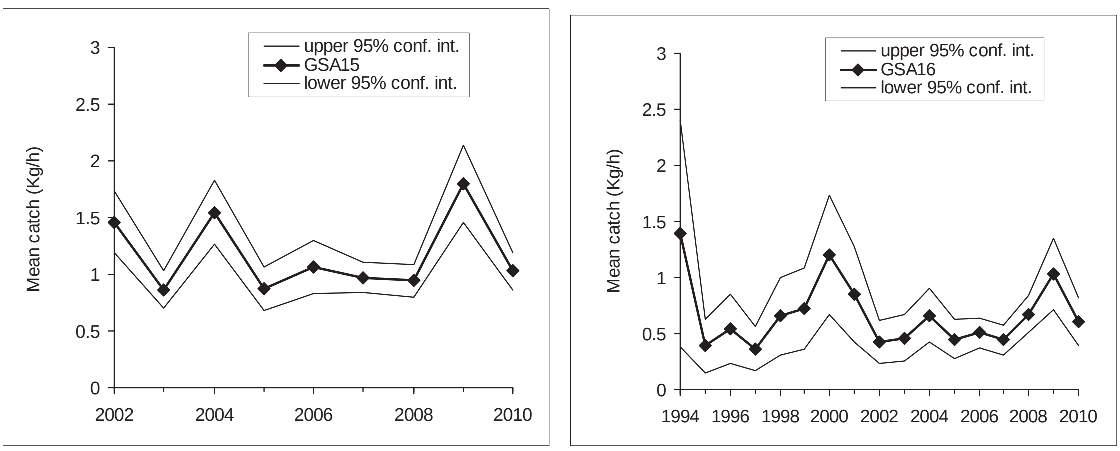


Figure 9. Biomass indices of *Aristaeomorpha foliacea* for the years 2002-2010 in GSA 15 (left) and 1994-2010 in GSA 16 (right).

Strength of recruitment
Based on a SURBA analysis (Needle, 2003) of GSA 16 MEDITS survey data for female giant red shrimp, STECF 11-14 (2011) concluded that in 1994-2001 both spawning stock biomass (SSB) and recruitment fluctuated significantly. SSB remained at low but stable levels in 2002-2010 (Figure 10). Recruitment fluctuated at low levels in 2002-2010; a low number of recruits were recorded in 2001, 2006 and 2010. Absolute estimates of female recruitment were in the range of 83 (2008) to 123 million recruits based on an analysis of GSA 15 and GSA 16 commercial data (STECF 11-14, 2011).

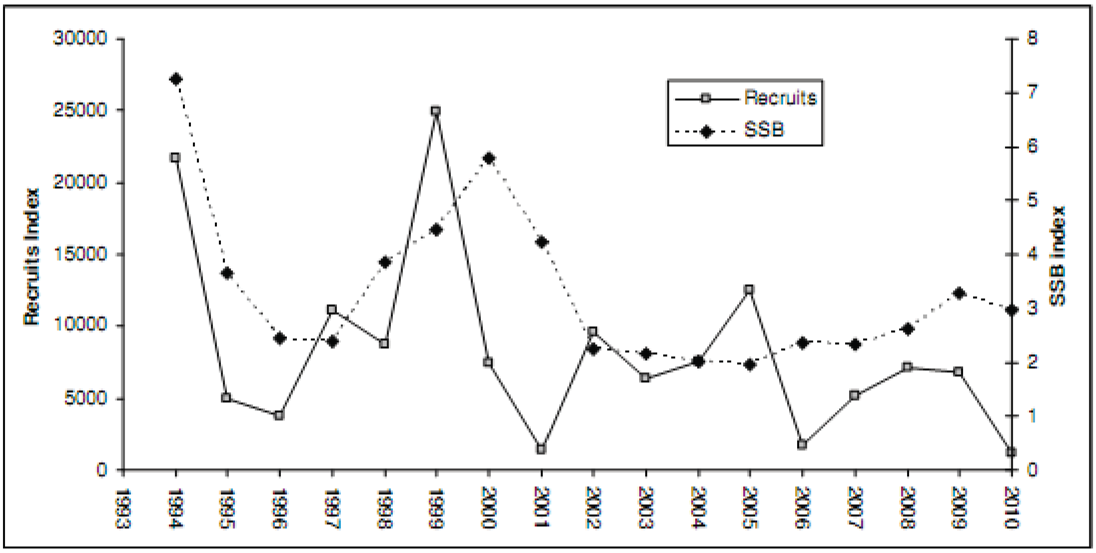


Figure 10. Female spawning stock biomass (SSB) in kg/km2 and recruits in n/km2 as a median of SURBA bootstrapped values (from STECF 11-14, 2011).

Stock assessment
The most recent stock assessment available for *A. foliacea* in the Strait of Sicily was done in 2011 by the STECF 11-14. Only the state of exploitation of the female component of the giant red shrimp stock was assessed. The assessment was presented to the GFCM Sub-Committee for Stock Assessments (SCSA) in 2011 and subsequently endorsed by the GFCM Scientific Advisory Council (SAC) in 2012.

Five complete years of length frequency distributions from Sicilian commercial data (2006-2010) and two years of length frequency distributions sampled onboard Maltese trawlers (2009, 2010) were analysed. The assessment was based on pseudo-cohort assumptions, keeping separate the available years. Cohort (VPA equation) and yield per recruit analysis as implemented in the VIT package (Lleonart and Salat, 1997) were carried out as well as a simulation of the likely variation in yield, biomass and spawning stock biomass per recruit as a function of varying fishing mortality with the Yield package (Branch *et al.*, 2001). A probability estimation of limit and target biological reference points was also carried out using the Yield package.

Total yields reconstructed by the VIT package for the study period were very close to the actual, observed yields. Other results such as absolute estimates of recruitment, current total mortality rates and fishing mortality rates are listed in Table 4.

Table 4. Overview of main results of VIT analysis based on the female fraction of the *Aristaeomorpha foliacea* population in the Strait of Sicily.

Year	2006	2007	2008	2009	2010	Median
Total Yield (t)	1450	1574	1287	1659	1684	1574
Estimated SSB (t)	1070	1370	1300	1580	1260	1370
Recruitment (ml)	98	114	83	118	122	114
Mean Z (all ages)	1.22	1.00	0.96	0.83	0.99	0.99
Mean F (all ages)	0.92	0.74	0.7	0.57	0.73	0.73
Mean F (ages 1-4)	1.14	1.07	1.05	0.81	1.09	1.07

The results of estimating spawning stock biomass per recruit (SSB/R) and yield per recruit (Y/R), by varying current fishing mortality (F_c) through a multiplicative factor for 2006-2010 catches as calculated by the VIT package are reported in Figure 11.

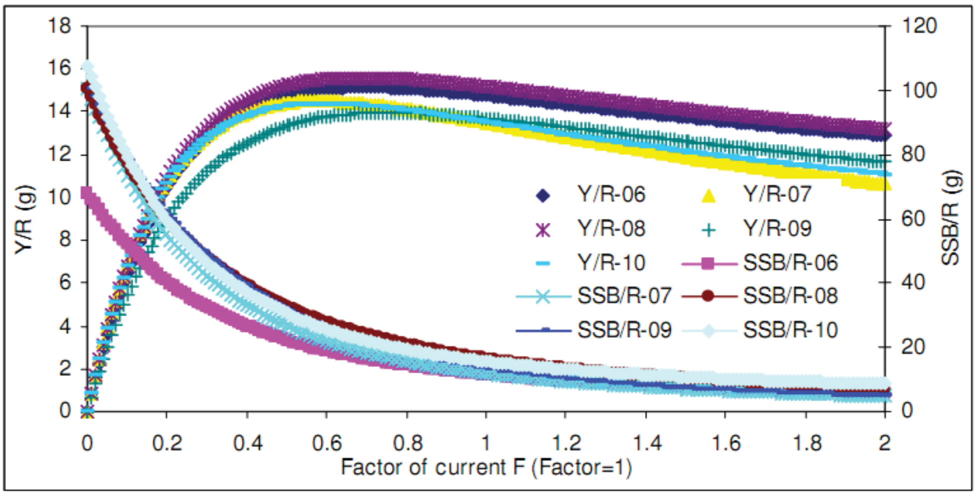


Figure 11. Spawning stock biomass and yield per recruit under varying current fishing mortality (Fc) scenarios for *Aristaeomorpha foliacea* harvested in the Strait of Sicily according to the VIT package.

The results of the yield per recruit analysis with regards to current levels of fishing mortality (F) as well as target ($F_{0.1}$) and limit (F_{max}) reference points are given in Table 5. The results of estimating spawning stock biomass per recruit (SSB/R) and yield per recruit (Y/R) according to the Yield package are illustrated in Figure 12.

Table 5. Yield (Y), biomass (B), spawning stock biomass (SSB) per recruit (R) varying fishing mortality (F) by a multiplicative factor; Y, B and SSB are given in g per R.

Year	Parameter	Factor	F	Y/R	B/R	SSB
2006	$F_{(0)}$	0.00	0.00	0.00	74.97	68.11
	$F_{(0.1)}$	0.44	0.36	14.41	31.03	24.68
	F_{max}	0.71	0.81	15.15	22.45	16.35
	F_c	1.00	1.14	14.77	17.36	11.51
2007	$F_{(0)}$	0.00	0.00	0.00	107.51	100.68
	$F_{(0.1)}$	0.38	0.41	13.82	40.97	34.85
	F_{max}	0.59	0.63	14.50	28.67	22.87
	F_c	1.01	1.07	13.50	17.21	12.01
2008	$F_{(0)}$	0.00	0.00	0.00	107.51	100.68
	$F_{(0.1)}$	0.42	0.44	14.72	44.35	37.98
	F_{max}	0.70	0.74	15.59	30.50	24.39
	F_c	1.01	1.05	15.17	22.37	16.51
2009	$F_{(0)}$	0.00	0.00	0.00	107.51	100.68
	$F_{(0.1)}$	0.49	0.40	13.30	38.17	32.11
	F_{max}	0.76	0.61	13.96	25.49	19.75
	F_c	1.01	0.81	13.69	18.84	13.36
2010	$F_{(0)}$	0.00	0.00	0.00	107.51	100.68
	$F_{(0.1)}$	0.39	0.42	13.73	38.06	31.94
	F_{max}	0.60	0.65	14.36	26.15	20.33
	F_c	1.01	1.09	13.51	15.62	10.31

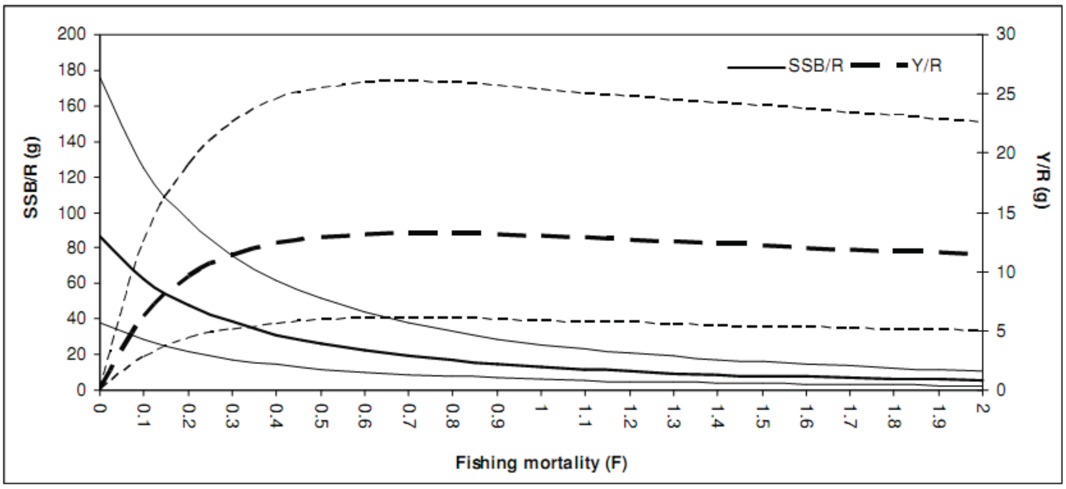


Figure 12. Median of yield and spawning stock biomass per recruit as well as the corresponding uncertainty limits for *Aristaeomorpha foliacea* in the Strait of Sicily as estimated by the Yield package.

The simulation of biological reference points (BRP) with 2000 repeats gave the F_{max} and $F_{0.1}$ probability distributions shown in Figure 13; the median value of $F_{0.1}$ was 0.4 and the median value of F_{max} was 0.75. The $F_{0.1}$ estimate is thus the same as that estimated by VIT, whilst the F_{max} estimate is slightly higher.

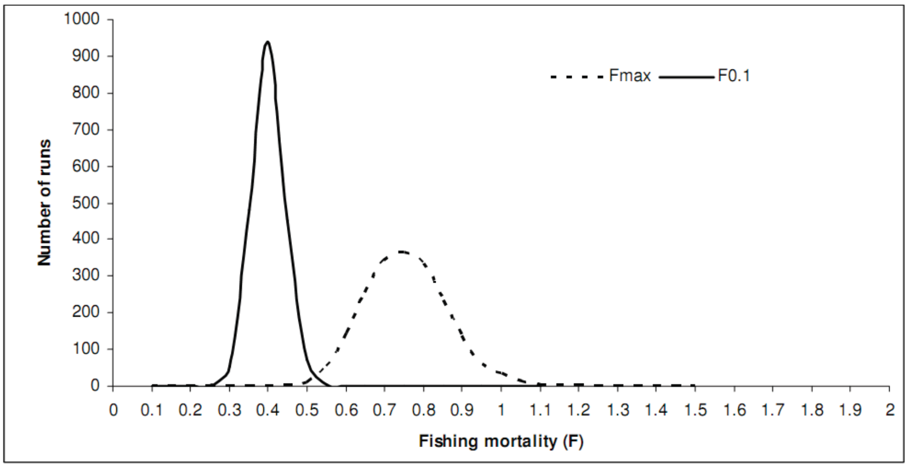


Figure 13. Probability distribution of F_{max} and $F_{0.1}$ according to the Yield package.

Based on this information STECF 11-14 (2011) and GFCM SAC (2012) proposed F_{MSY}=0.4 ($F_{0.1}$ basis) as management reference point of the female part of the *A. foliacea* stock, and concluded that the stock in the Strait of Sicily is considered to be subject to overfishing since the current fishing mortality (F_c=1 in 2010) exceeds this reference point. Indeed, the median current F in 2006-2010 was 0.73, and thus higher than both F_{max} (median in 2006-2010 = 0.73) and $F_{0.1}$ (median in 2006-2010 = 0.41) during the study period.

GFCM SAC recommended a reduction in fishing mortality. STECF similarly advised to continuously reduce current fishing mortality through consistent effort reductions and an improvement in current exploitation patterns. STECF further advised the relevant fisheries' effort to be reduced until fishing mortality is below or at the proposed reference level, in order to avoid future loss in stock productivity and landings, and suggested this should be achieved by means of a multi-annual management plan taking into account mixed-fisheries effects (STECF 12-19, 2012).

Fisheries

A. foliacea is an important target species for bottom otter trawlers operating on the continental slope in the Strait of Sicily. Although no specific information on Italian vessels targeting red shrimp fisheries is available, the number of trawlers larger than 24 m LOA can be considered as an overestimated proxy of vessel that potentially can catch red shrimps. In 2011, 140 Italian trawlers measuring over 24m in length carrying out longer fishing trips (up to 4 weeks) were active in both the Italian and the international waters of the Central and Eastern Mediterranean. The Tunisian fleet was composed of 75 trawlers measuring over 24 m, which targeted deep water crustaceans primarily in Northern Tunisia. The great majority of Tunisian catches are landed in the towns Bizerte and Kelibia. In the Maltese Islands 14 trawlers measuring 12-24 m and 8 measuring over 24 m in length were active in 2011, 11 of which had a license to operate within the 25 nm Maltese Fisheries Management Zone (Ben Meriem *et al.*, 2012a; 2012b). The contribute of Libyan trawlers to red shrimp catches can be considered negligible.

With regards to fishing effort, data submitted by Italy and Malta in response to the annual EU fisheries Data Collection Framework (DCF) data-call in 2012 revealed a 32% decrease in fishing effort for Italian bottom otter trawl vessels larger than 24 m in the period 2004-2011 (Figure 14). Maltese vessels were only responsible for 1.6% of total trawling effort in GSAs 15 and 16 in 2006-2011, however the total nominal effort of Maltese trawlers increased by 67% in 2006-2011 (STECF 12-19, 2012).

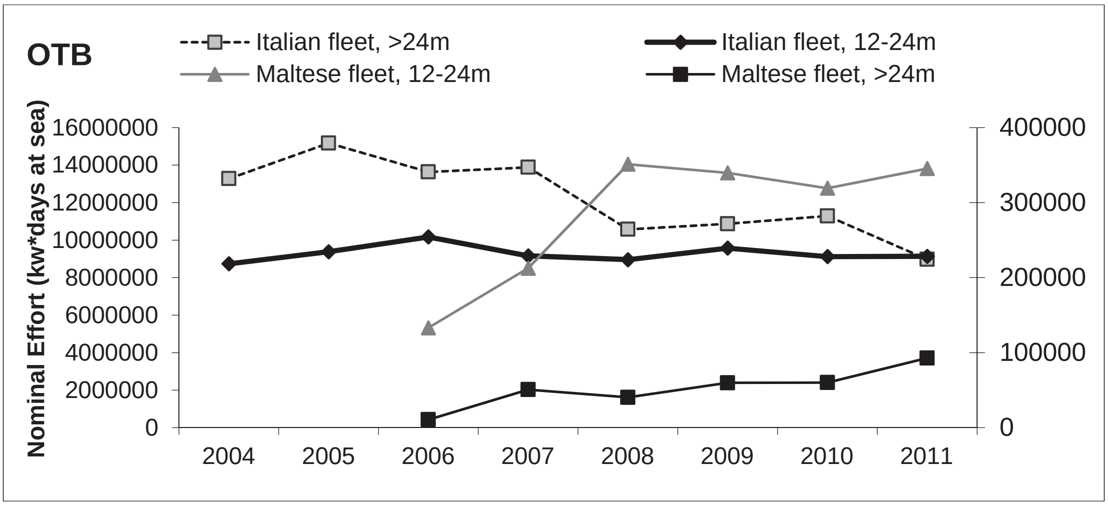


Figure 14. Nominal effort (kW*days at sea) trends for trawlers (OTB) by Italian (left y-axis) and Maltese (right y-axis) fleet segments (from STECF 12-19, 2012).

Although the deep water bottom otter trawling in the Mediterranean is a multispecies fishery, red shrimps represent the most abundant and highest value fraction of catches. Based on 102 daylight hauls Bianchini (1999) found the mean catch by weight of the *A. foliacea* fishery to be composed of: 49% giant red shrimp, 1% blue and red shrimp, 26% bony fish, 16% cartilaginous fish, 7% other crustaceans. Other commercial species frequently caught together with giant red shrimp are the deep water rose shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*), blue and red shrimp (*Aristeus antennatus*), greater forkbeard (*Phycis blennoides*), hake (*Merluccius merluccius*), rockfish (*Helicolenus dactylopterus*), black-bellied anglerfish (*Lophius budegassa*), four spotted megrim (*Lepidorhombus boscii*), blue whiting (*Micromesistius poutassou*) and several species of squid (*Illex* spp., *Todarodes sagittatus*, *Todaropsis eblanae*). In terms of the absolute number of marketable individuals caught, deep water rose shrimp and Norway lobster, together with giant red shrimp, make up the bulk of catches (Bianchini, 1999; Knittweis, pers. observation).

Fishing zones and seasons

In order to estimate variations in crustacean catch compositions in the Strait of Sicily Vitale *et al.* (2006) divided the Central Mediterranean into seven sub-areas based on the morphology of the single areas, hydrological features as well as feedback from fishers with regards to target areas for different species (Figure 15). In spring 2001 estimates of catches (i.e. landings and discards) were made for *P. longirostris*, *N. norvegicus* and *A. foliacea* in each sub-area. Based on three day and three night hauls, made by the employed commercial crews at random locations in each area, the Authors recorded the following total catch for giant red shrimp in decreasing order of importance: area 7 = 50 t, area 4 = 33 t, area 3 = 18 t, areas 1 and 4 = 8 t, areas 6 and 2 = 1 t, area 5 = no catches.

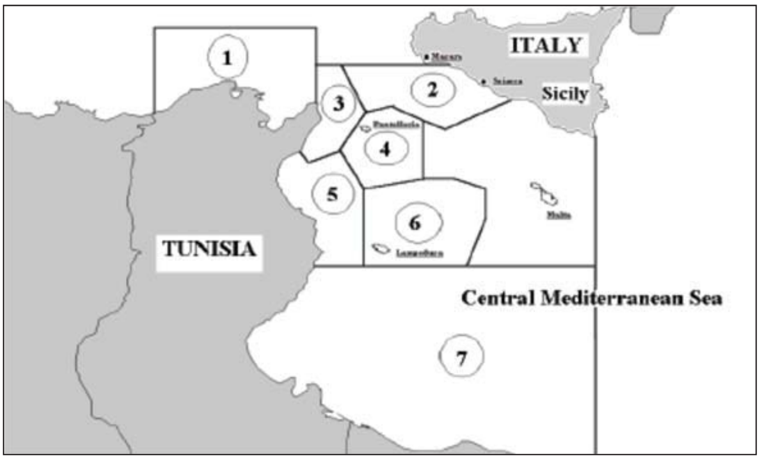


Figure 15. Areas surveyed by Vitale *et al.* (2006) to estimate catch composition of decapod crustaceans from trawl fishery catches in the Central Mediterranean.

Bonnet (1980) carried out a survey of demersal fishery resources along the Tunisian coast, and found *A. foliacea* to be dominant in hauls at depths of ~500 m taken off the coast of Tabarka, in the north of Tunisia. More recently, Missaoui (2004) list giant red shrimp as one of about twenty commercial crustacean target species caught in Tunisian fisheries, stating that *A. foliacea* is concentrated on the northern side of Tunisia.

In Maltese waters, trawlers target giant red shrimp within the 25 nm trawl fisheries management zone to the north-west of the Island of Gozo and south-west of Malta, at depths of 600-700 m (Dimech *et al.*, 2012)(Figure 16).

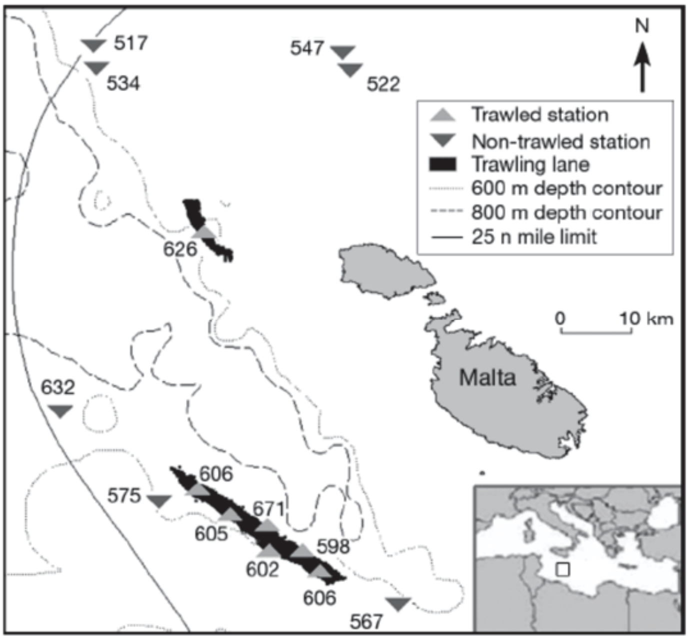
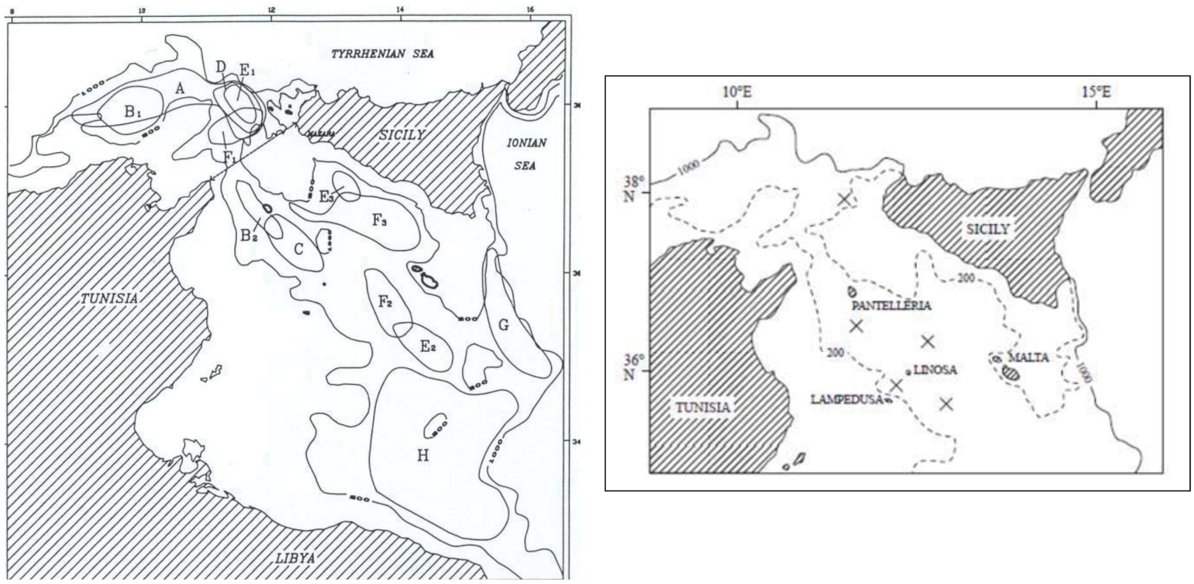


Figure 16. Trawl lanes within the Maltese 25 nautical mile Fisheries Management Zone (after Dimech *et al.*, 2012).

Information on the location of fishing zones targeted by the Sicilian trawl fleets is available from Ragonese (1995) as well as Bianchini *et al.* (2003), who give an outline of the most important *A. foliacea* target areas in the Strait of Sicily (Figure 17).

Due to a reduction in catch rates since 2004, some distant trawlers based in Mazara del Vallo, which is the main fleet in the area, moved to the eastern Mediterranean (Aegean and Levant Sea) to fish red shrimps (Garofalo et al., 2007).

Italian and Maltese trawlers catch *A. foliacea* on the continental slope of the Strait of Sicily throughout the year; a slight decrease in total landings during the first quarter of the calendar year (January-April) is generally followed by a peak in landings in the second quarter (May-August) (STECF 11-14, 2011).



(A) (B)

Figure 17. Main fishing grounds of *Aristaeomorpha foliacea* targeted by Sicilian fishers; (A) after Ragonese (1995), (B) after Bianchini *et al.* (2003).

Yield

No information is available on total yield of *A. foliacea* from Tunisian trawlers. As Missaoui (2004) pointed out, sampling is difficult for several crustacean species in Tunisia, including *A. foliacea*. Part of the reason for this is that giant red shrimp are generally landed frozen since the species is primarily destined for export markets (Mosbah *et al.*, 2012; Ben Meriem, pers. communication). Yield of both the Italian and Maltese trawlers reached the highest values of the period 2004-2009 in 2009, with 1620 t and 42 t respectively (Figure 18).

The most abundant size classes in 2006-2009 catches by Sicilian trawlers were 42-50 mm carapace length (Figure 19). Giant red shrimp caught by Maltese trawlers in 2009 and 2010 were generally smaller, with the most abundant size classes measuring 32-34 mm carapace length (STECF 11-14, 2011) (Figure 20).

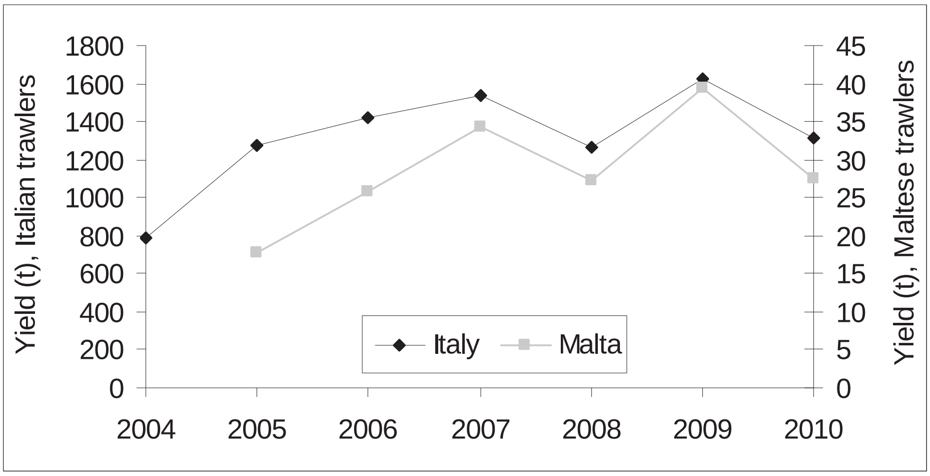


Figure 18. Bottom otter trawl fleet landings (t) by year in 2004-2009 as reported through the EU fisheries Data Collection Regulation (based on STECF data 11-14, 2011).

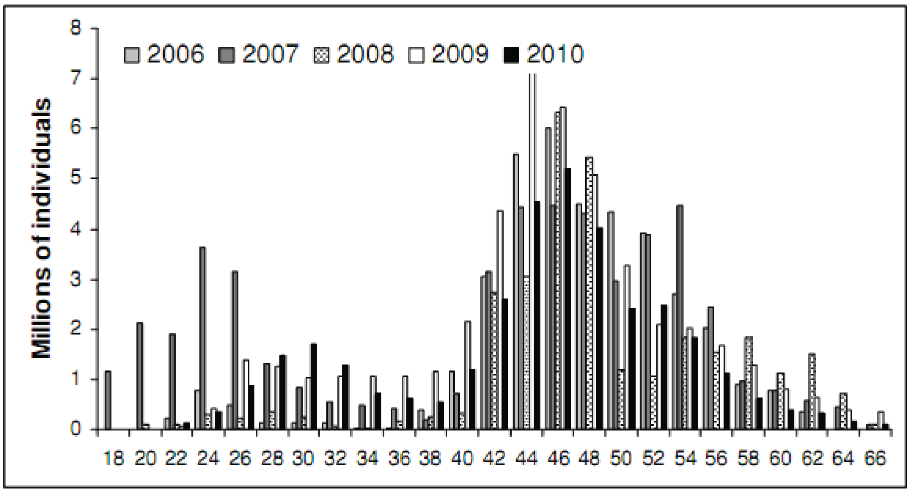


Figure 19. Annual length structure of giant red shrimp landed (absolute numbers) by Sicilian trawlers fishing in the Strait of Sicily (from STECF 11-14, 2011).

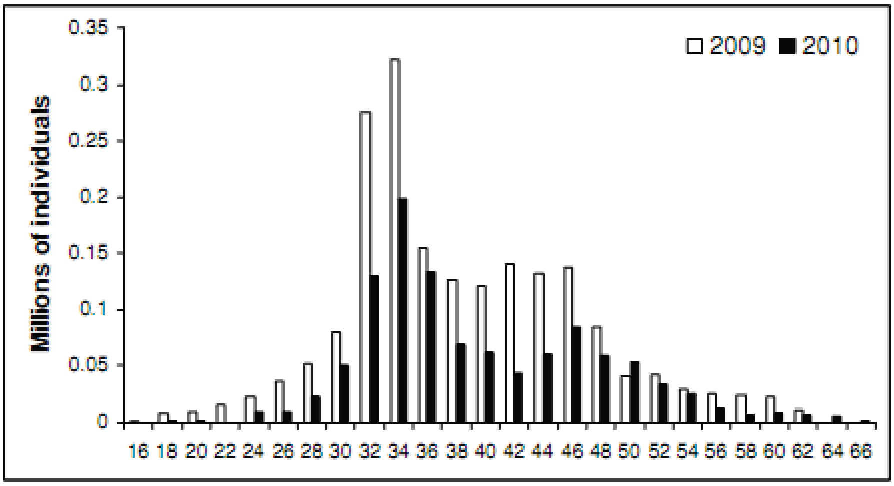


Figure 20. Annual length structure of giant red shrimp landed (absolute numbers) by Maltese trawlers fishing in the Strait of Sicily (from STECF 11-14, 2011).

Fishing and discards

Mediterranean bottom otter trawling is a multi-species fishery which discards both undersized commercial species and unwanted species with no commercial value. It has been estimated that over 560 000 t of unwanted species are discarded in the Mediterranean every year, although the composition of discards varies depending on seasons, depth, gear characteristics, haul duration and the location of the fishing ground (Alverson *et al.*, 1994). More recently a lower estimate of discards produced by fisheries in the Mediterranean, was given by Tsagarakis et al. (2103). Discard is around 230 000 t, corresponding to 18.6% (13.3–26.8%) of the catch.

Altough Castriota *et al.* (2001) reported a mean discard rate in shrimp fisheries of 49% of catch in the Strait of Sicily, the overall amount of discards generated by red shrimp fisheries is generally low (Ragonese *et al.*, 2001; STECF 11-14, 2011) as a significant fraction of the by-catch is made up of economically important species (Bianchini, 1999). However long-haul fishing vessels aiming to maximize profits have been reported to discard practically all non-crustacean catches (Bianchini, 1999; Castriota *et al.*, 2001).

Discarding of undersized juvenile commercial species is also an important concern (Vitale *et al.*, 2006) (Figure 21). An analysis of discards data collected onboard Maltese trawlers in 2009 and 2010 revealed that the Maltese fleet discarded an estimated 1.3 t of *A. foliacea* in 2009 and 0.2 t in 2010 (STECF 11-14, 2011). On average the ratio of discards to landings for Maltese trawlers in 2009 and 2010 was 2%; the majority of discarded individuals were too small to be of commercial value, whilst some larger specimens were crushed during fishing and too damaged to be sold. The decrease in discards in 2010 is likely to be due to the general drop in giant red shrimp landings in 2010 as well as the introduction of larger mesh sizes on Maltese trawlers in line with the Mediterranean Regulation (EC 1967/2006) (STECF 11-14, 2011).

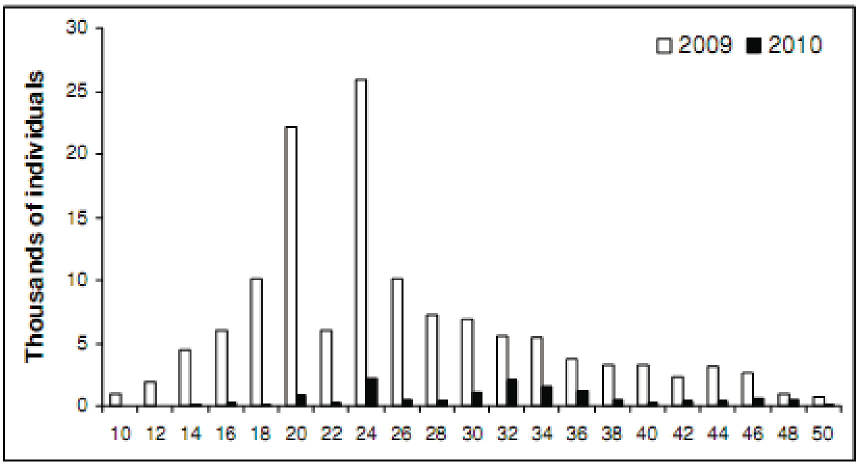


Figure 21. Annual length structure of *Aristaeomorpha foliacea* discards in absolute numbers by Maltese trawlers fishing in the Strait of Sicily.

A number of discarded species with no commercial value are caught as by-catch in the giant red shrimp fishery. They include several species of grenadier (*Hymenocephalus italicus*, *Nezumia sclerorhynchus*, *Coelorhynchus coelorhynchus*), argentines (*Argentina sphyraena*, *Glossanodon leioglossus*), shortnose greeneye (*Chlorophthalmus agassizi*) and several species of cartilaginous fish: blackmouth catshark (*Galeus melastomus*), small-spotted catshark (*Scyliorhinus canicula*), velvet belly lanternshark (*Etmopterus spinax*), thornback ray (*Raja clavata*), longnosed skate (*Dipturus oxyrinchus*) and rabbit fish (*Chimaera monstrosa*) (L. Knittweis, pers. observation).

Regarding invertebrates and overall benthic communities, the gorgonian *Isidella elongata* is generally caught by trawlers targeting red shrimps. In the Mediterranean *Isidella elongata* characterises bathyal compact mud biocenoses between 500 and 1200 m depth (Peres, 1967), providing a habitat for a multitude of fish and invertebrates. *I. elongata* is removed during bottom trawling activities and, as a result, is becoming increasingly rare. Destroying coral communities is likely to have a long term negative impact on the bottom otter trawling industry by reducing species richness, abundance and biomass of commercial species (Maynou and Cartes, 2011).

Gears

Up to recent years Italian and Maltese trawlers targeting giant red shrimp in the Strait of Sicily used a type of bottom otter trawl net known as a ‘fondale’ net. In shallower waters a different net referred to as a ‘banco’ net is used. Banco nets have a shorter extension piece, larger cod end mesh sizes and smaller extension piece mesh sizes compared to fondale nets. Both nets were characterized by a low vertical opening of only up to 1.5 m, although dimensions change with the engine power of individual vessels (Fiorentino *et al.*, 2003) (Tble 6).

A detailed study of the functions between otter door spread, horizontal and vertical net opening as well as warp length on fishing vessels with differing engine strengths the performance of demersal fishing gears used in Italy was carried out by Fiorentini *et al.* (1994). In the last years some changes in the structure of the mazarese net were introduced. They were aimed at reducing the weight and increase the vertical opening during trawling.

Table 6. Main characteristics of traditional Sicilian trawl nets based on a study carried out using a reference trawler of 375-450 kW engine (Fiorentino *et al.*, 2003 in MedSudMed, 2008).

Net Characteristics	**Banco net**	**Fondale net**
Length of cod end	5 - 6 m	5 - 6 m
Length of extension piece	20 - 21 m	23 - 25 m
Lastridge rope	Absent	Absent
Circumference of cod end	400-500 mesh * 40-36 mm	600-600 mesh * 28-26 mm
Circumference of extension piece	900-1000 mesh * 44-40 mm	400 mesh * 50-52 mm

Legislation and management

At present there are no formal management objectives for giant red shrimp fisheries in the Strait of Sicily. As in other areas of the Mediterranean, the stock management in Tunisia, Italy and Malta is based on control of fishing capacity (licenses), fishing effort (fishing activity), technical measures (mesh size and area/season closures) (Jarboui, 2009; STECF 12-19, 2012).

In Tunisia law 94-13, issued on the 31st January 1994 as well as an order of the Ministry of Agriculture issued on the 28th September 1995 regulate marine fishing activities (Jarboui, 2009). In Malta and Italy both national legislation and EU legislation apply; key pieces of EU legislation are the recently reformed Common Fisheries Policy (EC 1380/2013), the Fisheries Data Collection Framework (DCF) (EC 199/2008, EC 665/2008, EC 93/2010), the Mediterranean Regulation (EC 1967/2006) and the Control Regulation (EC 1224/2009, EC 404/2011).

In order to limit the over-capacity of the fishing fleet, no new fishing licenses have been assigned in Italy since 1989 and a progressive reduction of the trawl fleet capacity is currently underway. Maltese fishing capacity licenses had been fixed at a total of 16 trawlers since 2000, but eight new licenses were issued in 2008 and one in 2011, a move made possible by capacity reductions in other segments of the Maltese fishing fleet (STECF 12-19, 2012). In order to control fishing effort, Tunisia also restricts the number of fishing licenses (Jarboui, 2009); the number of Tunisian trawlers has increased from 70 in 2009 (GFCM SCSA, 2010) to 75 in 2011 (GFCM SCSA, 2012).

A compulsory 30-day fishing ban in August-September was recently adopted by Sicilian Government (STECF 12-19, 2012). In Tunisia closed seasons were established for the first time in 2009 for the Gulf of Gabès (south Tunisia, GSA 14). The ‘biological rest period’ (*Repos Biologique*) is in July, August and September each year. Although *A. foliacea* does not benefit directly from this measure since it is not fished in the Gulf of Gabes, this new regulation may in future be extended to other areas if stocks are found to be overexploited and in need of protection (Jarboui, 2009).

There is no closed season in place in Malta, but the Maltese Islands are surrounded by a 25 nautical mile fisheries management zone, in which fishing effort and capacity are being managed by limiting vessel sizes, as well as total vessel engine powers (EC 813/04; EC 1967/06). 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. Vessels fishing in the management zone hold a special fishing permit in accordance with Regulation EC 1627/94. Moreover, the overall capacity of the trawlers allowed to fish in the 25nm zone can not exceed 4 800 kW, and the total fishing effort of all vessels is not allowed to exceed an overall engine power and tonnage of 83 000 kW and 4 035 GT respectively. The fishing capacity of any single vessel with a license to operate at less than 200m depth cannot exceed 185 kW.

In order to protect coastal habitats, the use of towed gears is prohibited within 3 nm of the coast or within the 50 m isobath if the latter is closer to the coast (EC 1967/2006; Res. GFCM

36/2012/3). In order to protect deep water habitats, trawling at depths beyond 1000 m is also prohibited at EU and GFCM level (EC 1967/2006; Rec. GFCM 2005/1).

In terms of technical measures, EC 1967/2006 fixed a minimum mesh size of 40 mm (opening) for bottom trawling by EU fishing vessels. In July 2008 the mesh size had to be modified to square 40 mm mesh or, if duly justified by the vessel owner, a 50 mm diamond mesh; derogations were only possible up to 2010. Moreover, diamond mesh panels can only be used if it is demonstrated that size selectivity is equivalent to or higher than using 40 mm square mesh panels (EC 1343/2011). In Tunisia benthic trawlers targeting demersal species have a minimum diamond mesh size of 20 mm side, corresponding to 40 mm opening (Jarboui, 2009). There is at present no minimum landings size for *A. foliacea* in European or Tunisian legislation.

Melicertus (Penaeus) kerathurus (Forskål, 1775)

Figure 22. *Melicertus kerathurus* (Foskål, 1775)

Species Description

The caramote prawn, *Melicertus kerathurus* (Forskål, 1775, Figure 22) belongs to the family Penaeidae. This species is also known by the scientific names *Penaeus sulcatus* (Leach, 1814) and *Penaeus caramota* (Risso, 1816). Common names used locally to refer to this shrimp are: caramote (France), langostino (Spain), mazzancolla (Italy), caramote (England), gombri and shrimp (Tunisia). The hierarchy in the super-class Crustacea was studied by Véron (1995) and Falciai and Minervini (1996).

This is a large shrimp exceeding 22 cm in total length it has a beige coloured esoskeleton with dark transverse bands forming separate spots on the side of the body and with blue uropodes. The first three pairs of legs have pincers. The telson is sharp and has three sides of movable spines. Laterally, the first abdominal segment covers the second. The rostrum is short and barely goes beyond the eyes; it has eight to thirteen dorsal spines and just one ventral spine.
The caudal end is sky blue, bordered with red. The appendages are yellowish. Behind the last dorsal tooth, there is a double hull with a typically deep median furrow extending to the posterior edge of the carapace; a long ridge runs parallel to the rostrum.
In the hepatic region there is a ridge in the anterior – ventral direction; the gastrointestinal front peak is present. The abdomen has a dorsal keel in all segments and ends with a spine on the sixth segment.

Morphological aspects
The body of the caramota is segmented and protected by a chitinous carapace, and can be divided into two distinct regions (Figure 23):

- Carapace: composed of 14 segments, protected on the back and sides by a vast carapace partly merged with the ventral segments and ending before a rostrum.

- Abdomen: a hinged piece that consists of six mobile segments and an end piece (telson) where the anus opens. The sixth segment has two fan-like appendages on each side (uropods) which together with the telson form the swimming apparatus.

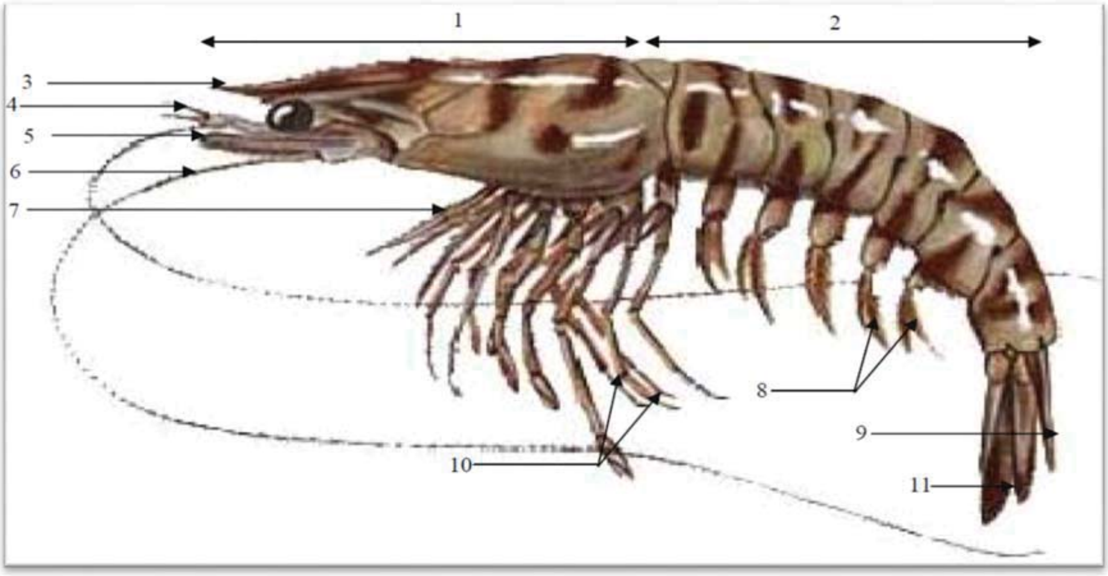


Figure 23. Morphology of caramote *Melicertus kerathurus* (Foskål, 1775). 1 - Carapace, 2-Abdomen, 3-Rostrum, 4-Antennules, 5-Scaphocérite, 6-Antennas, 7-Maxilliped, 8 - Swimmerets, 9-Telson, 10-Peraeopods, 11-Uropods; *cephalon = acron.*

The head includes six pairs of cephalic appendages. Thus we can distinguish in order, a first pair stalked eyes and two pairs of sensory appendages that are suites consisting of antennules and antennae, the last three pairs of appendages are masticatory (mandibles maxillae and maxillules). The head extends forward with a short snout, barely above the eyes, armed with teeth numbering from 8 to 13 on the dorsal edge and a single tooth on the ventral edge which is characteristic of this species. Duplication of the dorsal keel to form a deep and narrow furrow is the salient feature of this species.

Thorax (Pereion)

The thorax (Pereion) is surmounted by a heavily calcified carapace with a hepatic spine, a short neck between the groove of the head and two branchiomotor heart grooves allow recognition of the longitudinal median cardiac region and two lateral gill regions.

It has eight pairs of appendages or peraeopods, the first three pairs or maxillipedes belong to the mouthparts and provide masticatory functions, the posterior five pairs permit movement and terminated by pincers (first 3 pairs) or claws (both others). The third pereiopod is slightly more developed than the second. Furthermore, there are gills for breathing.

Abdomen

There are six perfectly distinct metameric segments, each bearing a pair of biramous pleopods or appendices. Pleopods generally used for swimming. In males, the endopodites of the pleopod have a modified copulatory organ (petasma), with which the male introduces a spermatophore to the female during mating.

Telson

It is pierced by the anal orifice that is ventrally visible and terminated by a three-pointed sharp tip.

Ecology

Geographic distribution

Melicertus kerathurus has a wide geographical distribution in the world (Figure 24). It is found throughout the Mediterranean basin (including the Marmara Sea) and in the Atlantic from Portugal to Angola (d'Udekem d'Acoz, 1999). In the eastern Atlantic it has been occasionally reported in the south of England.

Figure 24. Geographical distribution of Melicertus kerathurus (Jaziri *et al.*, 2011)

In Tunisia this species is especially abundant in the Gulf of Gabès, which has been known for a long time. Indeed, Ponzevera (Heldt and Held, 1954) reported its existence on the Tunisian coast since 1891. Darboux in 1906 (Heldt and Held, 1954), reported the prawn (*Penaeus caramota*) in the Bay of Bizerte in Tunisia, off Sousse and Sfax. It was caught, in the sandy-muddy area of Medjerda where the best catches occur. In 1920, the species was found for the first time in the Gulf of Gabès and in the North-East of Djerba. In 1923 Charcot caught this prawn by trawling in the Eastern Kerkennah Archipelago (Heldt and Held, 1954).

Habitats

M. kerathurus is a demersal species living in coastal areas or in brackish water on sandy or sandy mud bottoms. It can be found at depths of 0.5 to 100 m but it is common between 5 and 40 m. The largest concentrations are in the Gulf of Gabès (Ben Meriem, 1995). Although the caramota is considered to be present at all depths, the best catches are recorded at shallow depths reflecting the coastal nature of this species (Azouz, 1972; Ben Mustapha, 1967). In addition, the abundance of this species appears to decrease with depth (Gharbi and Ben Meriem, 1996). Exceptionally, in the Strait of Sicily, the species has been recorded at maximum depths of 640 m (Ragonese and Giusto, 1998).

M. Kerathurus live in very different environmental conditions. It was found in brackish estuaries, in water with high salinity and in very shallow waters at the shore, as well as further offshore at greater depths on muddy bottoms in pits of debris and on clean seabeds with sand and seagrass (Heldt, 1932; Heldt, 1954; Heldt and Heldt, 1954; Azouz, 1972).

Migration

Very small juveniles lead a sedentary life near the shores at very shallow depths. At 5 to 8 cm juveniles begin migrating to a depth of about 50 meters where they await the spring season to reach the spawning grounds. George (1977) reported that the shrimp caught off buoys 6 and 7 in the Gulf of Gabès were likely to come from the coast of the Kerkennah islands and those caught in the North and North East of Djerba island from the pits in the Gulf of Gabès.

The caramote performs two types of migration: one trophic vertical and one genetic, horizontal migration (Zouari, 1984). During the day it reacts to the solar irradiance with a negative phototropism and goes towards the bottom, sinking completely into the sand or mud, hiding among the vegetation such as algae, *Posidonia* or plant debris. On the contrary, at night the shrimp temporarily leaves this area to swim and make incursions into neighboring areas to feed (Ben Mustapha, 1967).

In the Gulf of Gabès, caramote appears to migrate in April-May to the pits at a depth of about 25m, where there is a breeding ground with favorable spawning conditions (Heldt, 1954). These pits are mainly those of Chaffar Skhira and Zarrat and buoys in front of the area of Fora Mustapha.

In relation to bathimetric distribution during the horizontal migration Ben Meriem (1998) reported that the young fraction of the population stays strictly within the coastal area while the largest prawns occupy the deepest areas. Most catches are based on the oldest fraction of the population. In addition, Ben Khemis (1984), indicated that all young individuals of this species are to be found in very shallow waters and migrate slowly to deeper waters occupying different ecological niches. Larger individuals are more abundant over 40 m depth.

Biological information

Maximum size

M. kerathurus is a large shrimp: the total length from the tip of the rostrum to the end of the telson is usually 11-14 cm for males and 13-17 cm for females. The maximum size ($L\infty$) were observed in Greece and in Italy, respectively, of 25.2 and 27.2 cm total length (TL) (Anon., 2011).

Ben Meriem (1995), following a sample of commercial landings in the Gulf of Gabès, indicates that the largest females measured 64.4 mm carapace length (CL) and, for males, maximum length was 45.2mm CL. Very similar sizes were observed during the shrimp monitoring campaigns in the Gulf during the last decade. A larger size (66.3 mm CL) was observed in the trawl landings in Mahdia in 1998. Fairly similar sizes were reported in the Amvrakikos Gulf (Ionian Sea, western Greece) and off the southern coast of Sicily. Conides *et al.* (2006) indicated a size of 62 mm CL based on sampling carried out from June 1999 to

May 2001. Vitale *et al.* (2010) reported a maximum size of 63.3 mm CL in commercial catch of Selinunte artisanal fleet in month sampling from May to September 2006.
It is important to note that these differences observed on maximum size should be interpreted with caution: shrimp are caught in different regions with different gears (trawl, net, weir) and selectivity can play an important role in the observed size. In addition, the different levels of exploitation and the state of the various stocks could play a role.

Spawning

Benthic spawning begins from June to July and lasts until late September, early October, while older females are more precocious (Ben Meriem, 1993).
It is important to note that a similar pattern of seasonal reproduction (April-September) has been observed in Greece in the Ionian Sea (May to September; Conides *et al.*, 2008), in Turkey in the Aegean Sea (May to October; Turkmen *et al.*, 2007) and in Sicily.

Size at first sexual maturity

The size at first sexual maturity of female of *M. kerathurus* in the Gulf of Gabes (Tunisia) was determined using two performance criteria: the presence of spermatophore and/or an ovigerous condition. To do this, the proportion of mature or fertilized females, depending on the size, was adjusted by a logistic function of the type: P=1/(1+exp(-a(CL-CL50))). The carapace length, corresponding to 50% of mature females is between 29 and 30 mm CL (130 mm total length). The egg-laying period, measured by the monthly monitoring of the maturation index (MI = ovary weight/size), spans from June-July to October (Table 7, Figure 25). In addition, spawning in older females precedes that of younger females by 3 months.

Table 7. Monthly evolution of the maturation index estimated as ovary weight/size of mature females of *M. kerathurus* in southern Tunisia.

Month	Jan.97	Feb.97	Mar.97	April 97	May 97	June 97
Maturity index	6.9	3.2	3.7	6.4	43.3	36.8
Month	July.98	Aug 98	Sept. 98	Oct. 98	Nov. 98	Dec. 98
Maturity index	-	30.4	35.0	6.7	2.8	-

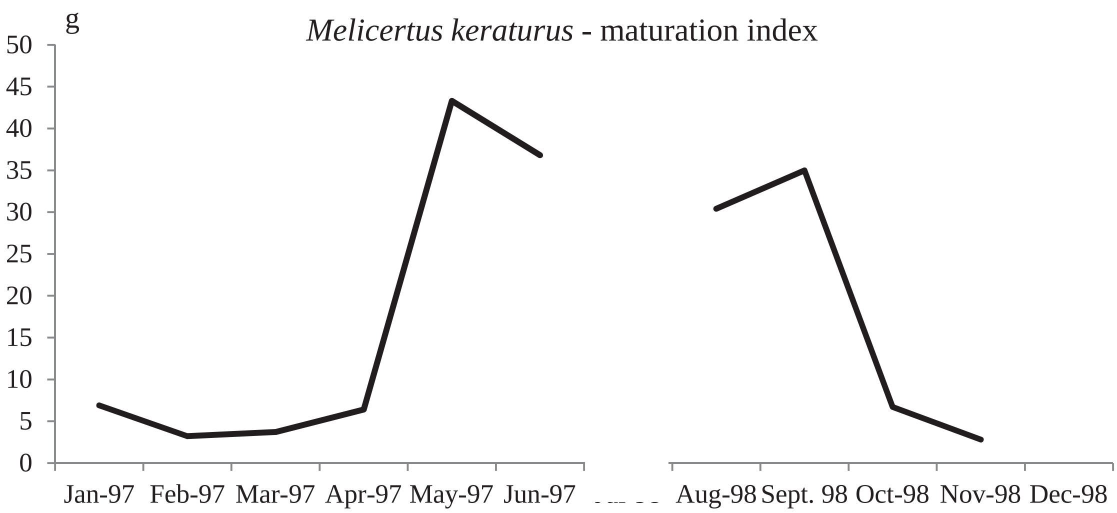


Figure 25. Monthly evolution of the maturation index estimated as ovary weight/size of mature females of *M. kerathurus* in southern Tunisia.

The size at first maturity expressed as carapace length (CL) was estimated using a logistic function of the type: $P = 1 / (1 + \exp(-a (CL-CL_{50})))$. The parameters obtained are shown in Table 8.

Table 8. Size at first maturity equation parameters for *M. kerathurus* the Gulf of Gabes, Tunisia. CL_{xx} = carapace length at xx percentage of maturity; CL_{50} = approximation ofr size at first maturity (Ben Meriem, 1993).

Parameters	**estimated value (mm)**	**standard error**
A	0.2219	0.0148
CL_{50}	30.3	1.58
R^2	0.965	-
CL_{25}	~27.0	-
CL_{75}	~33.0	-

Turkmen *et al*. (2007) indicates a CL_{50} = 4.8 cm CL (or 17.8 cm total length) for females in Turkey. Similar size at first maturity values were estimated by Conides *et al.* (2008) in western Greece. These results are significantly higher than those found in the Gulf of Gabès. This could be attributed to environmental conditions and fishery operations that are not the same.

Stock units

Genetic studies of populations of *M. kerathurus* from Eastern and Western Tunisia show distinct units (Zitari-Chatti *et al.,* 2008). According to Pellerito *et al.* (2009), differences in mDNA of *M. kerathurus* from Selinunte (southern Sicily) and Sfax (Gulf of Gabes) were also found. These results, together with fisheries information, suggest the existence of separate stocks of *M. kerathurus* in the Strait of Sicily, although their boundaries are still unknown.

Eggs, larvae and post-larvae

Information on this aspect in the MedSudMed geographical area is scarce. According to Heldt (1938), eggs released by females remain on the bottom where they undergo embryonic development. At hatching, Nauplius larvae emerge and during successive metamorphoses relevant morphological changes take place. During the next phase, comprising three stages, the larvae become pelagic Protozoea rising into open water where they will be transformed into Mysis. The pelagic period ends one or two metamorphoses after Mysis stage IV; at this time the advanced larvae migrate to the coast, where they metamorphose into post-larval stages.

Recruitment and Nursery Areas

Nurseries of *M. kerathurus* were in very shallow water near the shore and juveniles migrate later to 25m pits at first sexual maturity size. According to surveys carried out in the Gulf of Gabes (Gharbi and Ben Meriem, 1996; Ben Meriem, unpublished), recruitment to fishery occurs in autumn in areas very close to the nurseries. According to Vitale *et al.* (2010) the first wave of recruitment to the commercial stock occurs in August. The small shrimps caught in April and May are likely to be specimens born late in the previous year’s reproduction period. The relatively small size of these shrimps is probably due to the low temperature they face during autumn and winter time that reduce their growth.

Sex Ratio

During the surveys carried out in the Gulf of Gabès (Gharbi and Ben Meriem, 1996; Ben Meriem unpublished), the sex ratio of *M. kerathurus* was about 0.5 at size of first maturity. Overall, a larger number of males (sex-ration in favour of males) at small size classes was found. A dominance of females (sex-ratio in favour of females) at larger size classes was also observed.

With respect to the spawning season, the overall sex ratio is generally close to 0.5 during the period of sexual rest but vary substantially in favour of females during the reproduction period (summer), when abundance peaks are generally observed (from bottom trawl surveys and commercial catch observations, data not published). In addition, females dominate at all depths throughout the spawning period at the end of which (autumn) bathymetric distribution changes in favour of males which prevail at greater depths while females become more coastal.

Moreover, females carrying spermatophores are present all year round but the fertilization rate remains low until the approach of the spawning period during which it involves all individuals that have reached the size of first sexual maturity. Furthermore, in the Gulf of Tunis, Ben Mustapha (1967) indicated a high percentage of females (60%) from the late spring to early summer. So it seems that there is some gender segregation favouring females at the time of reproduction. In addition, a sex-ratio of 59.1 % in favour of females was registered in Turkey (Turkmen and Yilmazyerli, 2006).

Length–weight relationships

The length-weight relationship by sex resulting after the surveys carried out in the Gulf of Gabès (Ben Meriem unpublished) is reported in Table 9.

Table 9. Length-weight relationship ($W = a L^b$) parameters for *M. kerathurus* in the Gulf of Gabès (Ben Meriem, 1993).

Coefficients	males	females	males + females
a	0.00465	0.00356	0.00469
b	2.413	2.478	2. 406

Maximum age and natural mortality

According to Ben Meriem (2004), the life cycle of caramota lasts about three years. This species is characterised by rapid growth and a relatively high rate of natural mortality. Studies in Italy and Greece indicate longevity between 2 and 3 + years. Along the southern coast of Sicily, the longevity is 3.85 years (Vitale *et al*., 2010). These results suggest 3-4 years as longevity as already found for other Penaeid shrimps (Sheehy, 1990a, b; Sheehy *et al.*, 1995; Vila *et al.*, 2000).

Mortality M was calculated using the Pauly and Rikhter and Efanov formulas, and values varied from 0.44 to 0.98 yr^{-1} (Ben Meriem unpublished). This latter value seems most plausible given the biology of the species. Using the Pauly formula and a seawater mean temperature of 17°C, Vitale *et al*. (2010), found a M value = 0.94 yr^{-1}. Conides *et al.* (2006) indicates a value of 1.15 M for both sexes combined in the Ionian Sea. In a recent study, Kevrekidis and Thessalou-Legakia (2011) found that the total mortality in the Thermaikos Gulf (Aegean Sea) ranged from 1.64 to 3.98 year−1.

Von Bertalanffy growth function (VBGF)

Ben Meriem (1995) approached growth of *M. kerathurus* by splitting the length frequency distribution into normal (Gaussian) components. Ben Meriem (1995) assigned each of these components an average size and an age based on the spawning date and the sampling age. An overview of VBGF parameters for *M. kerathurus* is provided in Table 4. The estimated mean length at size and the growth curve are shown in Figure 26.

Vitale *et al*. (2010), described the growth of the species by sex combined in the coastal water off southern Sicily, through the seasonalised VBGF. The value of the amplitude parameter C indicates that the growth rate increased by 29% at the peak of the growth season.

The parameters of the Von Bertalanffy growth curve by sex available for different Mediterranean areas are summarized in the Table 10.

Table 10. Comparison of growth parameters of *M. kerathurus*. Wp = Winter Point, and indicates the period of the year (expressed as fraction of the year) when growth is lowest; C = factor which expresses the amplitude of the growth oscillations according to the seasonalized version of VBGF as reported in Pauly (1987).

Author	**Area/GSA**	**Sex**	**CL_∞ (mm)**	**K**	**t_0**	**Remarks**
Dall et al., 1990	Gulf of Cadiz	F	41,9	0,795	n.a.	-
Rodriguez, 1987	Gulf of Cadiz	F	78,8	0,43	n.a.	-
El Mekki, 1994	GSA 4	F	64,14	0,8	n.a.	-
Ben Meriem (1995)	GSA 12	F	54,25	0,6	-0.88	-
“	GSA 14	M	37,46	0,78	-1.00	-
Rodriguez, 1987	Gulf of Cadiz	M	58,33	0,382	n.a.	-
El Mekki, 1994	GSA 4	M	45,5	1	n.a.	-
Conides et al., 2005	GSA 20	F	69.7	1.06	0.238	-
Conides et al., 2005	GSA 20	M	62.66	1.25	0.001	-
Vitale et al., 2010	GSA 16	F+M+I	72	0.78	n.a.	Wp=0.55;C=0.29;
Kevrekidis and Thessalou-Legakia (2011)	GSA 22	F	62.48	1.15	-0.158	C = 0.87 WP = 0.16 Rn = 0.170
Kevrekidis and Thessalou-Legakia (2011)	GSA 22	M	47.78	1.28	-0.138	C = 0.97 WP = 0.12 Rn = 0.205
Ben Meriem (2004)	GSA 14	F+M	180.3	0.69	-0.94	

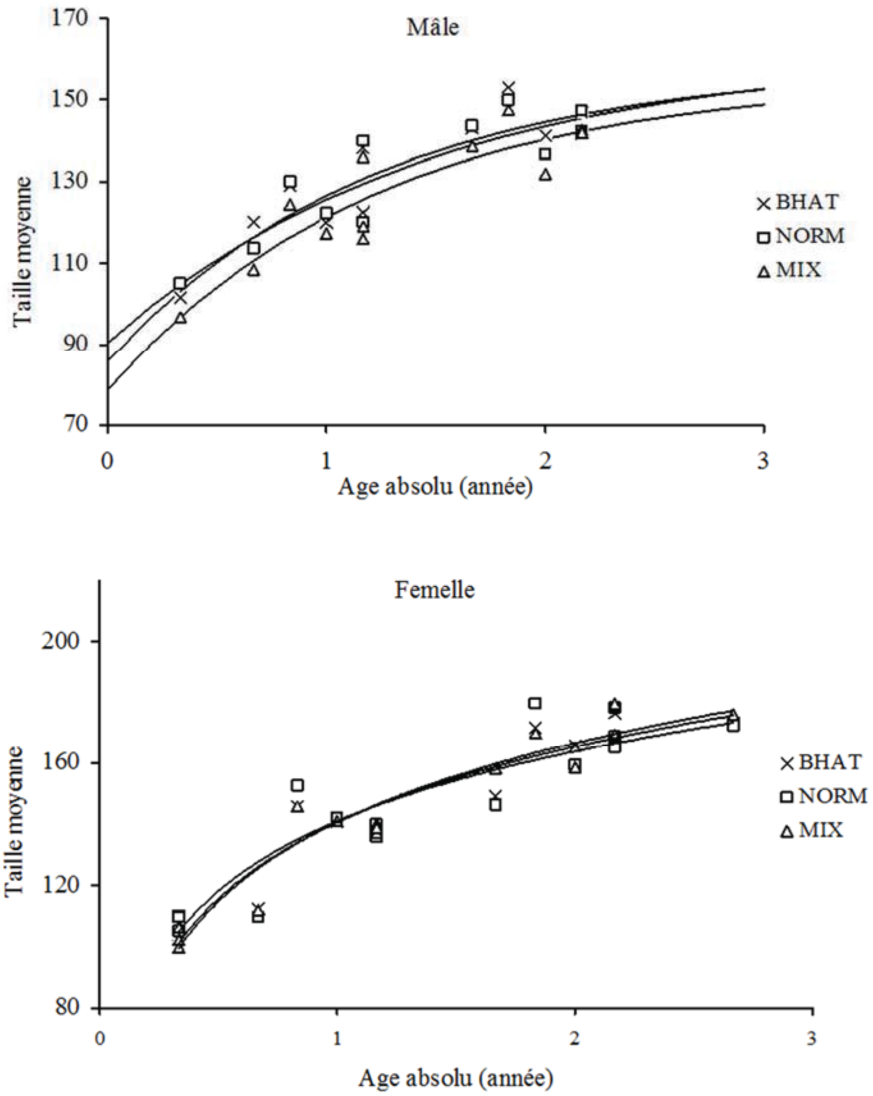


Figure 26. Growth curves of *M. kerathurus* in the Gulf of Gabès, Tunisia (Ben Meriem, 2004).

Feeding ecology

No specific studies of the diet of *M. kerathurus* in the MedSudMed region have been carried out, except very old observations by Heldt (1938) and Ben Mustpha (1967). However, a study by Karani *et al*. (2005), reported information on the diet of adults and juveniles of *M. kerathurus* in thenorth-west of the Aegean Sea. Multivariate analyses showed that the diets of juvenile and adult individuals differed significantly. Adults showed a diet consisting mainly of molluscs, crustaceans and polychaetes. Juveniles feed mainly on crustaceans.

Evaluation and exploitation – Stock assessment

Catch rates from experimental trawling and monitoring of fisheries
Biomass index of *M. kerathurus* has not regularly been monitored in the central Mediterranean. However, some experimental hauls were carried out in the past, in Tunisia (Ben Khemis, 1984; Ben Meriem, 1992, 1998), Libya (Daw, pers. comm.; Lamboeuf *et al*., 1995) and southern Sicily by monitoring catch and fishing effort (Cannizzaro *et al*., 2011).

Mean catch rates from experimental trawling from Tunisia vary from year to year and between the seasons (Table 11).

Table 11. Mean catch rates of *M. kerathurus* in the Guf of Gabès, Tunisia (Ben Khemis, 1984; Ben Meriem, 1992, 1998).

Season	Summer	autumn
end 1980s	6kg/h	5kg/h
end 1990s	4kg/h	1.2kg/h
2006	3.2kg/h	3.2kg/h

The results of experimental trawling conducted in Libya in 1993-1994 (Lamboeuf *et al*, 1995), show that *M. kerathurus* is exclusively fished in the western part of Libyan waters (GSA 21) and at depths not exceeding 100 m. In Figure 27 are illustrated the Biomass Index of *M. kerathurus* and *Parapenaeus longirostris* reported in Rawag (2004)

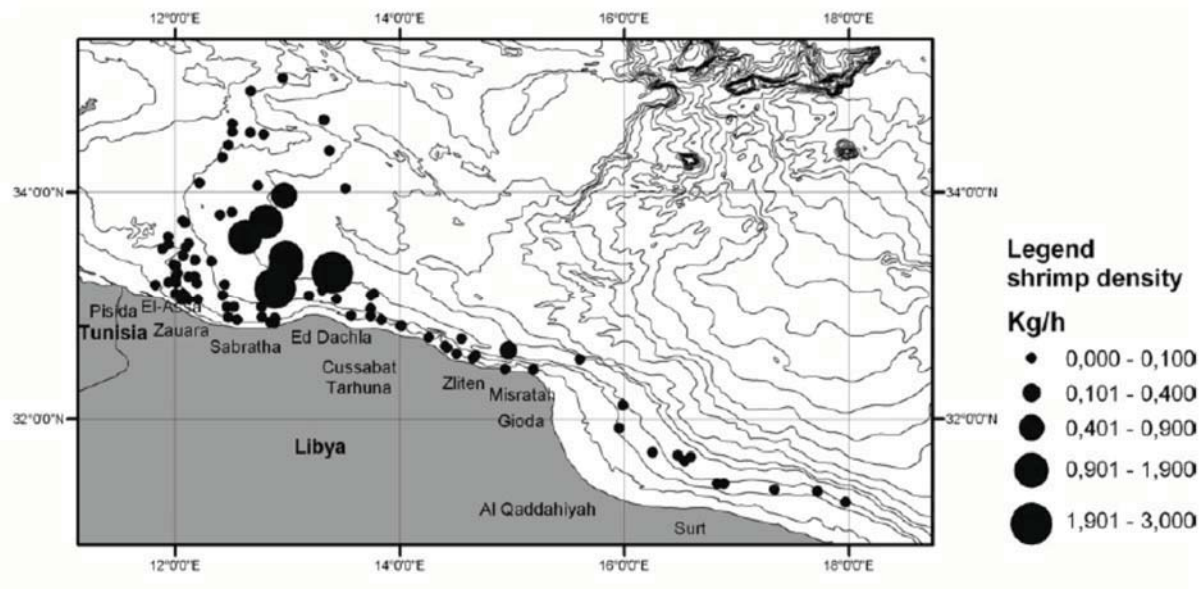


Figure 27. Biomass indices (kg h-1) *M. kerathurs* (depth <100m) and *P. longirostris* (from Rawag *et al.*, 2004).

Monitoring of catch and fishing effort of *M. kerathurus* off the west coast of Sicily (Italy) between Cape San Marco and Cape Granitola from 1998 to 2010 shows that the catch per unit effort decreased substantially from 2002 to 2009 with the exception of 2005 probably due to favorable climatic conditions (Figure 28) (Cannizzaro *et al*., 2011).
In addition, CPUE of this species has been calculated for the Gulf of Amvrakikos in Greece showing that the *M. kerathurus* population is seasonally distributed between 0 and 63m depth, with a negative CPUE-depth relationship (Kevrekidis and Thessalou-Legaki, 2006). Peak of CPUE was also observed in Italy (Lesina lagoon) in the months from August to October (Scordella and Lumare, 2001).

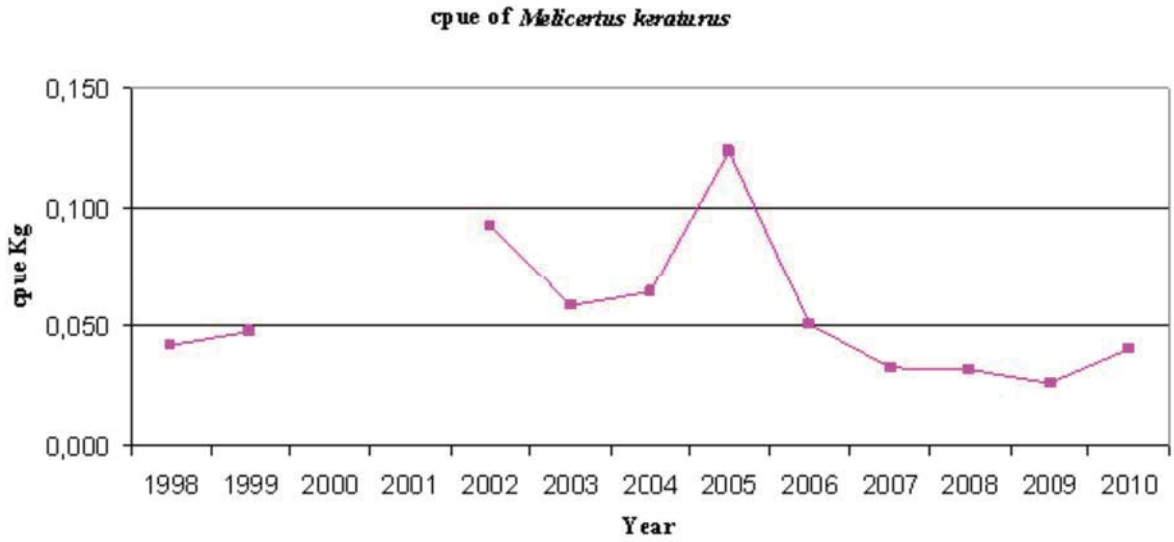


Figure 28. CPUE in weight (kg) of *M. kerathurus* (Cannizzaro *et al*., 2011).

Recruitment

There is little information on this aspect for caramota. The size at fishery recruitment in the Gulf of Gabès was 7 cm total length. Indirect estimates from the analysis of cohort size conducted in 1998 (Ben Meriem, 1998) and 2004 (Ben Meriem, 2004) show that recruitment varies substantially. Indeed, the estimate made in 1998 gives a value near 27 * 10^{10} while the 2004 gives a value of about 40 * 10^{10}.

Fishing mortality (F) and abundance (N)

Studies of stock dynamics on *M. kerathurus* are very rare in the central Mediterranean. In the Gulf of Gabès caramota is fished by trawlers and artisanal fisheries, with the most of the catch by trawlers. Stock assessment exercises carried out using analytical models (Length Cohort Analysis, LCA) showed that fishing mortality is generally moderate, the average being about 0.35 (Ben Meriem and Guirah, 2007). However, F values differ significantly depending on the size. F is very low (< 0.1) for very young individuals with a size of less than 100 mm (Figure 29), but it increases rapidly at the size of first sexual maturity (127mm) when it nears a value of around 0.4. Exploitation therefore chiefly targets adults, providing the stock a certain robustness and resistance to exploitation.

The F values of trawlers on the classes below 120 mm remain relatively low. In contrast, fishing mortality by artisanal coastal fisheries, although lower than that caused by trawlers, shows the capture of a larger percentage of juveniles (= immature) compared to trawlers. The evolution of survivors and catches in numbers according to the size is shown in Figure 30.

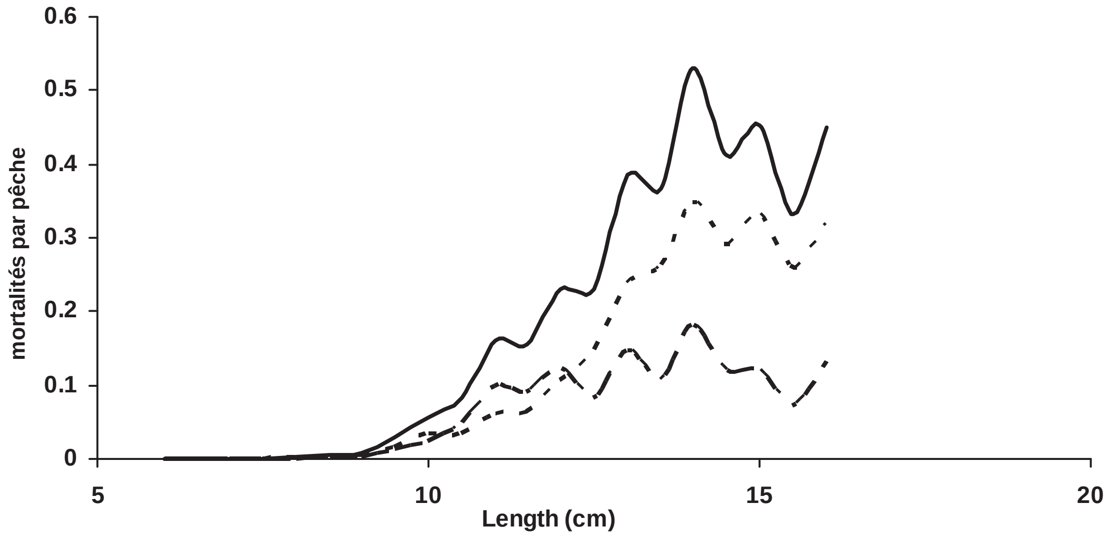


Figure 29. Fishing mortality of shrimp in the Gulf of Gabès (Ben Meriem and Guirah, 2007).

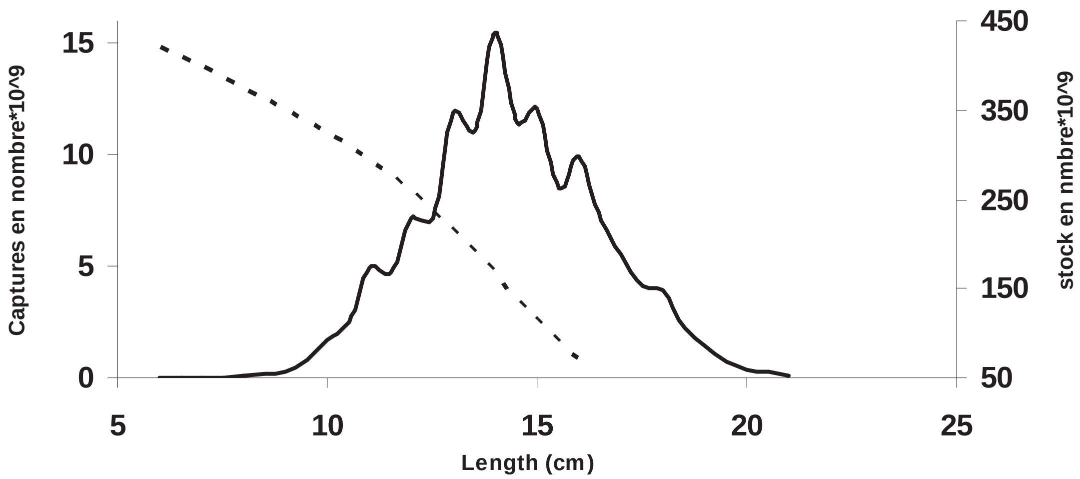


Figure 30. Stock and catch in numbers of *M. kerathurus* the Gulf of Gabès, Tunisia (Ben Meriem and Guirah, 2007).

According to Vitale *et al.* (2010), the exploited stock off the south-western Sicilian coast is composed of two dominant modes (i.e. one and two years old individuals) plus a few individuals up to three years old. The assessement of stock status was based on analysis of the exploitation rate (E=F/Z). A total mortality, Z, based on the mean carapace length of shrimp in the catch, was 1.49 yr^{-1} using the Beverton and Holt equation and 1.28 yr^{-1} using the Ault and Ehrhardt equation. Considering an instantaneous natural mortality M = 0.94

yr^{-1}, the exploitation ratio E was estimated between 0.26 and 0.37. Based on the above information, Authors concluded that off the south-western coast of Sicily the Caramote prawn stock was exploited at relatively low level.

Yield per recruit

According to Yield per Recruit Analysis (Ben Meriem and Guirah, 2007), an increase in current fishing effort would bring about an increase in production in the long term (Figure 31). This increase would reach 17% if current effort is doubled. On the contrary, any increase in effort would have a significant effect on the spawning stock biomass. Indeed, a 50% increase in effort would result in a long-term decline exceeding 10% and would jeopardise the success of the recruitment for the following years (Figure 9). The results of this analysis on the spawning biomass show a reduction in effort would improve biomass substantially. Thus, for a 50% reduction in effort, the gains that can be expected would be approximately 16%.

Despite the apparent state of exploitation of the shrimp stock in the Gulf of Gabès, according to the results of the yield per recruit, the current level of fishing effort should not be increased to ensure high level of standing stock and the sustainability of the caramota fisheries in this region.

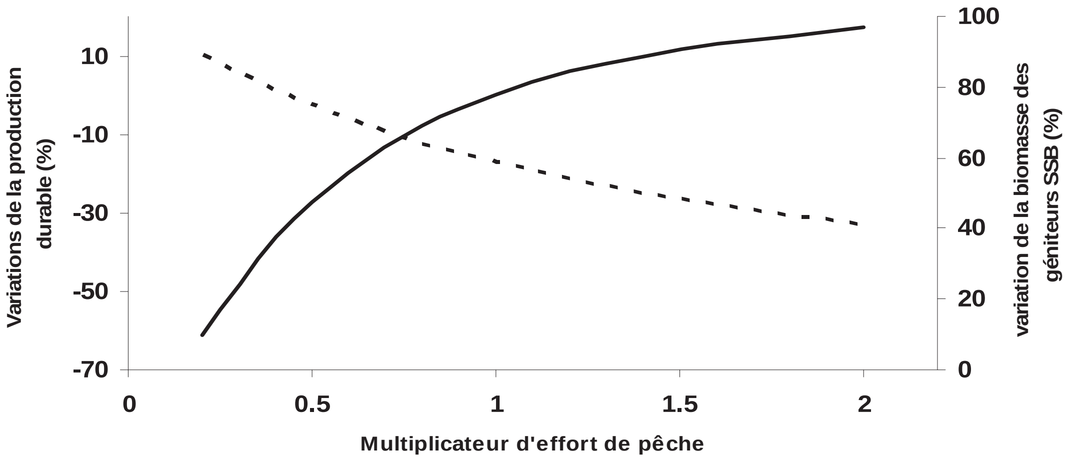


Figure 31. Relative variations of sustainable production and of spawning stock biomass (SSB) as a function of fishing effort for *M. kerathurus* in the Gulf of Gabès, Tunisia. Dashed line = SSB; continuous line = production (Ben Meriem and Guirah, 2007).

Increase in mesh size of trawlers

Overall, a moderate increase in the trawl mesh size (from 10 to 30 % of the existing mesh) does not seem, in the long run, to have a significant impact on production (Figure 32). On the contrary, a further increase of mesh size would result in significant decreases in production. Moreover, expected gains in spawning biomass remain very low and do not exceed 3% of the virgin biomass with an increase of 30% of the current mesh (Figure 32).

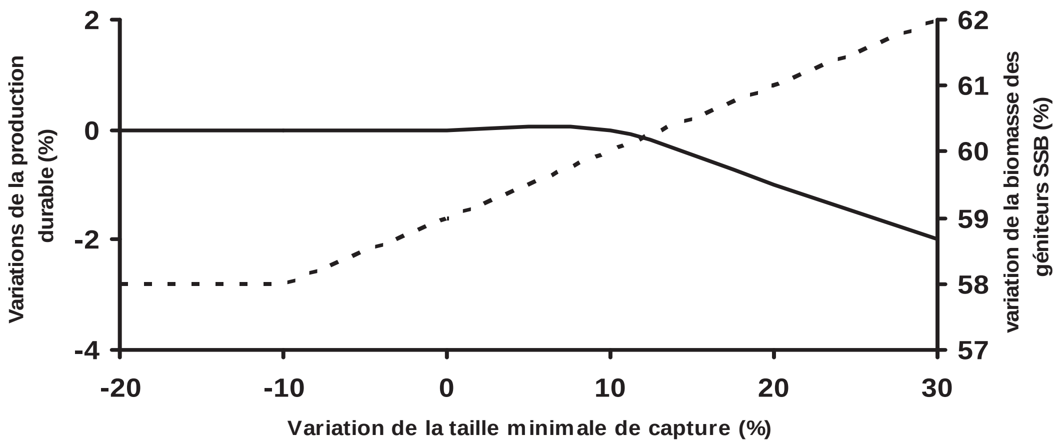


Figure 32. Variations of sustainable production and spawning biomass as a function of the size at first capture of *M. kerathurus* in the Gulf of Gabès, Tunisia. Dashed line = SSB; continuous line = production (Ben Meriem and Guirah, 2007).

Fisheries

In the MedSudMed region the most important *M. kerathurus* fisheries are located in the Gulf of Gabès. In this region, the caramota is caught by two fleet segments: artisanal and trawl fleet. Artisanal fishing is commonly known as coastal fishing using trammel nets with mesh sizes in the central part of 40 to 48 mm (stretched); and trawl fisheries using shrimp trawl gear (modified Mexican trawlers) with a mesh size of 36 mm at the codend. According to Ben Meriem and Gharbi (1988), shrimp is about 20% by weight and 65% by value of the landings of trawlers, being the main target species, while it does not exceed 2% (by weight) for coastal fisheries. A large number of fish species (especially sparidae) and cephalopods (mainly squid) forms the by-catch of the caramota fisheries. Fisheries in Sicily (Italy) and Libya (west coast) of this species are mainly conducted by gill and trammel nets (Vitale et al., 2010).
A test on the restocking trial of caramote prawns was carried out in the southwestern Sicilian coast from wild breeders. No significant effects were recorded. The number of specimens released was probably too low to allow for a lasting effect on the population; probably a higher number of nauplii must be released for a long period (over several years) to have an impact on the standing stock and fisheries in the area (Vitale et al., 2013).

Fishing zones and seasons
The most important *M. kerathurus* fisheries extend along the northern Mediterranean coast (FAO, 1987), in particular on west coast of Italy and Greece (Amvrakikos Gulf) and the northern Aegean Sea (Conides *et al*, 1990; Lumare and Scordella, 2001). The main fishing grounds in the southern Mediterranean are in the Gulf of Gabès, although other important fishing areas occur in western Libya. The majority of fisheries for this species are located in the coastal zone, generally not exceeding 50m depth. This species can be fished throughout the year but most is captured in spring-summer and feasibly also in autumn (Vitale et al., 2010).

Yield

Statistics on caramote production in the Mediterranean are fragmented over space and in time. According to FAO statistics, catches in the Mediterranean are as follows: 3,785 tonnes Tunisia, 1,459 tonnes Greece, 50 tonnes Spain, 18 tonnes Albania (FAO, 2000). More recently (FAO, 2008) indicates that catches of this species in 2006 reached 3,263 tonnes Greece, 2303 tonnes Tunisia, 546 tonnes Italy, 202 tonnes Spain, 102 tonnes Albania, and 1 ton France.

For the MedSudMed area, Tunisia captures a greater quantitiy of this species, fisheries are essentially carried out in the Gulf of Gabès (southern Tunisia).

Production of shellfish in the Gulf of Gabès area has fluctuated but the general trend over the last three decades is increasing (Figure 33).

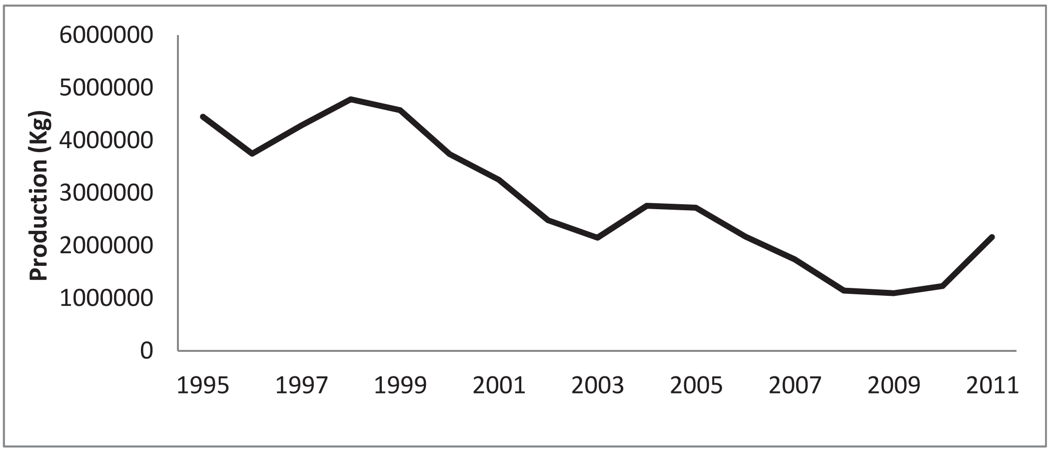


Figure 33. Evolution of reported shrimp capture production in the Gulf of Gabès, Tunisia (DGPA, 2011).

In Tunisia, crustaceans were exclusively represented by caramote (*M. kerathurus*) during the 1980s and until the mid-1990s. White shrimp, *Metapenaeus monoceros* (lessepsian species) appeared in the catches of crustaceans in the Gulf for the first time in 1995. In the following decade, during which statistics began for shrimp fisheries, an increase was demonstrated and it contributed to approximately 37% of crustaceans caught in the Gulf of Gabès (Figure 34).

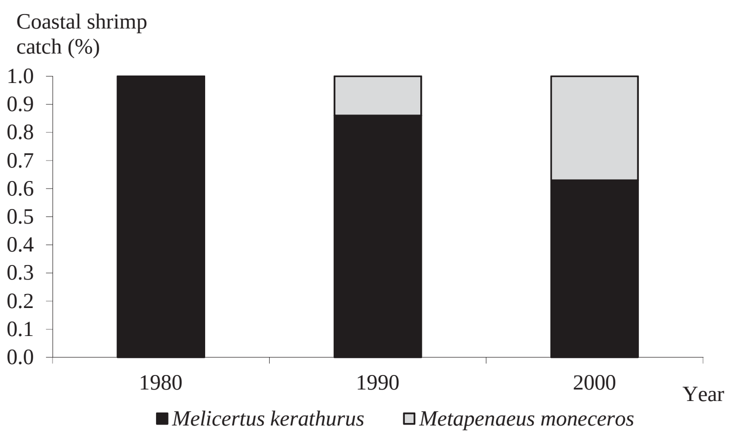


Figure 34. Changes of the specific composition of crustacean catches in the Gulf of Gabès area (DGPA, 2011).

Caramote is also caught in other regions of Tunisia, from north to south and, particularly, in the Gulf of Tunis. In this Gulf the amount of caramota caught remains very low, from a few dozen pounds to a few tons. This species is also caught in Libya but landings are weak and knowledge is poor (Daw, pers. comm.).

Fishing and discards
Fishing for caramota is carried out by the traditional Mediterranean-type bottom trawl with low vertical opening. This activity has grown substantially in Tunisia, in the Gulf of Gabès. In other parts of the fishing sector, there are smaller vessels using trammel and gill nets which operate in Tunisia, Libya and Italy (Sicily). To our knowledge, all catches are landed and marketed, discards are almost null.

Legislation and management

In Tunisia shrimp fishing activities are regulated by seasonal and spatial closure of fisheries. The seasonal fishing closure was introduced for the first time in 1951. Since then, several changes have followed concerning the delimitation of fishing zones, opening and closing dates of the season and so forth, in order to ensure a good yield, to safeguard certain areas and to avoid the capture of juveniles. In general, in the Gulf of Gabès, trawlers are subject to special spatial regulations, trawling is banned at depths below 50 m.

The first law of 1951 regulating shrimp fisheries in the Gulf of Gabès (Article 17 of the Decree of the Director of Public Works) authorises trawling in this area for shrimp between the 20 m isobath and the North-South meridian buoy No. 8, during the period from April 1st to September 30th of each year.
Three years later a new decree dated 02.17.1954, amended the old law as follows:
- The fishing season was set in two phases, the first starting from May 1st to September 30th, the second from December 1st to late February.
- The number of trawlers authorised to fish was reduced to 7 units of a total of 9 units.

In 1956, an amended Decree of the Ministry of the Economy (May 31st 1956) authorised shrimp fishery in the three pits (Chaffar, Skhira and Zarrat) and set a limit to the engine power of trawlers to 110 hp for the first time, each owner can only fit out one trawler for this type of fishing operation.

The Decree of the Ministry of Agriculture of 26th May 1973, assigned the annual organization of shrimp fishery in the Gulf to the Director of Fisheries. This decree was issued following the progressive and significant increase in the number of trawlers, and fixed the fishing period from 20th May to 31st August, moreover only trawlers with an engine power of 220 hp can participate.

Several orders and circulars came followed the amendment in 1973 modifying the period, the fishing areas and regulating the engine power of the vessels exploiting these new areas.

In 1974, the fishing season was split into two phases, the first from June 1st to August 31st and a second from September 15th to December 31st for this fishery in the following areas:

- The Gulf area which includes the three pits: Mahrès, Skhira and Zarrat;
- Zone of buoys n. 6, 7 and 8. Trawlers operating in the area should not have engine power in excess of 250 hp.

The 1975 Act amended the fishing periods and arranged for two seasons: a first period from 12th May to 15th August and from June 9th to August 15th for the Zarrat pit, and the second period from 15th September to 31st December. The engine power of trawlers allowed to fish in the Fora Mustpha was increased to 300 hp.

The decree of 16th April 1977 defined the following three fishing zones:

- Zone A: the fishing season in this area is scheduled from May 25th to August 15th each year. However, in the Zarrat pit, fishing is only permitted from June 15th of each year. Only trawlers with an engine power less than 220 hp are allowed to fish there.
- Zone B: including the area of buoys n. 6, 7 and 8 over a depth of 35m. This zone is operational during the same period and with the same trawler categories as zone A.
- Zone C: is the area of the Fora Mustapha pit over a depth of 40m. Trawling is allowed only in this area (Fora Mustapha) during the period of 15th October to 15th December and for all trawlers.

Trawling in the Zarrat pit has not been allowed since the end of 1982, this because of the fragility of this nursery area for fish and shrimp species. As part of this same step, the closure of the Skhira pit also took place in 1984.

The orders of 20th June 1992 and 28th September 1995 allowed shrimp fishery in a single three-month period from November 1st to January 31st. The permitted fishing zone covers the seabeds above 30m and is located west of the meridian passing through buoy n. 6 and north of latitude 33° 55' N. Vessels whose power exceeds 500 hp cannot participate in the fishery in the Fora Mustapha area beyond the 40m isobath.

The Ministerial Decree of 3rd June 1997 changed the organization of shrimp fisheries once more, spreading it over the period from June 1st to July 31st with the possibility of bringing the season forward by 15 days, and a second from 16th October to 15th November with possibility of extending this phase until November 30th. Moreover, the minimum depth allowed for trawl fisheries was set at 30 m.

The current regulations (Ministerial Decree of 19 December 2001) authorise caramota fisheries using towed nets beyond 30m in the Gulf of Gabes during two periods in the year, the first is a month and a half (from 15th May to 30th June) and the second of the same duration from 16th October to 30th November.

No specific regulations for caramote fisheries are in force for Italy and Malta and catch processes are regulated by the EU reg. 1967/2006 and other European and national rules on fisheries.

Metapenaeus monoceros (Fabricius, 1798)

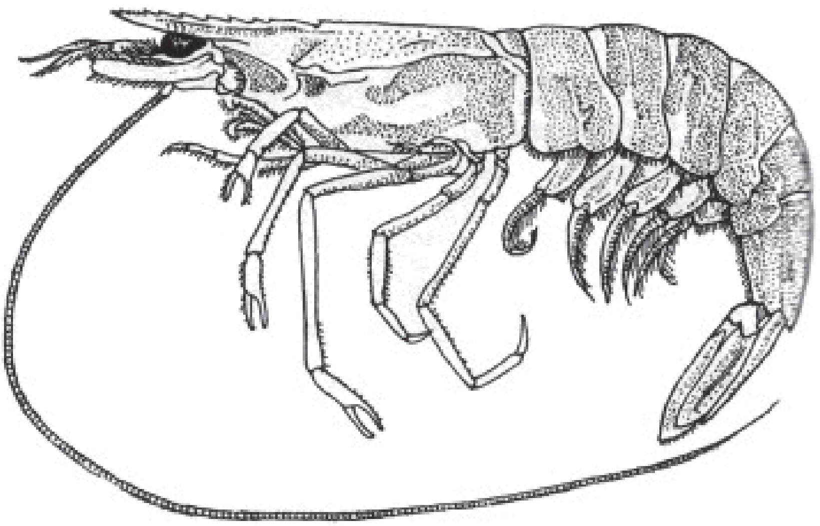


Figure 35. *Metapenaeus monoceros* (from Fischer *et al.*, 1987).

Species description
Metapenaeus monoceros (Speckled shrimp) belongs to the family Penaeidae. It is a medium size shrimp with maximum total length 15 cm for males and 19.5 cm females (Fischer et al., 1987). Generally, total length ranges from 1.05 to 13.5 cm. It has a pale grey with dark brown spots. The rostral and abdominal carenes are brown, the antennae red. The esoskeleton is covered with stiff. Pereopods and pleopods are of the same colour as the body, sometimes more vivid. The distal part of the uropods are purple blue, the outer edge of esopodites red. The rostrum is of the same length of the tip of antennular peduncle and has 9-12 teeth. The carapace has robust antennal and small hepatic spines. The ridge bounds a well-marked postantennular groove which meets cervical groove. The carina post-rostrum spans backward up to the posterior margin of the carapace. The body is pinkish, greyish green or whitish with brown spots. Rostral and abdominal carenes are brown, antennae red. The telson has lateral edges trimmed with tiny spines of the same size and culminate in a single sharp point.

Ecology

Geographical distribution
Metapenaeus monoceros was originally found in the Indo-West Pacific, along the African coast to the Red Sea and around India to the Bay of Bengal. It has migrated through the Suez Canal into the Eastern Mediterranean since 1927 [1924] (Balss, 1927), being recorded in Egypt, Syria, Lebanon, Turkey, Greece and Tunisia (Galil *et al.*, 2002; Holthuis, 1987).

Habitats

M. monoceros is a demersal species that lives in shallow water down to 60 meters, mostly between 10 and 30 meters. The species prefers sandy and sandy-mud bottoms. It is a euryhaline species which lives in brackish to marine salinities as low as 5 and up to 30‰. Juveniles are found in estuaries, lagoons or coastal areas, the adults further offshore. The species has high commercial value. It is important in some African countries like Mozambique, Kenya and Tanzania and it is one of the dominant species of Madagascar. It is also important in Somalia, the Gulf of Aden and the southern part of the Red Sea, as well as in most parts of India (especially Kerala and the Ganges Delta) and Pakistan. It is cultivated in rice fields in Bangladesh and India. Now, it is also trawled in the Eastern Mediterranean off the southern coast of Turkey, on the continental shelf off Palestine, off Alexandria, Egypt and off the southern coasts of Tunisia, Gulf of Gabès, (GSA 14) (Galil *et al.*, 2002; Missaoui and Zaouali, 1995; Holthuis, 1980; 1987).

Migrations

M. monoceros (Figure 35) shows a bathymetric distribution related to size: the smaller specimens are caught more frequently on the outer continental shelf (2-10m depth), whereas the larger ones are mainly distributed down to 50 m depth. Juveniles inhabit estuaries (Fisher and Bianchi, 1984; Wadie and Abdel Razek, 1985; Holthuis, 1987). The same bathymetrical pattern was also observed in the Gulf of Gabès (Ben Abdallah-Ben Hadj Hamida, 2012).

Biological information

Maximum size

The maximum size registered for *M. monoceros* in the Gulf of Gabès (GSA 14) is 178 mm total length (TL) for female (Ben Hadj Hamida-Ben Abdallah, 2012) and 160 mm for male (Ben Hadj Hamida-Ben Abdallah *et al.*, 2010).

Spawning

According to Serpil Yilmaz *et al.* (2009), in the Gulf of Antalya (Turkey, north levant Mediterranean, GSA 24), *M. monoceros* spawns, in December-January.
On the basis of the evolution of mature males by months, Ben Hadj Hamida-Ben Abdallah *et al.* (2010) reported that reproduction in the GSA 14 occurs all year round, although the highest percentage of mature males is found from May to December. They also reported that mature females occur twice per year with a first spawing period in spring (May-June) and a second more intense one in autumn (October-November).

Length at first maturity

In the GSA 14, length at 50% maturity was found 76.7 mm and 117.6 mm total length in males and females respectively (Ben Abdallah-Ben Hadj Hamida, 2012).
The length at first maturity in the GSA 24 was 75 mm TL for males and 115 mm for females (Serpil Yilmaz *et al.*, 2009).

Eggs, larvae and post larvae

The small amount information available on eggs and larvae is from the Indian Ocean.
Seasonal distribution of the larvae and post-larvae of *M. monoceros* of the Cochin area during the years 1966-67, 1967-68 and 1968-69 showed that annual fluctuations in the occurrence of the larvae and post-larvae of the species were very wide. A greater abundance of the larvae in the inshore waters during the year seems to indicate a good prawn fishery in the subsequent season. The larvae of the species are able to withstand a wide range in salinity (Rao, 1972).
Hassan (1983) studying the egg and larvae distribution of the species in the coasts of Pakistan, showed that increased larval abundance coincide with increasing temperature. Moreover, he indicated that abundance of larvae during summer is also correlated with increased production of phytoplankton and micro organisms. According to the same Author, there are also several other factors which presumably influence the abundance of the species eggs and larvae such as turbidity of sea water due to monsoonal turbulence that may facilitate survival and abundance of some larval stages.

Recruitment and nursery areas
Although no specific information on recruitment of this species is avaialble in literature it is generally thougth that *M. monocerus* recruits in very shallow waters.

Sex Ratio
In the Gulf of Gabès (GSA 14), the global sex ratio (SR), for *M. monoceros*, as number of females out of the total number of sexed specimens, was 0.6 (Ben Hadj Hamida-Ben Abdallah *et al.*, 2009). However, in the interval 70-100 mm (total length), the males prevail. Outside this interval, females are prevalent (Figure 36).
In the same area, the monthly evolution of the sex-ratio during the period between January 2007 and January 2008 shows that this parameter is always in favour of females. However, there are significant variations according to the months, especially in March, September and October (Ben Hadj Hamida-Ben Abdallah *et al.*, 2009).
In the Gulf of Antalya (GSA 24), Serpil Yilmaz *et al.* (2009) reported that females and males of this shrimp made up 0.72 and 0.28 respectively.

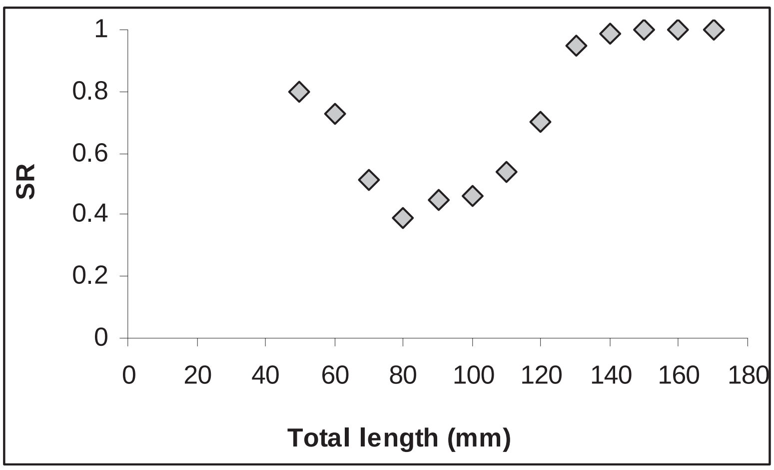


Figure 36. Sex ratio by size of *M. monoceros* in GSA 14 (Redrawn from Ben Hadj Hamida-Ben Abdallah *et al.*, 2009)

Length-weight relationships

The parameters of the length-weight relationships for *M. monocheros* are reported in Table 12. *M. monocheros* generally idsplays an isometric length-weight relationship in females and a positive allometric length-weight relationship in males.

Table 12. Parameters of the length-weight relationships of *M. monoceros* in GSAs 14 and 24.

Author	GSA	Sex	a	b	Period
		F+M	1.2788E-05	3.0508	
Ben Abdallah- Ben Hadj Hamida (2012)	14	F	6.5046E-06	3.0294	2005-2008
		M	5.7174E-06	2.8672	
Serpil Yilmaz *et al.* (2009)	24	F+M	0.1287	2.97	2002-2003
Becer Ozvarol *et al.* (2006)	24	F	0.1313	2..97	2002-2003
		M	0.2417	2.35	

Maximum age and natural mortality

According to Ben Hadj Hamida-Ben Abdallah *et al.* (2010), life span of *M. monoceros* in GSA 14 is 2 years, being the maximum age 2.2 years for females and 1.5 years for males.

The natural mortality (M) values, for this shrimp in the Gulf of Gabès (GSA 14) were estimated by Ben Abdallah- Ben Hadj Hamida (2012), on the basis of a comparison of results produced by different methods (Pauly, 1980; Rikhter and Efanov, 1976; Taylor, 1959; Cushing, 1968) varying between 1.73 year^{-1} in female and 2.74 year^{-1} in male.

An estimate of the M vector for *M. monoceros* by the Gislason *et al.* (2010) model was used in length cohort analysis by Ben Abdallah-Ben Hadj Hamida (2012) (Figure 37).

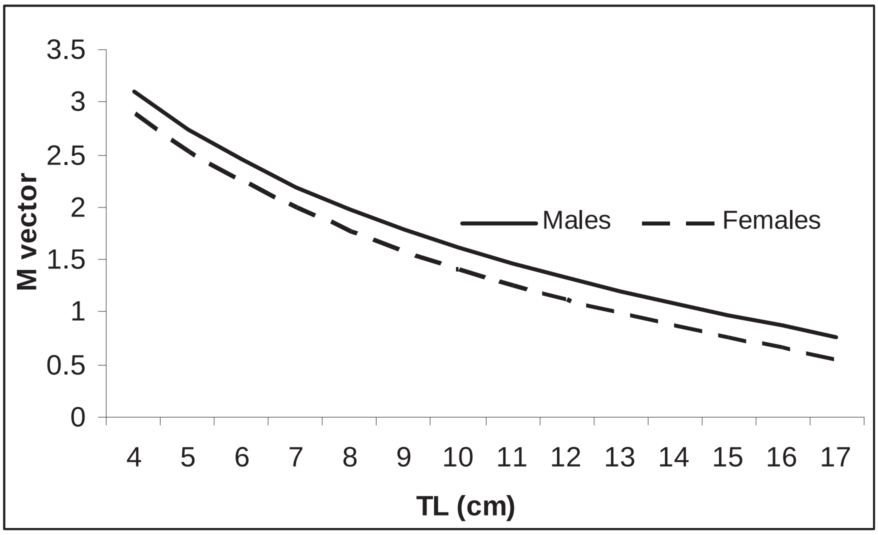


Figure 37. Vector of natural mortality for *M. monoceros* in the Gulf of Gabès estimated by the Gislason *et al.* (2010) model (Redrawn from Ben Hadj Hamida-Ben Abdallah *et al.*, 2009).

Von Bertalanffy growth function (VBGF)

The Von Bertalanffy growth function parameters, by sex available for the Gulf of Gabès area (GSA 14) are reported in the Table 13 (Ben Hadj Hamida-Ben Abdallah *et al.*, 2010).

Table 13. Von Bertalanffy growth function parameters of *M. monoceros* in GSA 14.

Author	GSA	Females			Males			Period
		L_∞	k	t_0	L_∞	k	t_0	
Ben Hadj Hamida-Ben Abdallah (2010)	14	19.33	1.36	0.04	16.96	2.02	0.01	2005-2008

Feeding behaviour
Working on stomach contents of *Metapenaeus monoceros* in the Gulf of Gabès, Tabka-Belkhodja (2004) noted the existence of crustaceans (amphipods and copepods), molluscs (cephalopods, bivalves and gastropods), Polycheata, sponge spicules, prickles of echinoderms, fish scales, foraminifera and plant debris. This author also demonstrated that the food spectrum of this species varies seasonally and according to size. In fact, in fall shrimp feeds mainly on plants and foraminifera as well as amphipods and copepods. In winter, the diet of this crustacean is composed largely of Polycheata beside amphipods and copepods. While in spring crustaceans, molluscs and Polycheata dominate the stomach contents of the species. According Tabka-Belkhodja (2004), smaller individuals feed mainly on copepods and shells while the biggest prefer amphipods, cephalopods, Polycheata and echinoderms.

Stock units
This species appeared in the Gulf of Gabès (GSA 14) in 1995. Although no information on stock structure of this species in the Mediterranean are available, the *M. monocerus* in the GSA 14 is assumed to be one stock unit.

Evaluation and exploitation

Biomass indices from trawl surveys
No information on the biomass indices of the species from trawl surveys is available.

Strength of recruitment
In 2007-2008, the mean number of recruits for *M. monoceros* in the Gulf of Gabès (GSA 14) estimated by Length Cohort Analysis was 102207802 (91.402 tones) for females and 93210120.72 (90.421 tons) for males (Ben Abdallah-Ben Hadj Hamida, 2012).

Stock assessment
Ben Abdallah-Ben Hadj Hamida (2012) assessed the speckled shrimp stock in GSA 14 by Length-Cohort and Yield-per-Recruit analyses of length–frequency distributions, by sex representative of *M. monoceros* landings in 2007-2008 (mean: 1006 tons). Regardless of the different value of natural mortality used, speckled shrimp appears to be overfished (Table 14). To reach Y/Rmax current F should be reduced by 67% for females and 68% for males. More severe reduction of current F is advisable if Y/R0.1 is chosen as a target reference point. Furthermore, the current SPR, calculated as current SSB/R excluding virgin SSB/R, was only 8-13%, suggesting overfishing especially on recruits. This low value is very far from the value currently considered as a limiting reference point (SPR about 20–40%) to avoid the reduction of recruitment in an exploited stock.

The results of pseudo-cohort analysis on *M. monoceros* showed that the average annual biomass of this species in the gulf of Gabès during 2007-2008 was estimated to be about 1148.9 tons and 2604 tons respectively for males and females. In this area, the individuals' total number was estimated to 260.8 million and 409.3 million respectively for the two sexes. Furthermore, the fishing mortality coefficients variation, as a function of size, shows that trawling primarily targets medium-sized individuals, while artisanal fishing is directed specifically towards large and medium size individuals (Figures 38 and 39).

Fisheries

M. monoceros is regularly caught by trammel nets in shallower waters (5-25 m) and by trawlers in a depth range of 30 to 50 m (Ben Hadj Hamida-Ben Abdallah *et al.*, 2009; 2010).

Table 14: Main results of length-cohort and Y/R analyses *M. monoceros* in GSA 14 (from Ben Abdallah-Ben Hadj Hamida, 2012). Recruitment is in millions of individuals, age is in years, total length (TL) is in centimetres, weight is in grams. *R* = recruit; *Y* = yield; *M* = natural mortality; *F* = fishing mortality; *SSB* = spawning stock biomass; *SPR* = spawning potential ratio.

Parameter	Vectorial M	
	Females	Males
Recruits at 5 cm TL (in millions)	102.207	93.210
Mean Z	0.632	0.972
Mean F	0.546	0.856
Exploited critical age	7.319	5.2
Virgin critical age	15.433	8.487
Exploited critical length (TL)	11	10
Virgin critical length (TL)	16	13
Current Y/R (in grams)	5.708	4.536
Y/R_{max}	6.536	5.043
$Y/R_{0.1}$	6.194	4.761
Current SSB/R	8.433	8.674
Virgin SSB/R	105.495	67.124
Current SPR	0.08	0.13
Factor per Y/R_{max}	0.33	0.32
Factor per $Y/R_{0.1}$	0.19	0.18

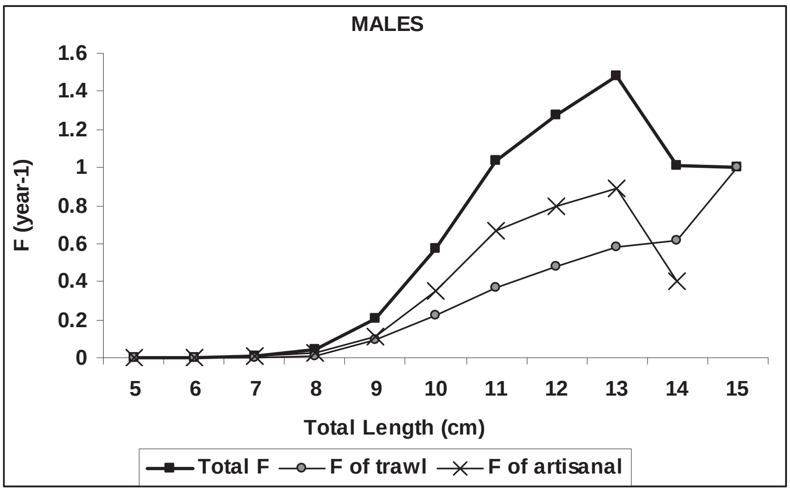


Figure 38. Fishing mortality variation regarding total length of *M. monoceros* males in GSA 14 (Redrawn from Ben Abdallah-Ben Hadj Hamida, 2012)

Fishing zones and seasons

In Tunisian waters, *M. monoceros* is only encountered in the south-eastern coasts represented by the Gulf of Gabès (Ben Hadj Hamida-Ben Abdallah *et al*., 2009; 2010).

In this area, trawling for shrimp fishing is authorized each year, at depths greater than 30 metres during two periods of a month and a half each; the first from 15th May to 30 th June and the second from 16 th October to 30 th November. Shrimp fishing by trammel nets goes from April to August, coinciding with the summer during which climatic conditions and abundance of shrimp foster good yields. During this period, the activity of the fleet is not regular. It is conditioned by the strength of tidal currents that can tilt the threads on the bottom. No information is available for Libyan coast.

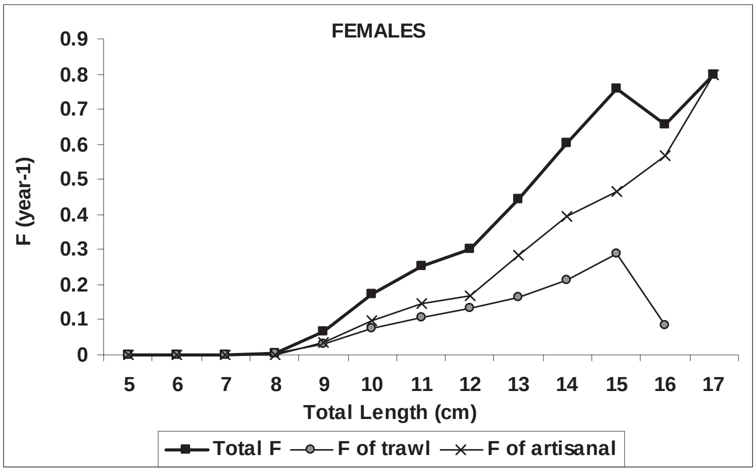


Figure 39. Fishing mortality variation regarding total length of *M. monoceros* females in GSA 14 (Redrawn from Ben Abdallah-Ben Hadj Hamida, 2012)

Yield

Since its appearance in 1994, the speckled shrimp *Metapenaeus monoceros* has been exploited in the Gulf of Gabès (GSA 14) by trawlers as well as artisanal fishery units. Over the years, this species has increasingly been landed at the main ports of the southern part of Tunisia. Production has also fluctuated significantly.

During the first five years after its appearance in the GSA 14, the speckled shrimp yield was low and did not exceed 200 tons. Since 1999, yield has increased considerably to reach a first peak in 2000 with more than 2484 tons. The contributions of this species have declined then during 2001 (770 tonnes). In 2002, the yield of *M. monoceros* recovered and rose again to record a maximum of more than 2557 tonnes in 2004. Over the last five years, the contribution of the species has declined significantly until 2008 when it was at its lowest since the onset of the shrimp in the Gulf of Gabès (Figure 40).

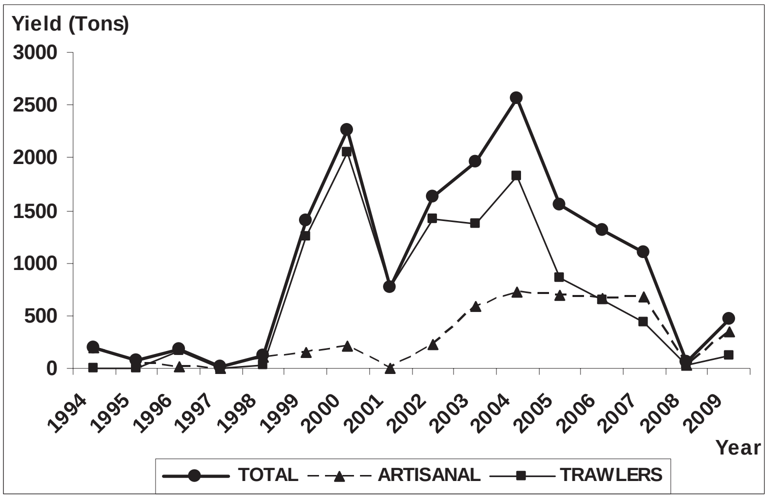


Figure 40. Total, artisanal fishery and trawlers yield of *M. monoceros* in GSA 14 from 1994 to 2009 (Redrawn from Ben Abdallah-Ben Hadj Hamida, 2012).

The landings from benthic trawling are larger than the contributions of artisanal fishery. Indeed, the first units contribute, on average, about 70% of the total yield of the species.
For all the fleets, the most important landings of *M. monoceros* in the Gulf of Gabès are recorded in the main ports of the governorate of Sfax (Figure 41).

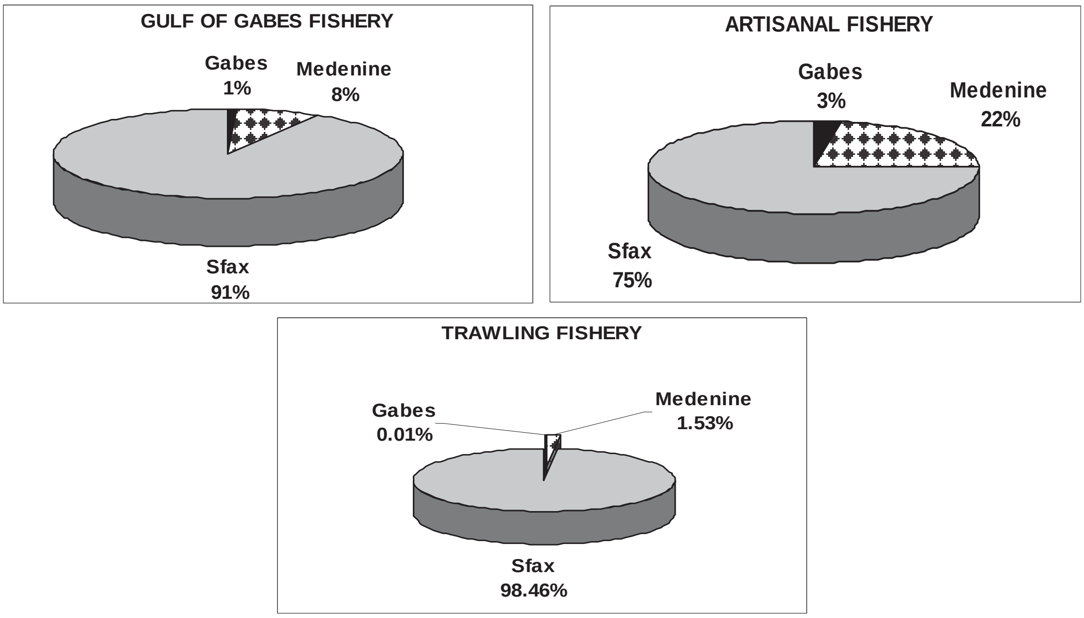


Figure 41. Contribution of the main fleets in the governorates of Sfax, Gabès and Medenine to the yield of *M. monoceros* in 1994-2009 (Redrawn from Ben Abdallah-Ben Hadj Hamida, 2012).

Fishing and discards
M. monoceros is generally fished together with *Melicertus kerathurus* (Caramote prawn), *Sepia officinalis* (Common cuttlefish), *Diplodus annularis* (Annular seabream), *Mullus barbatus* (Red mullet), *Lithognathus mormyrus* (Striped seabream) and *Solea sp.*

The landings of this species by the banned gear called ‘kiss’ or mini-trawl, which operates in very low depths (10-20 m), are usually accompanied by significant quantities of discards.

Gears

The speckled *M. monoceros* exploitation in the Gulf of Gabès is carried out by two types of fishing: coastal or artisanal fishery (using trammel nets) and benthic trawling (using the shrimp bottom trawl). Moreover, it should be noted that this species is also landed in significant quantities by fishing units through illegal gear called mini-trawl or ‘kiss’. However, the contributions of these units are not reported in the fishery statistics.

Bottom trawling for shrimp, essentially in the southern region of Tunisia (Gulf of Gabès), is carried out with netting with a small mesh size (from 48 mm in the wings to 40 mm in the cod-end). The average vertical mouth opening is 2 m.

Trammel wire 40 000 (40 000 mesh / kg) is used in southern Tunisia for shrimp fishery and is composed of three layers of netting. The middle layer presents a mesh size of about 22 to 24 mm and a low hanging ratio which is less than 0.5 for some slack that promotes capture. The two other layers are in turn stretched mesh 5 to 7 times greater than that of the previous one.

Legislation and management

No legislation or management measures concerning the speckled shrimp *M. monoceros* fishery in the Gulf of Gabès.

However, this species is generally captured in association with the caramote prawn *M. kerathurus* of which fishing activities are regulated by the law of September 28th 1995. This regulation only allows trawling for shrimp at depths greater than 30 meters during two periods:

- From 15th May to 30th June
- From 16th October to 30th November.

Outside these two periods trawling activities are authorised in the area beyond 50m depth.

An historical excursus of the regulations on shrimp fisheries in the GSA 14 is reported in the chapter on *M. kerathurus*.

Nephrops norvegicus (Linnaeus, 1758)

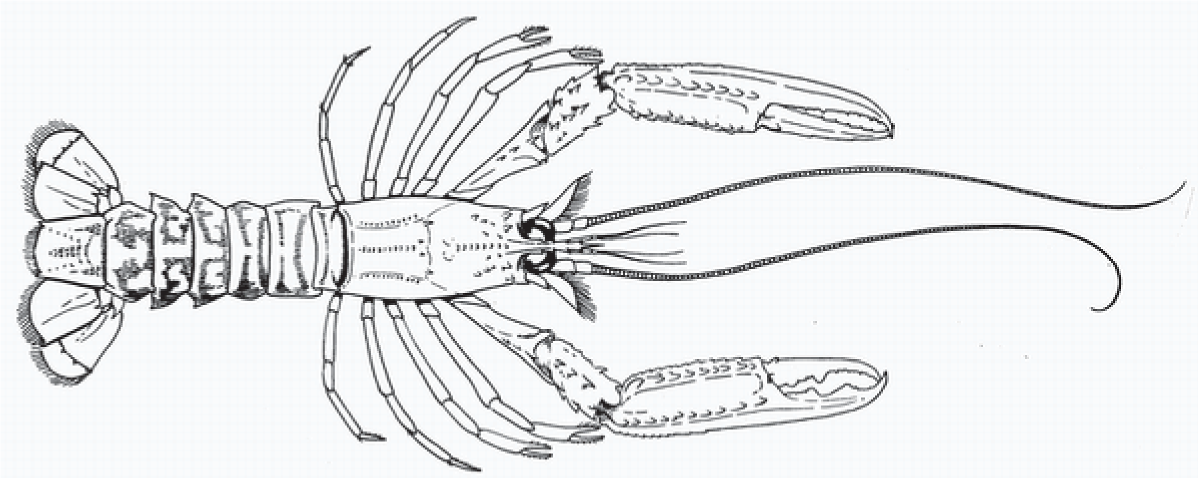


Figure 42. *Nephrops norvegicus* (from Fischer *et al.*, 1987).

Species Description

Norway lobster (Figure 42), *Nephrops norvegicus* (Linnaeus, 1758), also called Dublin Bay prawn, langoustine or Scampo, is a slim orange-pink lobster up to 24 cm (TL) long. The body is long, robust and more or less flat laterally. The head and thorax have a non-segmented cover (the carapace) while the long abdomen is clearly segmented with a broad fan-like tail. The first pair of cephalic appendices has composite eyes, each with a mobile peduncule. The first pair of antennae is short and forked, while the second pair much longer and thinner than the first. The first pair of legs is well developed with strong chelae. The second and third are thinner and bear claws (Relini *et al.*, 1999).

Ecology

Geographical distribution

Norway lobster is a commercially important benthic decapod crustacean commonly found in northeastern Atlantic waters from the coast of Iceland to Morocco and in the Mediterranean Sea (d'Udekem d'Acoz, 1999). Its depth range extends from 15 to 800 m, although it is typically found on the northeastern Atlantic shelf at depths between 300 and 600 m (Tuck *et al.*, 1997) and beween 200 and 800 m in the Mediterranean (Maynou and Sarda`, 1997) (Figure 43).

Figure 43**.** Distribution of *Nephrops norvegicus* in the Mediterranean Sea and north-east Atlantic Ocean (from Fishbase.com).

Habitats

Nephrops norvegicus is generally found sublittorally in soft sediment, commonly at depths range of 200-800 m, although considerable populations exist at depths <200 m, for example in the Adriatic Sea. There are many records of *Nephrops norvegicus* populations <20 m in Scottish Sea Lochs. They live in shallow burrows and are common on grounds with fine cohesive mud which is stable enough to support their unlined burrows. In the Mediterranean Sea its bathymetric distribution ranges from the continental shelf to bathyal grounds, reaching depths of 871 m in the western Mediterranean (Abelló *et al.*, 1988); however maximal densities are found between 245 and 485 m (Cartes *et al.*, 1994).

Migrations

Norway lobsters are considered good walkers; however they do not seem to be good swimmers. Although, Hammond and Naylor (1977) have presented qualitative evidence that the nocturnal activity peak appears to be synchronized by falling light intensity at dusk, no clear migration patterns have been described for *N. norvegicus*.

Feeding behavior

N. norvegicus is known as an euryphagous and non-selective species, consuming a great variety of crustaceans, fish and molluscs, either as an active predator or scavenger (Loo *et al.*, 1993). Cristo and Cartes (1998) in *N. norvegicus* stomach contents found about 119 prey-categories: small pieces of crustacean carapace, bivalve and gastropod shells, fish vertebrae and otoliths and other hard and soft parts of prey.

Biological Information

Maximum size

Nephrops norvegicus is a species with separate sexes, with males, on average, larger than females (Table 15). Relini *et al.* (1999) stated that its maximal total length is 24 cm, and 75 mm carapace length. However larger specimens have been caught, primarily in the northern Adriatic. Crnković (1965), for example, found specimens up to 26.5 cm TL in northern Adriatic channels. Mytilineou *et al.* (1998) in a comparative study among different areas in the Mediterranean Sea and the adjacent Atlantic listed maximum carapace length (mm) of *Nephrops* specimens in several Mediterranean areas for each sex separately. In the Strait of Sicily (GSA 16) data obtained in the MEDITS trawl surveys from 2008 and 2012 show the largest specimens ranging from 59 to 70 mm (CL) for males and from 47 to 49 mm (CL) for females.

Table 15. Maximum carapace length (mm) by sex of *Nephrops norvegicus* specimens in the Mediterranean region.

Author	Area	Males	Females
Mytilineou *et al.* (1998)	Atlantic	63	50
Mytilineou *et al.* (1998)	GSA 2 - Alboran Island	60	48
Mytilineou *et al.* (1998)	GSA 6 – Northern Spain (Catalan Sea)	79	66
Mytilineou *et al.* (1998)	GSA 9 - Ligurian and North Tyrrhenian Sea	63	55
Mytilineou *et al.* (1998)	GSA 10 - South Tyrrhenian Sea	75	60
Mytilineou *et al.* (1998)	GSA 17 – Northern Adriatic Sea	65	54
Ragonese *et al.* (2004)	GSA 16 - South of Sicily	70	49

Spawning areas

The periods of hatching and spawning, and the length of the incubation period, vary with latitude and the breeding cycle changes from annual to biennial moving from south to north (Bell *et al.*, 2006). Incubation of eggs is temperature-dependent, and in colder climates, the duration of the incubation period increases (Bailey 1984). In all areas reproduction showed clear seasonality both in terms of ovarian maturation and the brooding period.

In the Adriatic Sea, *N. norvegicus* spawns once a year (Froglia and Gramitto, 1981).

The Norway lobster females in the Strait of Sicily undergo ovary ripening mainly in spring and spawn in summer-autumn. Orsi Relini *et al.* (1998) gave an overal picture of the reproductive pattern of Norway lobster from different Mediterranean areas. The proportion of females bearing a mature ovary peaks in spring or at the beginning of summer.

The highest values were found in June in the Gulf of Euboikos, in June and July in the Adriatic, in July in the Ligurian and Tyrrhenian Seas, in April, June and July in the Catalan Sea, in June and May- August in the Alboran Sea and in May and June in the Algarve Sea.

The presence of berried females shows a seasonal trend characterized by summer and autumn peaks The highest values were registered in July and December in the Gulf of Euboikos, in October and November in the Adriatic, in September-November in the Ligurian and Tyrrhenian Seas, in August and December in the Catalan Sea, in September-October and December in the Alboran Sea and in September and December or January in the Algarve Sea.

Persistent spawning areas have been identified in the southeast sector of the Strait, next the extreme south border of GSA 16 (GSA15+16) and the south border of GSA15 (GSA15+16) (Garofalo *et al.*, 2011) (Figure 44). However, there is also evidence of concentration areas of spawners, although not very persistent ones, in the bathyial basin to the northwest of Malta and to the west of the Adventure Bank, (the latter co- occurrent with a nursery ground) (Garofalo *et al.*, 2011).

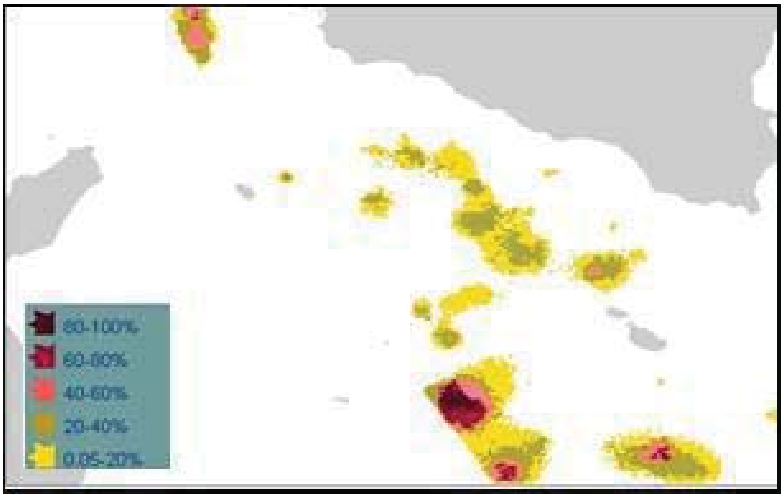


Figure 44. Main spawning areas in GSAs 15 and 16, south-central Mediterranean (Colloca *et al.*, 2013).

Recruitment and nursery areas
Recruitment of *N. norvegicus* occurs more or less continuously in the Strait of Sicily even though a stronger recruitment pulse is detected in autumn. The mean size of the first Gaussian component in length structure (about 22 mm CL) is well below the estimated size at 50% maturity, suggesting a precocious recruitment to the fishery (Figure 45).

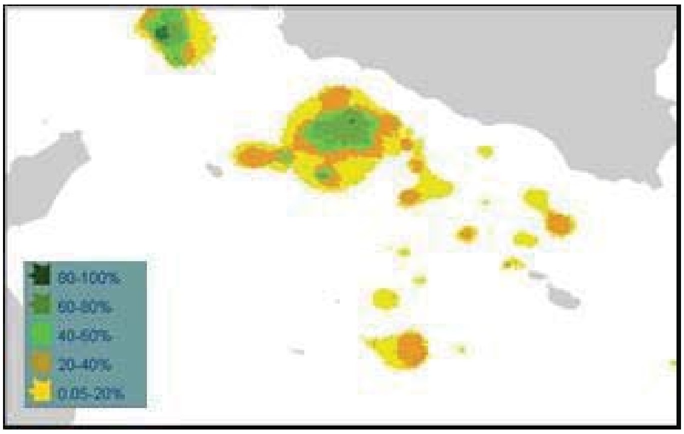


Figure 45. Main nursery areas in GSAs 15 and 16, south-central Mediterranean (Colloca et al., 2013).

Recruits of Norway lobster in the Strait of Sicily are mainly distributed on muddy bottoms of the upper slope between 250 and 500 m depth. Persistency analysis of density hotspots shows the presence of two large nurseries located in the northwest sector of the Strait of Sicily, to the west (GSA15 and 16) as well as to the east (GSA15 and 16) of the Adventure Bank at about 300-450 m depth (Garofalo *et al.* 2011). No stable recruitment area is identified in the easternmost part of the Strait, although high concentrations of immature specimens, located to the North of Gozo and to the south/southwest of Malta, have been described in a previous study (Knittweis and Dimech, 2011).

Length at first sexual maturity

Orsi Relini *et al.*, (1998) estimated that lobster females in the Mediterranean are able to spawn very precociously (18-29 mm CL), at two or three years old. Moreover, Norway lobster females spawning size seems linked to the geographical area with variations along the latitudinal gradient; minimum spawning size is lower in the Atlantic (18-20 mm CL: Symonds, 1972), the Adriatic (18-22 mm: Froglia and Gramitto, 1988) than in the Northern Mediterranean Sea (29 mm: Orsi Relini and Relini, 1989; Campillo *et al.*, 1991). Orsi Relini *et al.* (1998) reported these differences among seven areas in the Central Mediterranean Sea and in the Atlantic. In Table 16 carapace length of the smallest female in advanced maturation, smallest berried individuals and 50% maturity size in each area are reported.

Table 16. Carapace length of smallest females in advanced maturation, smallest berried individuals, length at 50% maturity and mean number of egg per female in each area. Redraw by Orsi Relini *et al.* (1998).

GSA/AREA	Smallest female in advanced maturation	Smallest Ovigerous	Length at 50% maturity	Mean number of eggs for berried female
Atlantic Ocean	25 mm	24 mm	30mm	1300
GSA 2 - Alboran Island	30 mm	30 mm	36 mm	2200
GSA 6 – Northern Spain, Catalan Sea	24 mm	27 mm	30 mm	530
GSA 9 - Ligurian and Northern Tyrrhenian Sea	29 mm	27 mm	32 mm	2070
GSA 10 – South Tyrrhenian Sea	27 mm	27 mm	32 mm	1110
GSA 17 – Northern Adriatic Sea	25 mm	24 mm	30 mm	1110
Euboikos Gulf	19 mm	23 mm	33 mm	1550

At GSA 16 minimum spawning size of Norway lobster females resulted higher than that described for the other basins, ranging from 30 to 32 mm (CL) (Ragonese *et al.*, 2004). The trend in length at 50% maturity of female in GSA 16 derived from MEDITS trawl survey data is reported in Figure 46. A clear decreasing trend is evident for the analysed time series.

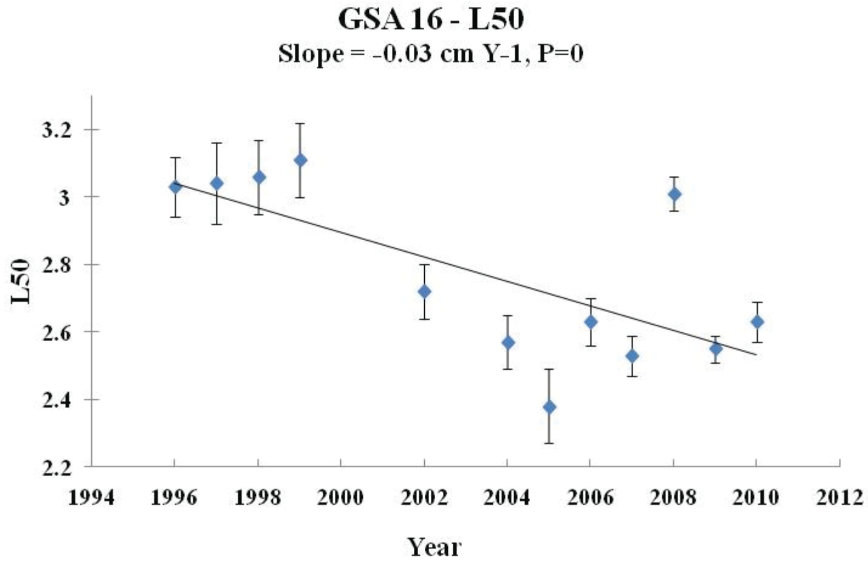


Figure 46. Length at first sexual maturity (L_{50} in cm of Carapace Length) in GSA 16 from 1996 to 2010.

Eggs, larvae and post-larvae

Information on eggs and larvae of *N. norvegicus* in the Mediterranean Sea are rare or insufficient. However, Relini *et al.* (1999) reported the presence of Norway lobster larvae in the Adriatic plankton from January to April.

Sex Ratio

Usually the *N. norvegicus* sex ratio fluctuates around 1:1 also comparing different and very distant geographical areas (Sardà *et al.*, 1998). However, several Authors described a significant change through the year. This oscillation depends on the mating period (Froglia and Gramitto, 1981; Ungaro *et al.*, 1999) and bon the minor female activity, when they carry external eggs.

In GSA 16, the sex ratio derived from the MEDITS Trawl Surveys from 1994 to 2012 remained stable and close to 0.5 (Figure 47).

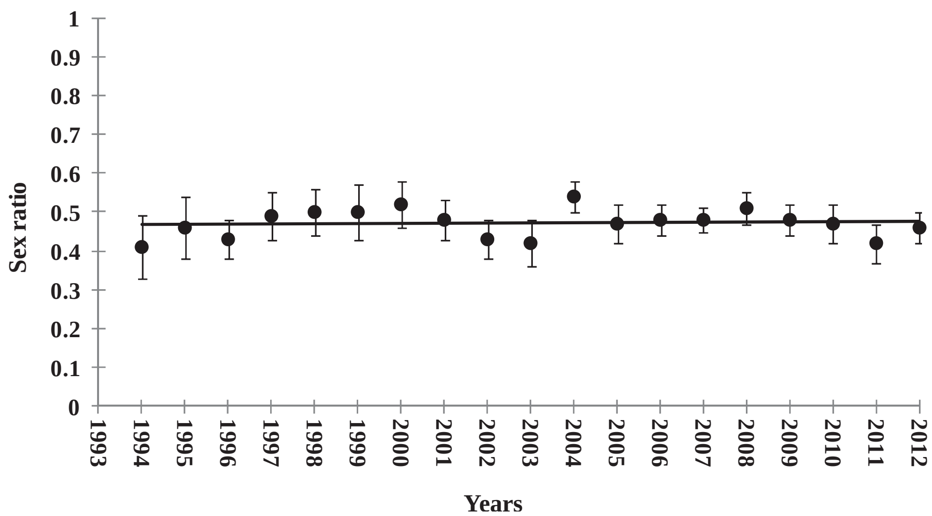


Figure 47. Sex ratio of *N. norvegicus* in GSA 16, calculated as the ratio of the number of females to the total number of sexed individuals, from MEDITS Trawl Survey data.

Length–weight relationship

Ragonese *et al.* (2004) calculated the length–weight relationship for *N. norvegicus* in GSA 16 using the standard allometric model (Table 17).

Table 17. Length–weight relationship (total weight = a carapace length^b) parameters calculated on the GSA 16 population (To be verified. Posible errors were found in Ragonese *et al.*, 2004).

Parameter	Females	Males
a	0.00044	0.000424
b	3.133	3.158

Natural mortality

Natural mortality estimated for the two sexes combined in the GSA 16 is 0.20 (Ragonese *et al*., 2004).

Von Bertalanffy Growth Function (VBGF).

There are some differences in growth parameters between males and females. Males grow larger than females. Differences in growth were also observed; these differences were related to differences in density among settlements in different parts of the Adriatic (Marano *et al.*, 1998; Froglia and Gramitto, 1988). They are the result of differences in ecological conditions, however, the methods used in calculating the parameters might influence the growth parameter estimates. A synthesis of VBGF parameters available in the Mediterranean is reported in Table 18.

According to Mytilineou *et al.* (1998), the the growth parameters obtained for different areas of Mediterranean and adjacent Atlantic Ocean areas showed differences which could not be considered very important except in the case of the *Nephrops* population of the Alboran Sea, which was characterised by a high growth rate. All other areas seemed to be close; among them the populations from Euboikos Gulf and Catalan Sea being the most different.

Stock Units

No information on stock units of Norwey lobster in the Mediterranean are available.

Evaluation and exploitation

Biomass and density indices from trawl surveys

Density and biomass indices calculated for the *N. norvegicus* stock in the GSA 16 (Medits Trawl survey) since 1994 show a clear increasing (Figures 48 and 49). The positive trend, in particular, is evident in the period 2003 – 2012 when the biomass increase from about 1 Kg/Km^2 to 10 Kg/Km^2 and the abundance increase from about 150 n/Km^2 to about 300 n/Km^2.

Table 18. Growth parameters of *N. norvegicus* according to the VBGF. Lengths refer to carapace length; Time unit = year; F = females, M = males; Unsex = unsexed; Bhattac. = Bhattacharia; * = total length.

Author	**GSA**	**Area**	**Method**	**Sex**	**L∞ (mm)**	**K (yr^{-1})**	**t0 (yr)**	**Φ'**
Froglia and Gramitto (1988)	17	-	NORMSEP	M	226*	0.036	-1.70	10.00
				F	230*	0.044	1.48	10.24
		Pomo Jabuka Pit		M	200*	0.027	-1.91	9.47
				F	140*	0.044	-0.03	9.25
IMBC et al. (1994)	17	Ancona	MULTIFAN	M	56.6	0.426	-	7.22
				F	-	-	-	-
			MIX	M	63.5	0.327	-0.13	7.18
				F	55.4	0.361	-0.18	7.01
	17	NW Ancona	MIX	M	82.5	0.325	0.28	7.70
				F	59.5	0.450	0.06	7.37
	17	Pomo Jabuka Pit	MULTIFAN	M	43.4	0.382	-	6.58
				F	43.2	0.437	-	6.70
			MIX	M	55.9	0.229	-0.56	6.57
				F	36.0	0.498	-0.27	6.47
Marano et al. (1998)	18	SW Adriatic	BHATTACH.	M+F	65.0	0.140	-	6.38
				M	67.3	0.140	-	6.45
			SURF AND SHEPER	M+F	79.6	0.210	-	7.19
				M	77.6	0.170	-	6.93
Sardà et al. (1998)	17	off Ancona	-	M	81.5	0.110	-0.95	6.59
				F	67.0	0.140	-0.88	6.44
Maiorano et al. (2010)	19	NW Ionian Sea	LFA	M	79.7	0.200	-	
				F	58.0	0.250	-	
Guijarro et al. (2010)	09	Ligurian and NTyrrhenian Sea	LCA	M	72.1	0.169	-	
				F	56.0	0.214	-	
Ligas et al. (2011)	09	Ligurian and NTyrrhenian Sea	LCA	M	72.1	0.170	0.00	
				F	56.0	0.210	0.00	
				F+M	74.0	0.170	0.00	
				Unsex.	74.0	0.170	0.00	
Ragonese et al. (2011)	16	Strait of Sicily	VBGF	M	62.0	0.130	0.50	
				F	53.0	0.140	0.50	

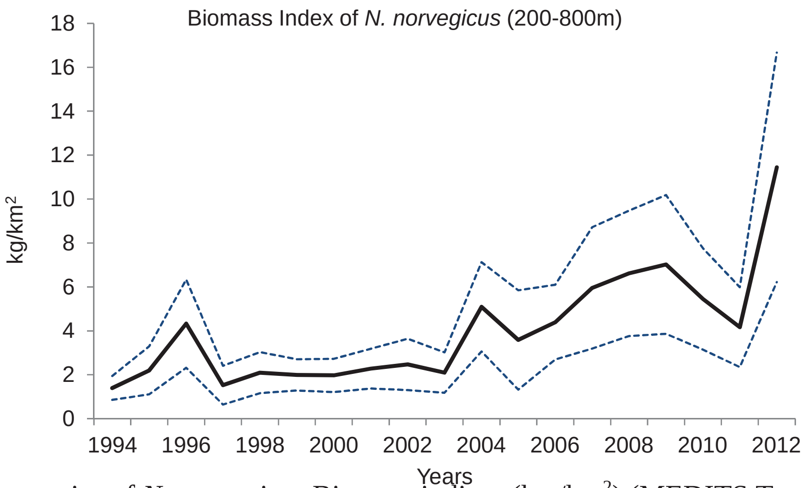


Figure 48. Time-series of *N. norvegicus* Biomass indices (kg /km^2) (MEDITS Trawl Surveys; 10–800 m depth range) in GSAs 16.

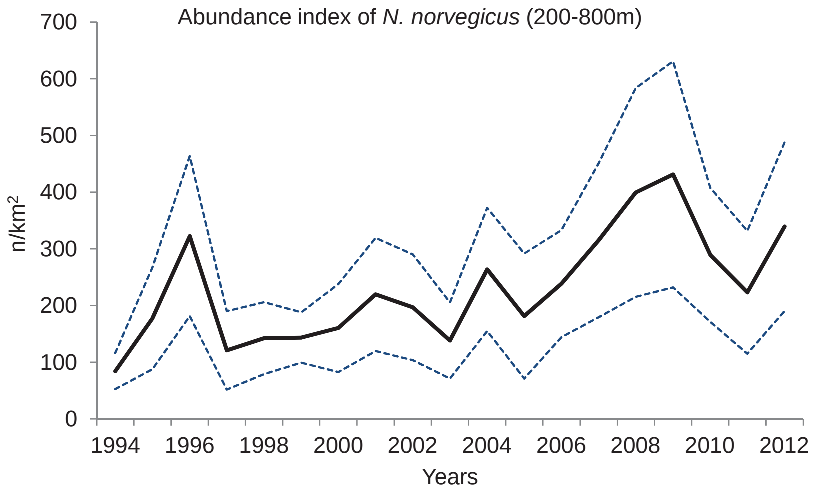


Figure 49. Time-series of *N. norvegicus* Abundance indices (kg /km^2) (MEDITS Trawl Surveys; 10–800 m depth range) in GSA 16.

The Medits trend for adults Norway lobster in GSA 16 shows a clear increasing trend since 2000 ranging from about 20 individuals per square kilometer in 2002 to about 60 specimens per square kilometer in 2012 (Figure 50). On the contrary any specific trend can be observed for juveniles (Figure 51) (STECF EWG 13-09).

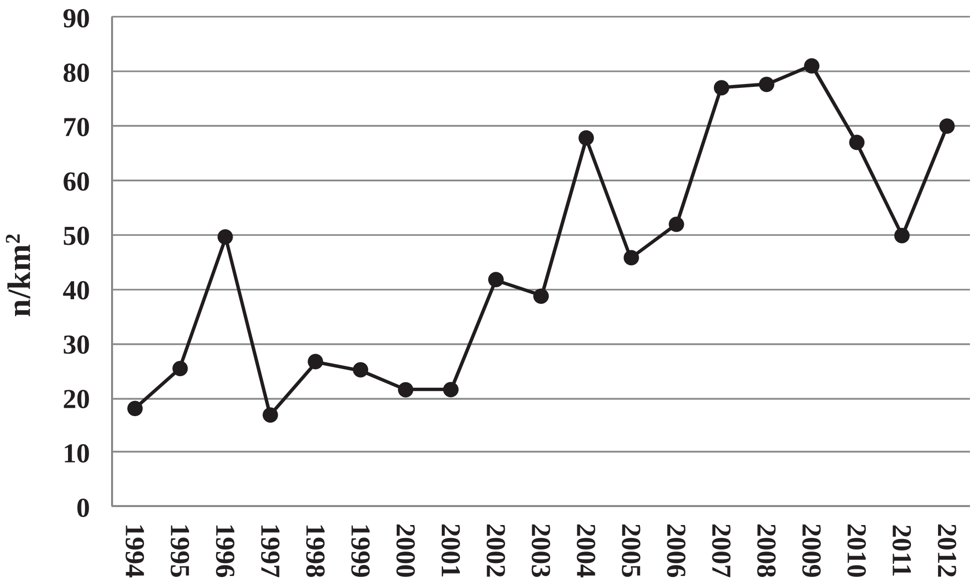


Figure 50. Abundance indices of Norway lobster adults (ages 4-8+) in GSA 16.

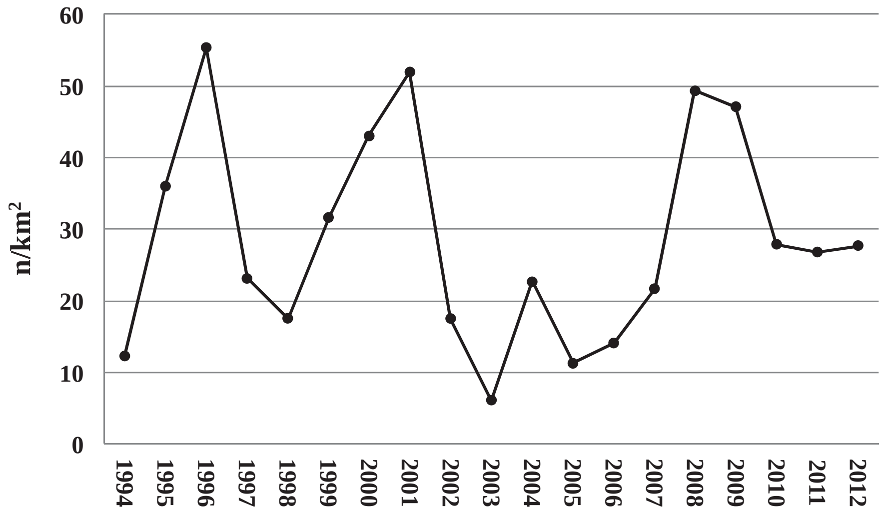


Figure 51. Abundance indices of Norway lobster juveniles (ages 1-2) in GSA 16.

Stock assessment

Assessment of historic stock parameters

A stock assessment of Norway lobster was carried out by applying an eXtended Survival Analysis (XSA) to the annual landings data of the GSAs 16 and 15 (Malta) for the period 2002 – 2012. The assessment was calibrated using MEDITS survey data collected in the same period (STECF EWG 13-09). The growth parameters for the two sexes combined were $L\infty=72.1$, $K=0.17$, $t0=0$ and the length-weight relationships parameters were $a = 0.000373$, $b = 3.1576$. The vector of mortality and maturity at age were reported in Table 19.

Table 19. Natural mortality (M) vector used for the stock assessment of *N. norvegicus* for GSAs 15 and 16 combined.

Age class	M	Proportion of mature individuals
1	0.54	0.01
2	0.41	0.16
3	0.35	0.40
4	0.32	0.70
5	0.30	0.86
6	0.29	0.94
7	0.28	1.00
8	0.27	1.00

In the period 2002-2012, the SSB ranged between about 690 and 960 t. In the same period recruitment at age 1 fluctuated widely between 37.7 and 93.3 million (Table 5). XSA estimates of $Fbar_{2-7}$ showed a declining temporal trend from 0.89 in 2003 to 0.42 in 2012 (Table 20).

Table 20. Spawning stock biomass (SSB), recruitment and Fbar estimates by XSA for Norway lobster in GSA 15 and 16 from 2006 to 2011.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
SSB (tons)	795.3	875.75	710.22	694.57	857.84	926.21	964.8	944.5	791.7	788.86	773.77
Recruitment (millions)	37.781	56.934	86.337	93.391	84.656	65.004	60.5	77.642	84.391	72.266	74.866
Fbar$_{(2\text{-}7)}$	**0.52**	**0.89**	**0.63**	**0.63**	**0.69**	**0.62**	**0.57**	**0.77**	**0.62**	**0.66**	**0.42**

According to the statistical catch at age (SCA) as implemented in the a4a package gave a SSB ranged between about 860 and 1892 t 146.5.3 million (Table 20). The a4a estimates of Fbar$_{2\text{-}7}$ ranged between 0.15 (2012) and 0.65 (2003) (Table 21).

Table 21. Spawning stock biomass (SSB), recruitment and Fbar estimates by SCA for Norway lobster in GSA 15 and 16 from 2006 to 2011.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
SSB (tons)	990.9	1117.5	860	913.2	1026.2	1071.9	1180.1	1309.1	1151	1400.7	1892.4
Recruitment age 1 (millions)	56.178	61.146	79.374	73.29	78.717	76.003	72.141	87.502	146.46	230.332	22.383
Fbar$_{(2\text{-}7)}$	**0.36**	**0.65**	**0.41**	**0.37**	**0.43**	**0.4**	**0.36**	**0.52**	**0.32**	**0.29**	**0.15**

Long term prediction

Reference F for the Yield per recruit (YPR) analysis was estimated using 1 to 8+ years age classes using the FLR routine based on the exploitation pattern estimated by the statistical catch at age. F_{01} was estimated to be 0.20 (STECF EWG 13-09).

Scientific advice

The final advice of STECF EWG 13-09 has been based on the results of the statistical catch at age (SCA) carried out using the a4a package. The SCA was considered as more suitable in assessing F in the more recent years than the XSA also considering its flexible parameterization of selectivity-at-age. SCA, compared with XSA, returned a lower (30-60%) estimate of F_{bar} combined with higher and apparently, more reliable, estimates of SSB.

State of the spawning stock size

In the period 2002-2012 the SSB, as reconstructed by SCA, showed an increases from 990 t to about 1.892 t in 2012. Recruitment at age 1 varied between 60.5 and 85.4 million in the period 2002-2011 showing an abrupt decline to 19.3 million in 2012 (STECF EWG 13-09).

Management recommendations

STECF EWG 13-09 proposes F0.1 ≤ 0.20 as a limit management reference point consistent with high long term yields (F_{MSY} proxy) for the Norway lobster stock in GSas 15 and 16. Based on the F_{cur} estimated by the statistical catch at age (a4a assessment), the stock was exploited unsustainably in the period 2002-2011. The estimated F_{cur} was however below

F_{MSY} in 2012 indicating that in this year the stock was exploited sustainably. EWG 13-09 recommends the relevant fleets' effort or catches are not increased to maintain fishing mortality below the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan.

Fisheries

Nephrops norvegicus (Norway lobster), is fished almost exclusively by otter trawl, together with other species, notably *Parapenaeus longirostris* (Deep water pink shrimp), *Merluccius merluccius* (European hake), *Eledone* spp. (horned and musky octopuses), *Illex coindetii* (broad tail short squid), *Todaropsis eblanae* (lesser flying squid), *Lophius* spp. (anglerfish), and *Raja* spp. (rays) (Anon., 2000). Moreover, in the Adriatic Sea, where Norway lobster is distributed mainly in the neritic area, fishing is primarily based on two types of gear: the majority of the catch is by bottom trawl nets and the rest with traps (mainly in channel areas of the northern Adriatic).

Fishing zones and seasons

Norway lobster is one of the main commercial species for trawlers exploiting fishing grounds on the upper slope targeting mainly the deep sea pink shrimp (*Parapenaeus longirostris*) and the giant red shrimp (*Aristaeomorpha foliacea*). Figure 52 shows the main fishing ground of the Strait of Sicily. Table 22 lists the fishing area in which *N. norvegicus* is mainly caught. In the Western and Central part of the Strait of Sicily (areas A, C, D and E) Norway lobster fisheries operate all around the year. On the contrary in the southern part (areas F and G) of the Strait trawl vessels fish just fishery in winter and spring.

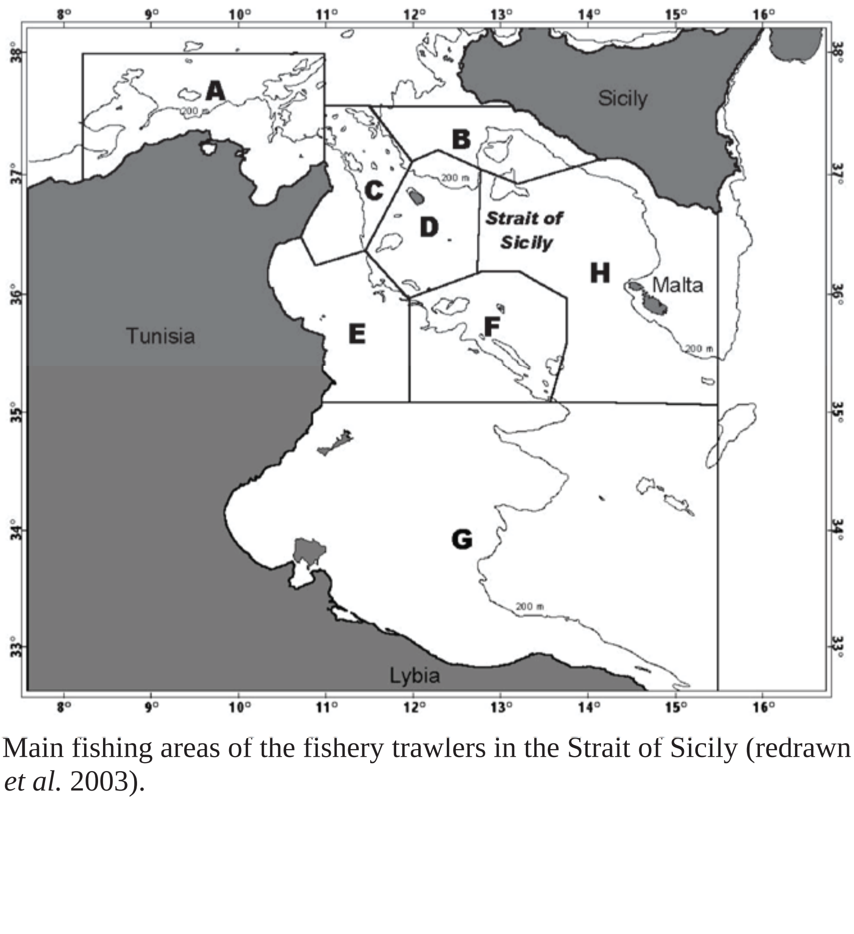


Figure 52. Main fishing areas of the fishery trawlers in the Strait of Sicily (redrawn from Fiorentino *et al.* 2003).

Table 22. Main fishing-grounds and fishery features of the Sicilian trawlers fishing Norway lobster in the Strait of Sicily (from Fiorentino *et al.*, 2003).

Areas	Target species	Season	Gear	Depth range (m)	Haul duration	Hausl per day
A + C (Ponente)	*P. longirostris* *A. foliacea* *N. norvegicus*	All year round	Fondale trawl net	250-750	250-500: 3-4 h daytime 5-6 h night time	250-500: 4-5 daytime +1 night time
C+V+E (Kelibia)	*P. longirostris* *A. foliacea* *N. norvegicus*	All year round one peak in spring	Fondale trawl net	200-500	250-500: 3-4 h daytime 5-6 h night time	250-500: 4-5 daytime +1 night time
D (Pantelleria)	*A. foliacea* *N. norvegicus*	Mainly Winter-Spring	Fondale trawl net	400-750	4-5 h	up to 4
F (Greco Linosa)	*A. foliacea* *N. norvegicus*	Mainly Winter-Spring	Fondale trawl net	400-750	4-5 h	up to 4
D (Deserto)	*A. foliacea* *N. norvegicus*	Mainly Winter-Spring	Fondale trawl net	400-750	4-5 h	up to 4

Discards

Discards for this stock are negligible.

Legislation and management

In GSA 16 and in the Strait of Sicily in general there is no formal management for Norway lobster. As in other areas of the Mediterranean, the stock management in GSA 15 and 16 is based on control of fishing capacity (licenses), fishing effort (fishing activity) and technical measures (mesh size and area/season closures). The minimum landing size is 20 mm CL and landing berried females is prohibited (Reg. EC 1967/06). A combination of these measures is at the basis of two long term management plan adopted by Italian Government in 2010 for management of Sicilian trawlers operating in the area (see also the P. longirostris chapter).
In Sicilian waters (GSA 15), in order to limit the over-capacity of fishing fleet, no new fishing licenses have been assigned in Italy since 1989 and a progressive reduction of the trawl fleet capacity is currently underway. Otherwise, Maltese fishing licenses have been fixed at a total of 25 trawlers since 2012.
There is no closed season in place in Malta, but the Maltese Islands are surrounded by a 25 nautical mile fisheries management zone where fishing effort and capacity are being managed by limiting vessel sizes, as well as total vessel engine powers (EC 813/04; EC 1967/06). 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. Vessels fishing in the management zone hold a special fishing permit in accordance with Regulation

EC 1627/94. Moreover, the overall capacity of the trawlers allowed to fish in the 25nm zone cannot exceed 4 800 kW and the total fishing effort of all vessels is not allowed to exceed an overall engine power and tonnage of 83 000 kW and 4 035 GT respectively. The fishing capacity of any single vessel with a license to operate at less than 200m depth cannot exceed 185 kW.
In order to protect coastal habitats, the use of towed gears is prohibited within 3 nm of the coast or within the 50 m isobath if the latter is reached closer to the coast (EC 1967/2006; Res. GFCM 36/2012/3). In order to protect deep water habitats trawling at depths beyond 1000 m is also prohibited at EU and GFCM level (EC 1967/2006; Rec. GFCM 2005/1).

In terms of technical measures, EC 1967/2006 fixed minimum mesh size for bottom trawling of EU fishing vessels. Mesh size had to be at least 40 mm squared at codend or at the duly justified request of the ship owner a 50 mm stretched diamond mesh in July 2008; derogations were only possible up to 2010. Moreover, diamond mesh panels can only be used if it is demonstrated that size selectivity is equivalent to or higher than using 40 mm square mesh panels (EC 1343/2011).

Palinurus elephas (Fabricius, 1787)

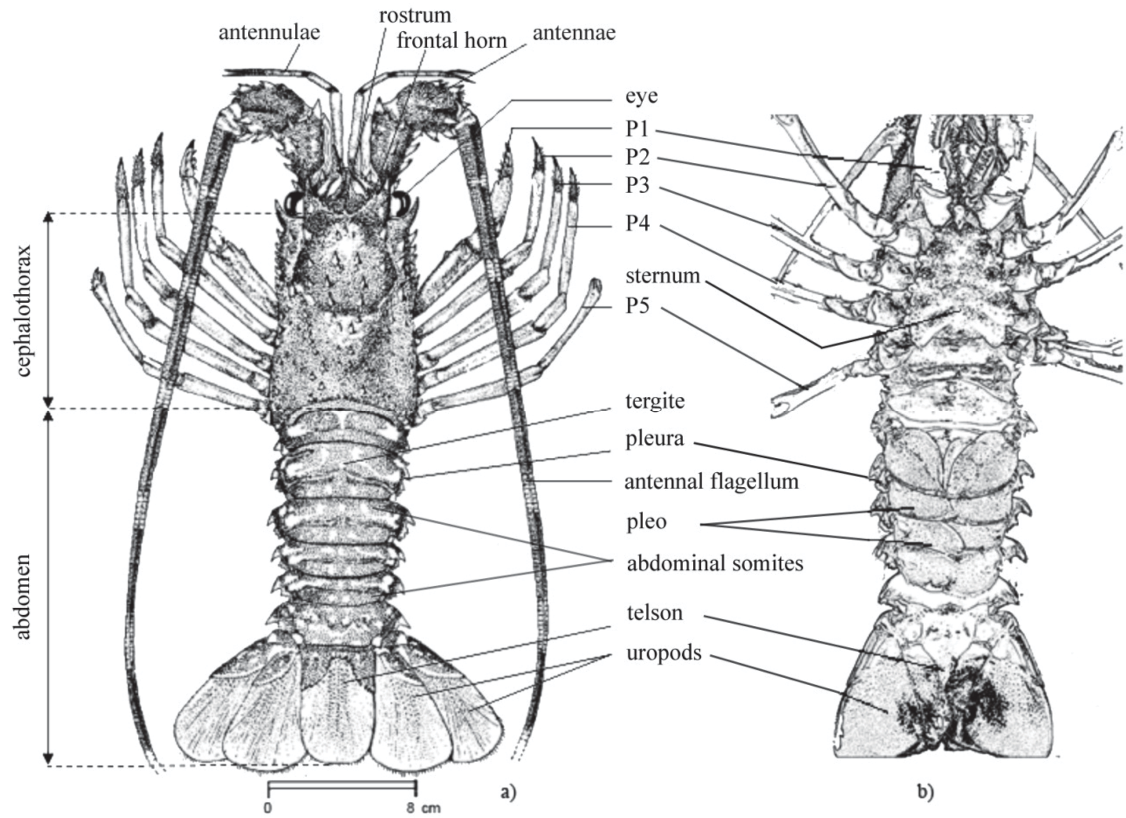


Figure 53. *Palinurus elephas* female: a) dorsal face (FAO, Fischer *et al.*, 1987) and b) ventral face (Rjeibi, 2012). P1, P2, P3, P4, P5: 1st to 5th pereiopods. Pleo: pleopods.

Species Description

Meristics

The external morphology of *Palinurus elephas* is similar to that of other members of the Stridentes group of Palinurids (Figure 53). The body of lobster is compartmentalized into a cephalotorax, which consists of the fused head and thorax and an abdomen, with their respective appendages (Holthuis, 1991). Appendages of cephalotorax include the movable eyes, the antennae and antennulae (with defensive, mechanoreception and chemoreception function), the mouth and five pairs of legs. Six separate somites form the abdomen, each protected by chitinous coverings on the dorsal, ventral and lateral (pleura) portions. The pleura encloses the pleopods, which are used to swim and form appendages on the first five abdominal somites. The first two pairs of pleopods form copulatory organ in the males, whilst in mature females the pleopods become setose to enclose the egg mass (Lipcius and Herrnkind, 1987). Colouration is reddish-brown dorsally with a white underside, although a wide range of variations is possible (Hunter *et al.*, 1996). *P. elephas* is further characterised by two large symmetrical white blotches on the tergites of somites 1-5, with a single, centrally located blotch on the final segment. A further two symmetrical blotches are located on the telson.

The relationship between the total length (TL), measured from the tip of the rostrum to the posterior end of the telson and the carapace length (CL), measured from the tip of the rostrum to the posterior margin of the cephalothorax, was manly studied for different populations. Hunter (1999) summarizes the TL-CL relationships for different Atlantic areas. In the Table 23, some available relationships for various Mediterranean areas were exposed.

Table 23. Total length (TL)–Carapace length (CL) relationship in *Palinurus elephas* in some Mediterranean areas. *GSA: Geographical Sub-Area*

Mediterranean areas	**Females**	**Males**	**Sources**
Corsica Island, GSA 8	$TL = 2.77\ CL + 6.38$ n=278, range 50-160 mm CL	$TL = 2.47\ CL + 22.07$ n=417, range 45-175 mm CL	Campillo and Amadei, 1978
Sardinia, GSA 11	$TL = 1.114\ CL^{1.009}$ n=356, range 44-98 mm CL	$TL = 1.272\ CL^{0.9613}$ n=465, range 44-98 mm CL	Tidu *et al.*, 2004
Columbretes (Balearic) Islands, GSA 5	$TL = 2.88\ CL + 12.51$ n=441, range 41-142 mm CL	$TL = 2.51\ CL + 32.04$ n=370, range 45-169 mm CL	Quetglas *et al.*, 2004
Northern Tunisia, GSA 12	$TL = 2.48\ CL + 32.54$ n=89, range 93-148 mm CL	$TL = 2.34\ CL + 38.36$ n=91, range 61-167 mm CL	Quetglas *et al.*, 2004
Northern Tunisia, GSA 12	$TL = 2.41\ CL + 42.25$ n=268, range 58-136 mm CL	$TL = 2.32\ CL + 39.68$ n=262, range 46-161 mm CL	Rjeibi, unpublished data

Ecology

Geographic distribution

The European spiny lobster *Palinurus elephas* (Fabricius, 1787), is common along the Northeast Atlantic coasts (Ireland and South of England), Azores and Canary Islands and also off Marocco (Figure 54). Throughout the Mediterranean *P. elephas* occurs over the entire western basin (Balearics, Corsica, Sardinia, Sicily and Tunisia, Marin, 1985), it is abundant in Adriatic and Aegean Sea (Morratoupolu Kassimati, 1973), but it is absent in the extreme eastern and south-eastern basins (Holthuis, 1991; Hunter, 1999).

Habitats

P. elephas lives between the shore and 200m depth on rocky and coralligenous substrates where micro-caves, crevices and natural holes are available (Ceccaldi and Latrouite, 2000). Habitation of shelters may be solitary or in pairs and small groups, probably dictated by gregarious behaviour adapted for protection from diurnally active predators. As documented for other palinurids (Zimmer-Faust *et al.*, 1985) the aggregative behaviour of *P. elephas* adult specimens (Mercer, 1973), may be driven by chemical (Gristina *et al.*, 2011) or visual stimuli depending on the quality of the surrounding habitat (Eggleston and Lipcius, 1992). Adults of *P. elephas* are primarily nocturnal (Giacalone *et al.*, 2006) when specimens left their shelters by foraging and reproduction. *P. elephas* is highly omnivorous and preys on hard–shelled bottom dwelling organisms, principally molluscs, echinoderms, crustaceans, polychaete worm tubes, bryozoans, fish bones and macroalgae (Ansell and Robb, 1977; Campillo and Amadei, 1978; Mercer, 1973). *P. elephas* appears to change its food preferences as a function of the abundance of benthic organisms present in the foraging area. While molluscs and sea urchins are the most important prey in the diet of the species, other preys are consumed in certain areas and not in others (Goñi *et al.*, 2001a). However, the predominance of shell fragments and calcareous algae may reflect calcium requirements prior the moulting phase (Campillo and Amadei, 1978; Mercer, 1973). Captive specimens rejected fresh fish in favour of mussel and oyster (Campillo and Amadei, 1978) and learned how to extract and consume hermit crabs (Wilson, 1949).

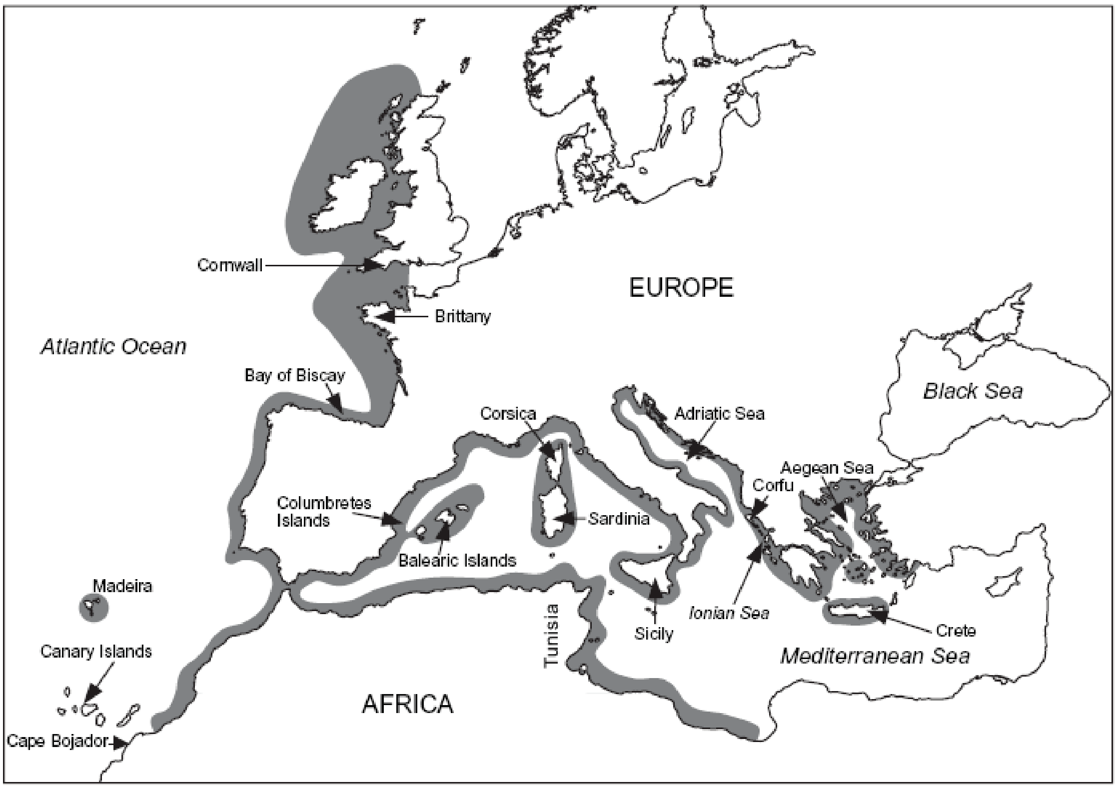


Figure 54. Distribution of *Palinurus elephas* in the Western Mediterranean Sea and north-east Atlantic Ocean, including the western coast of North Africa, Canary Islands, and the Azores (not on map) by Groeneveld *et al.*, 2006).

Migrations

In the Atlantic *P. elephas* undertakes a pre-reproductive spring onshore migration and a reverse post-reproductive offshore migration in late autumn (Mercer, 1973; Ansell and Robb, 1977). A similar behaviour has been postulated for *P. elephas* off the Columbretes Islands (GSA 5) (Goñi *et al.*, 2001b). Tag-recapture studies indicate that adult movement is restricted, with most animals moving less than 5 km and exceptionally up to 20 km after 1 to 8 years at large (Hepper, 1967; 1970; Marin, 1987; Goñi *et al.*, 2001b; Cuccu, 1999). Giacalone *et al.* (2006), in their experience to follow the movement of *P. elephas* released in the Isola delle Femmine MPA (GSA 10, South Tyrrhenian Sea) by the application of an ultrasonic telemetry system, showed that the longest distance travelled by target lobster was 2.2 km during the 79 days of study. However, two reports of movements of 50 and 70 km have been made in the Mediterranean (GSA 9, Relini and Torchia, 1998; GSA 11, Secci *et al.*, 1999). Although recent studies indicate that *P. elephas* undertakes limited movements, ca. 2.5 km year^{-1} (GSA 5, Goñi *et al.*, 2006; GSA 11, Follesa *et al.*, 2009). No available data on migration in the northern sector of Strait of Sicily (GSA 15 and 16) and also in the southern one (Tunisian costal, GSA 12 and 13).

Biological Information

Maximum size

According to Fischer *et al.* (1987) *P. elephas* in Mediterranean Sea may reach a maximum size of 50cm of total length.

In the northern sector of the Strait of Sicily (GSA 15 and 16) data on the maximum size of *P. elephas* are scarce or anedoctical. Gristina *et al.* (2005) using landing analysis at Marettimo fishery (Egadi Islands, GSA 10) reported a maximum size of 120mm (CL) both for male and female, whilst Gristina *et al.* (2008) at Isola delle Femmine MPA (N/W Sicily, GSA 10) reported a maximum size of 145mm (CL) both for male and female.

In the southern sector (GSA 12), Rjeibi (2012) by population size frequencies distributions analysis (during the period 2001-2006) reported a maximum size of 155mm (CL) for female and 195mm (CL) for male.

Length at first maturity

The mean size at maturity has been established for *P. elephas* populations in Atlantic and Mediterranean water. Available estimates of length at the first maturity for some Mediterranean population, especially for the southern Strait of Sicily (GSA 12), are given in Table 24. However, no data are available for the northern sector of the Strait of Sicily.

Table 24. Length (mm CL) at first physiological and functional maturity, by sex, for *Palinurus elephas* from some Mediterranean areas

Areas	Physiological maturity		Functional maturity	Method	Source
	Females	Males	Females		
GSA 5 Balearic Island	76.5 (n=192)	n.a.	77.2 (n=683)	Percent of mature or berried	Goñi *et al.*, 2003a
	74-76 (n=67)	82,7 (n=94)	n.a.	Plot Log(GW)-log(CL)	
GSA 8 Corsica Island	80 (n=98)	n.a.	86 (n=1169)	Percent of mature or berried	Marin, 1987
	76 (n=57)	78 (n=53)	n.a.	Plot Log(GW)-log(CL)	
GSA 12 North Tunisia	75,56 (n=120)	85,19 (n=91)	79,08 (n=35)	Percent of mature or berried	Rjeibi, 2012
	n.a.	83,1-85,1 (n=41)	n.a.	Plot Log(GW)-log(CL)	

Spawning

P. elephas breed once during the year. In the Atlantic**,** mating is reported to occur between June and November (Mercer, 1973; Hunter *et al.*, 1996; Gahlardo *et al.*, 2006) and egg laying peaks in September-October (Mercer, 1973; Hunter *et al.*, 1996; Latrouite and Noël, 1997). Spawning season has been also identified in Mediterranean areas and it varies depending on the region (Table 25). However, no data are available for the Sicilian side of the Strait of Sicily (GSA 15 and 16).

Oviposition takes place shortly after mating (i.e., 2 days, Mercer, 1973; 5-10 days, Ansell and Robb, 1977) and eggs are shed across the spermatophoric; egg extrusion may take place in less than two hours (Mercer, 1973).

Table 25. Spawning period and the peaks of laying for *P. elephas* in some Mediterranean areas

Area/GSA	**Spawning period**	**Peaks of laying**	**Source**
17 and 18 Adriatic Sea		September	Gamulin, 1955
20 Eastern Ionian Sea	August to November		Moraitopoulou-Kassimati, 1973
8 Corsica	August to November	September	Campillo and Amadei, 1978
8 Corsica	July to September	September	Marin, 1985
GSA 5Balearic Island	July to September	September	Goñi *et al.*, 2003a
GSA 12 North Tunisia	July to October	September-October	Rjeibi *et al.*, 2010; Rjeibi, 2012

In GSA 12, all mature males reach their gonad maturation during May-July and copulate during August-October (Rjeibi, 2012). The analysis of the evolution of male gonads index indicates that males copulate and re-charge the gonads repeatedly through the breeding season. This observation on male reproductive activity in spiny lobster may be supported by a perspective gonad male histological study.

Fecundity

In the Mediterranean Sea, the fecundity-body size relationship of *P. elephas* has been studied only in some region for exploited (GSA 8, GSA 12) and for protected populations (GSA 5) (Table 26). The mean fecundity of the population and means relative fecundity (nb eggs/body gram) have been also estimated. In the GSA 5 and 8, the equation of fecundity is linear. However, in the GSA 12, it is a power function, according to Authors; it explained the difference in reproductive trends between large and small females.

Table 26. Fecundity (F)-Carapace length (CL) relationship, mean fecundity and mean relative fecundity for some Mediterranean populations of *P. elephas*.

Area/GSA	F-CL relationship	Mean absolute fecundity	Mean Relative fecundity	Source
GSA 5 Balearic Island	F=2428 CL-148988 (R^2= 0.85, n=70)	99882 eggs	118±33 eggs/g	Goñi *et al.*, 2003a
GSA 8 Corsica	F=3003 CL-229809 (R^2= 0.97, n=24)	67188 eggs		Campillo and Amadei, 1978
GSA 12 NorthTunisia	F=3.8 10^{-4} $CL^{4.2}$ (R^2= 0.94, n=93)	92232 eggs	116±32 eggs/g	Rjeibi, 2012

Eggs, larvae and post-larvae

Egg incubation lasts 4-5 months in the Western Mediterranean, GSA 8 and GSA 5 (Campillo and Amadei, 1978; Marin, 1985; Goñi *et al.*, 2003a). No information is available for the Strait of Sicily (GSA 12, 13, 15 and 16) from the literature. But in a study on captivity on spiny lobster caught from the GSA 12 (Rjeibi *et al.*, unpublished data), they observed that egg incubation in Tunisian water must lasts 5 months. In GSA 12, berried females were caught from all the fishing areas (Gaamour *et al.*, 2005; Rjeibi, 2012).

Hatching occurs in December-February in the GSA 17, 18, 8 and 5 (Gamulin, 1955; Campillo and Amadei, 1978; Goñi *et al.*, 2003a). Hatching may be completed in 24 hours (Mercer, 1973), although in aquaria it may last up to 8 days (Karlovac, 1965). No information is available for the Strait of Sicily. However, in captivity it may be completed in 24h for specimens from the GSA 12 (Rjeibi *et al.*, unpublished data).

As all Palinurids, the larvae of *P. elephas* is a leaf-like, transparent planktonic zoea called phyllosoma (Cunningham, 1891, in Goñi and Latrouite, 2005), which adapted to a long offshore drifting life. There is no available information on its geographic distribution and its displacement in the Strait of Sicily.

P. elephas post larvae settle in holes and crevices of rocky coastal habitat. However, Marin (1987) off Corsica (GSA 8) and Jiménez *et al.* (1996) along the Iberian Peninsula (GSA 1 and 6) reported large quantities of juveniles over *Posidonia oceanica* beds. Settlement takes place in summer at a preferential bathymetric layer ranging from 5 and 15 m (Díaz *et al.*, 2001; Gristina *et al.*, 2008).

Recruitment and nursery areas

Due to the biological characteristics of the young of the year (camouflage, cripticity, solitary) and to the very low catchability to the traditional gears (pots, trammel nets) identification of nursery areas for *P. elephas* results, to date, very difficult. However, the introduction of trammel net with narrower mesh size and of gill net allows for general information to be obtained on the juvenile concentration areas. In addition, in the recent period, many studies based on the underwater visual census methods permit identification of the biological and geomorphologic characteristics of the preferential habitat of the European Spiny lobster. Diaz *et al.* (2001) in the western Mediterranean Sea (GSA 5 and 6) and Gristina *et al.* (2008) in N/W coast of Sicily (GSA 10) observed that calcarenitic rocks with a high number of crevices and holes represents an appropriate habitat for recruits and early juveniles. Although no specific surveys were carried out along the northern sector of the Strait of Sicily, it is reasonable to image that calcareous rock both along the coast and in the off-shore banks could represent an appropriate substrate for settlement. Interviews carried out with fishermen allow us to identify areas of concentration of juveniles in Marettimo Island and in high sea rocky banks.

Sex Ratio

In Spanish fisheries (GSA 6), the sex-ratio is variable depending on the month sampling. The females are dominant at the beginning of summer and winter with a femininity rate of about 66%. The abundance of male increases in June and middle winter, femininity rate is about 50% (Goñi *et al.*, 2001b). Predominance of females was also observed throughout the year for *P. elephas* from Corsica (GSA 8) (Campillo, 1982).

In Tunisian water (GSA 12), the sex-ratio of *P. elephas* is in favour of males. They dominate whatever the period and area sampling (Rjeibi, 2012). Femininity rates reach a maximum during August-September and decrease in October. The annual male dominance in Tunisian population can be explained by the difference in catchability between the two sexes, by the faster growth of males and/or by the greater natural mortality of females (Rjeibi, 2012; Rjeibi *et al.*, 2011).

Length–weight relationship

The carapace length versus weight (CL versus W) as morphometric relationships was studied and reported in Mediterranean Sea (Table 27).

Table 27. Parameters of the length–weight relationships ($W = a\ CL^b$, where W = Total body weight and CL = carapace length) of spiny lobster in some Mediterranean areas. CL is expressed in mm.

GSA/Area	Females			Males		
	A	b	CL range	a	b	CL range
8 Corsica	9.7×10^{-8}	2.94	50-160	7.4×10^{-8}	2.96	45-175
11 Sardinia	1.21×10^{-7}	2.95	40-98	2.93×10^{-7}	2.85	40.98
11 Sardinia	-6.031	2.74	40-98	-6.072	2.72	40-98
5 Columbretes Islands	0.0016	2.83	41-142	0.0012	2.88	45-169
12 North Tunisia	0.0069	2.48	58-132	0.0029	2.66	61-167
12 North Tunisia	0.0021	2.76	58-136	0.0013	2.84	46-161

Except for Tidu *et al.* (2004), these publications showed that for the same size males are slightly heavier than females. But, Rjeibi (2012), during length-weight relationships analysis for Tunisian spiny lobster (GSA 12), showed that this difference is more significant for specimens greater than 80mm CL (puberty) and he linked this difference to greater participation of females after the puberty in reproduction, especially during incubation. Tidu *et al.* (2004) have reported an interannual variability in length-weight relationships for both sexes from NW Sardinian water (GSA 11) and they related this difference to the changes in food availability that have been found linked to some physical environmental features such as temperature and salinity. Accordingly, for a better estimation of W from the length-weight relationships, we suggest yearly calculation of this relation for *P. elephas* and for two sizes intervals before and after puberty.

Maximum age and natural mortality

Maximum age and the coefficient of natural mortality have been estimated for some *P. elephas* Mediterranean populations as in Table 6. However, no data on the natural mortality are available for the Sicilian side of the Strait of Sicily.

Predation is probably the major cause of natural mortality of *P. elephas*. In particular juvenile and moulting specimens represent a very vulnerable stage threatened by a wide range of predators (Marin, 1985). In the southern sector, Rjeibi (2012) estimates the natural mortality for Tunisian population (GSA 12) in its exploitable phase and separately by sexes. He showed that, as in other crustaceans, this mortality varies with size, especially between juveniles and adults. Hence and in the case that it will be used in population dynamic analysis, natural mortality was estimated only for the exploitation phase size interval.

Von Bertalanffy growth function (VBGF)

The Von Bertalanffy growth function (VBGF) parameters, by sex, in different Mediterranean areas are given in Tables 28 and 29 and in Figures 55 and 56.

Table 28. Maximum age and natural mortality (M) for *Palinurus elephas* in Mediterranean areas

GSA	Maximum age	M	M estimation method	Source
8 Corsica	15 years (sex combined)	0.15-0.30 year^{-1}	speculative arguments	Marin, 1987
11 Sardinia	15 years (sex combined)	0.24-0.31 year^{-1}	modified standard method based on age frequency distributions	Bevacqua *et al.*2010
5 Balearic		0.14-0.26 year^{-1}	modeling approach	Goñi *et al.*, 2010
12 Northern Tunisia	15 year (female), 20 years (male)	0.31 year^{-1} (female), 0.24 year^{-1} (male)	Mean of seven indirect methods	Rjeibi, 2012; Rjeibi *et al.*, 2011

Table 29. Von Bertalanffy growth function parameters in *Palinurus elephas* by sex and area.

GSA	Sex	LC∞	K	to	CL range (mm)	Method	Source
8 Corsica	Male	166.0	0.15	-0.348	63-122	Tagging-recapture	Marin, 1987
	Female	136.0	0.18	-0.342	63-120		
11 Sardinia	Male	167.9	0.13	-0.399	44.6-107.6	Tagging-recapture	Follesa *et al.*, 2003
	Female	120.2	0,21	-0.349	49.8-94.1		
12 North Tunisia	Male	201.6	0,16	-0.270	45-195	Size frequencies analysis	Rjeibi *et al.*, 2011
	Female	155.4	0,22	-0.250	55-155		

The difference in growth between the GSA 12 and the two others areas can be due to the difference in the estimation method. The tagging-recapture based on a limited interval size could underestimate growth parameters. Size frequencies analysis, which can be influenced by the sampling method and its success, could provoke an overestimation of these parameters. But also, studies in Palinuridae suggested that food availability, environmental factors as temperature and dissolute oxygen rate and population density (which can be influenced by exploitation) are important in the determination of growth rate by region (Newman and Pollock, 1974; Pollock, 1979; 1982; 1991; McKoy and Esterman, 1981; Pollock and Beyers, 1981).

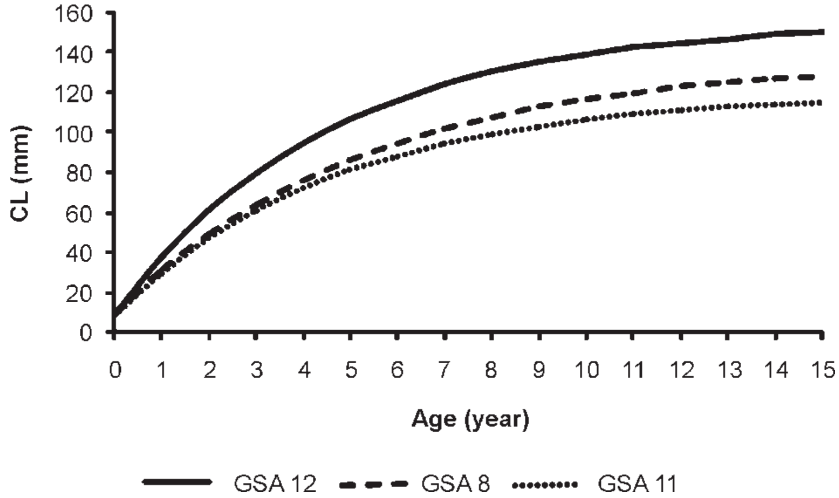


Figure 55. Growth curves of female red spiny lobster from Mediterranean areas (derived from parameters given in Table 29). GSA 12 = Northern Tunisia; GSA 8 = Corsica Island; GSA 11 = Sardinia Island.

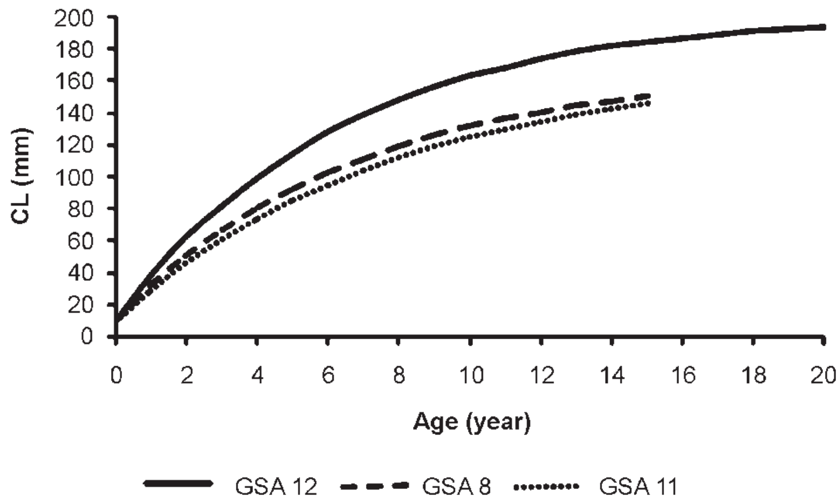


Figure 56. Growth curves of male red spiny lobster from Mediterranean areas (derived from parameters given in Table 29). GSA 12 = Northern Tunisia; GSA 8 = Corsica Island; GSA 11 = Sardinia Island.

Feeding behaviour

P. elephas preys on a variety of benthic organisms. It is highly omnivorous and preys on hard-shelled bottom dwelling organisms, principally molluscs, echinoderms and crustaceans. It is an opportunistic feeder that appears to change its food preferences as a function of the abundance of benthic organisms (Goñi et Latrouite, 2005). While molluscs and sea urchins are the most important prey in the diet of the species, other prey such as decapods crustaceans, ophiuroids or coralline algae are consumed in certain areas and not in others (Goñi *et al.*, 2001a). Mercer (1973) and Goñi *et al.* (2001a) have described quantitatively their diet off Ireland and the Western Mediterranean. There is no available information on the diet of this species in the Strait of Sicily.

Stock Units
The stock structure of red spiny lobster in the strait of Sicily is still not well known and needs further studies. The GSA 12 and an area of the GSA 10 close to it (Isola delle femmine and Capo Gallo from N/W of Sicily) were included in phylogeographic and population genetic structure studies (Palero *et al.*, 2008, 2011; Babbucci *et al.*, 2010). These studies showed genetic variability between Mediterranean areas and a possible higher gene diversity for the Tunisian population (GSA 12). This supposes that maybe there is more than one stock unit in the Strait of Sicily, which must be confirmed by genetic study in this region. However, Goñi *et al.*, (2006), in the case of their experience "Ocean circulation and Larval drift", released three drifting buoys in the Columbretes reserve (GSA 5) at the time of egg hatching of *P. elephas* (January). One of these buoys reached the Strait of Sicily in April. After egg hatching, pelagic phyllosoma larvae drift in ocean currents during 4-5 months, corresponding to its larval life period (January-May). This must suppose a possible drifting of phyllosoma from other Mediterranean areas to the Strait of Sicily.

Evaluation and Explotiation

Biomass and density indices
There is little information in literature on biomass and density indices from the northern side of Strait of Sicily (GSA 15, 16). In southern one, Gaamour *et al.* (2005) reported a catch rate of 3.4 (number of lobster/day/500m net) in the GSA 12.

Strength of recruitment
There is little information on recruitment and stock-recruitment relationships for *P. elephas* populations. Marin (1987) reported that recruitment occurs in fishing areas in GSA 8 from the size of 40mm CL. Based on Length Cohort Analysis (LCA), he estimated the number of recruit for each sex between 458000 to 801900. In the southern Strait of Sicily (GSA 12), based on LCA, Rjeibi (2012) estimated the number of recruit for females between 230053 and 346967 and for males between 370381 and 537020.

Stock assessment
Based on different models of population dynamics, the Tunisian stocks of *P. elephas* are at their maximum level of exploitation or in state of biologic overexploitation (Gaamour *et al.*, 2009; Rjeibi, 2012). These Authors have proposed some measures to improve the stock status: 1) Mimimum Legal Size can be ameliorated in order to increase the number of lobster which participate in spawning processes and increase the fecundity of the spawning stock biomass and the consequent recruitment. 2) based on Fox model, the total allowable catch (TAC) can be fixed to 31 tons per year. 3) based on length-cohort and relative yield-per-recruit analysis, by sex, the current fishing effort must be reduced for female and male by

32% and 42%, respectively, to reach an optimum exploitation of Tunisian populations. 4) based on the capture composition analysis of three mesh size of trammel nets used by professional vessels, the mesh size of nets during spiny lobster fishing season must be greater than 70 mm.

Fisheries

P. elephas is intensively exploited in the Mediterranean Sea and the north-eastern Atlantic (Goñi *et al.*, 2003a). It is traditionally targeted by artisanal fisheries, but the change in fishing strategy (from traps to trammel nets) that took place between the 1960s and the 1970s has severely impacted lobster populations (Hunter, 1999; Goñi and Latrouite, 2005). Consequently, lobster catches have declined in most of the distribution range during recent decades (Goñi *et al.*, 2003a; Goñi and Latrouite, 2005).

In Tunisian waters (GSA 12), a major change in the exploitation strategy took place during the 1980s with the introduction of trammel-nets that progressively replaced the traditional methods. This change in fishing strategy was followed by a greater increase in spiny lobster landings and in the number of vessels targeting it (especially during 1990s), hence excessive fishing of species. These changes and excessive fishing methods had an impact as observed on the populations of other species: on exploitation levels, demography and sex composition of the exploited populations (Hunter *et al.*, 1996; Goñi *et al.*, 2003b; Goñi et Latrouite, 2005). Those (negatives influences) were observed for Tunisian population since the year 2000. Since then, the average size of exploited fraction and fishing yields have been in decline.

Landings

The annual evolution of landings of European spiny lobsters in Mediterranean and Black Sae and in the Atlantic are reported in Figure 57. Since 2000, the landings increase in the Mediterranean and Black Sea however they decrease in the Atlantic.

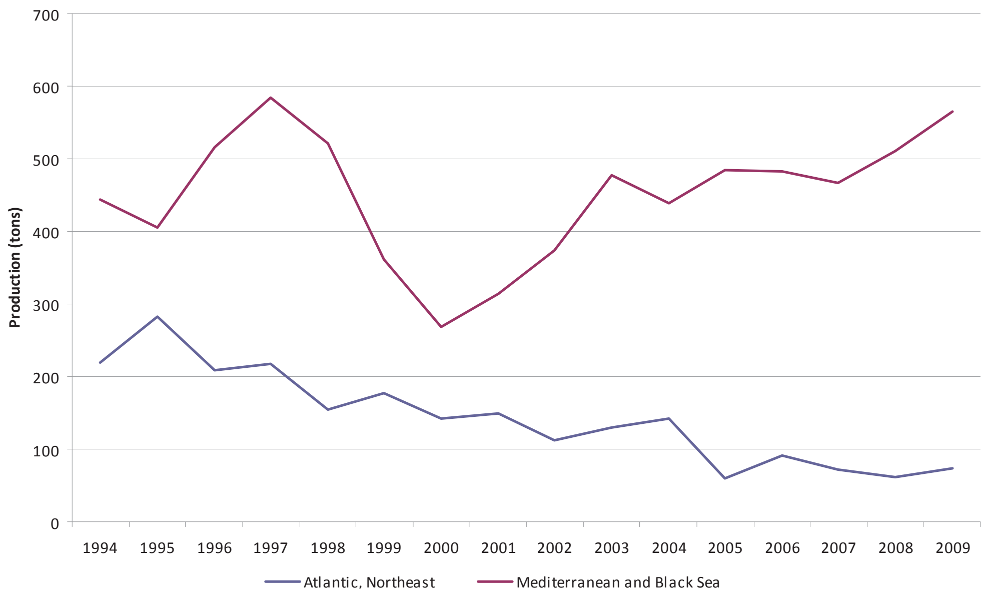


Figure 57. Annual evolution of landings of European spiny lobsters in Mediterranean and Black Sea and in the Atlantic (Northeast) (FAO FishStat Plus 2012).

The increase of European spiny lobster landings in the Mediterranean and Black Sea can be attributed to the evolution of Italian landings (Figure 58).

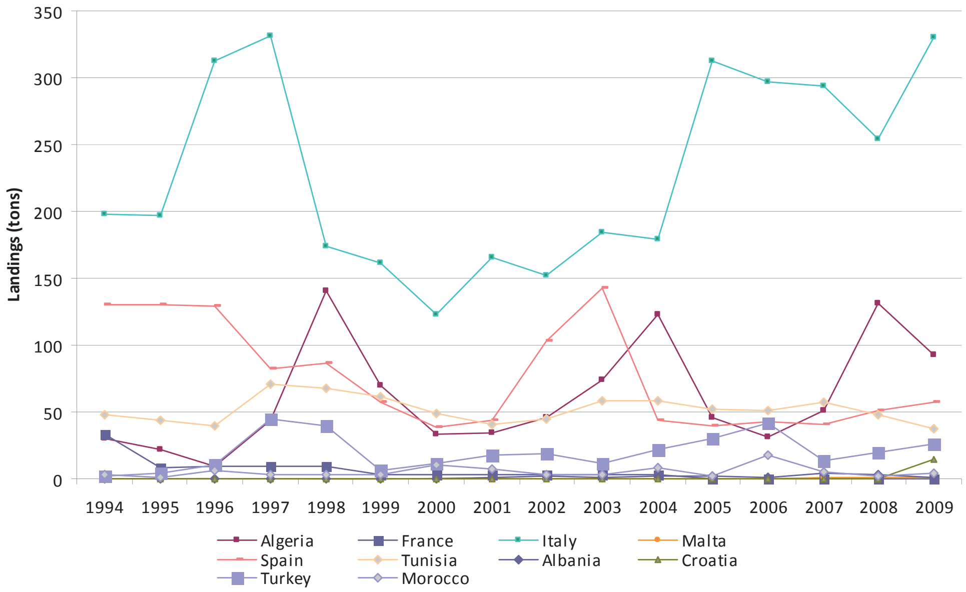


Figure 58. Annual evolution of landings of *P. elephas* in Mediterranean and Black Sea by country (FAO-FishStat Plus).

Fishing zones and seasons

In southern side of Strait of Sicily (GSA 12), 5 zones were the most frequented by Tunisian professional boat targeting red spiny lobster (Figure 59).

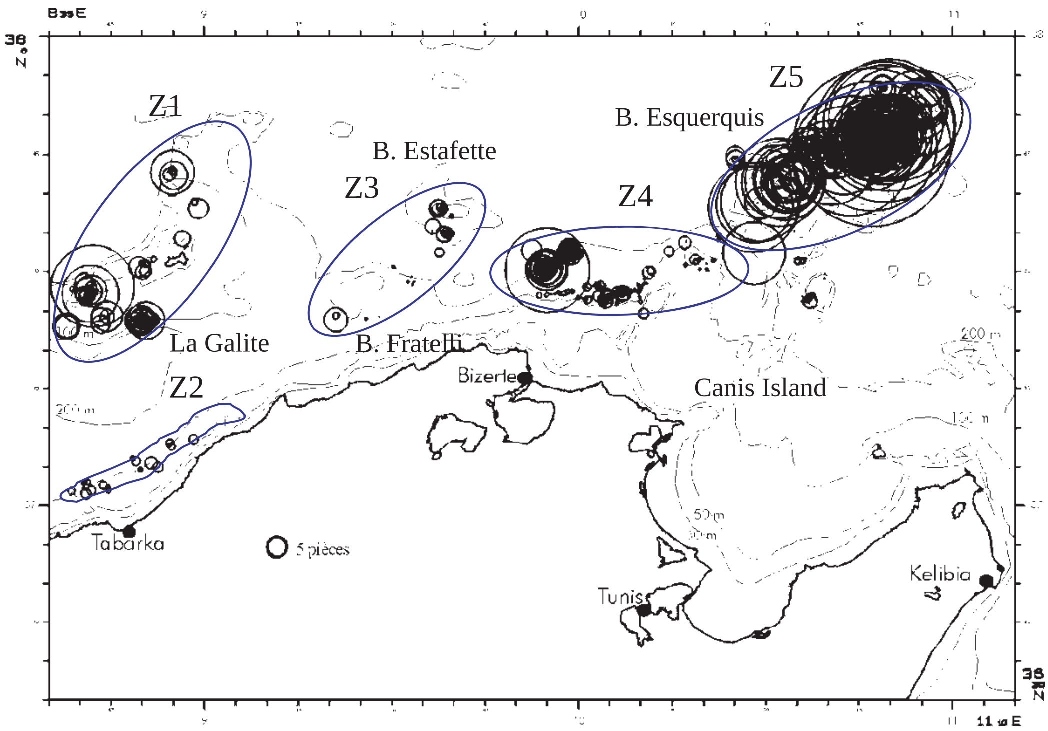


Figure 59. Fishing zones in GSA 12, Northern Tunisia (Rjeibi, 2012).

Yield

Since 2000 in the GSA 12, the fishing yields are in decline in Tunisian fisheries (Figure 60).

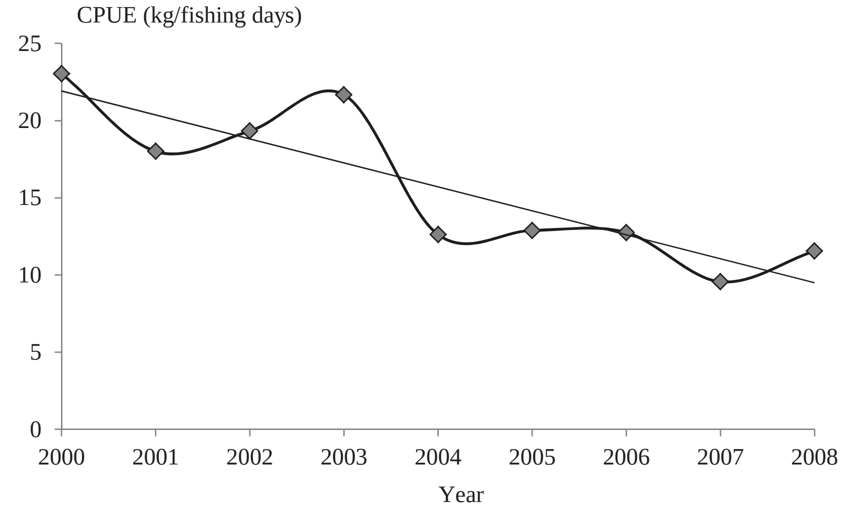


Figure 60. Evolution of CPUE (Kg per fishing day) during the period 2000-2008 in Tunisian *P. elephas* fishery, GSA 12, Northern Tunisia (Gaamour *et al.*, 2009).

Fishing pattern and discards

In Tunisian waters (GSA 12) generally, *P. elephas* present 47 % of the total weight of species caught by trammel net. This percentage can be divided into 3 parts: 73% are marketable specimens, 23% are discards (damaged) and 4% illegal size (Quetglass *et al.*, 2004).

Gears

P. elephas in Tunisian water is targeted by artisanal vessels called "langoustier" using trammel net with mesh size greater than 70 mm (length: 500-1000 m, height: 2.5m and mesh size: 70-80 mm, Gaamour *et al.*, 2009). *P. elephas* is also caught by artisanal vessels (using finfish netting of 40mm) and by bottom trawling (Figure 61).

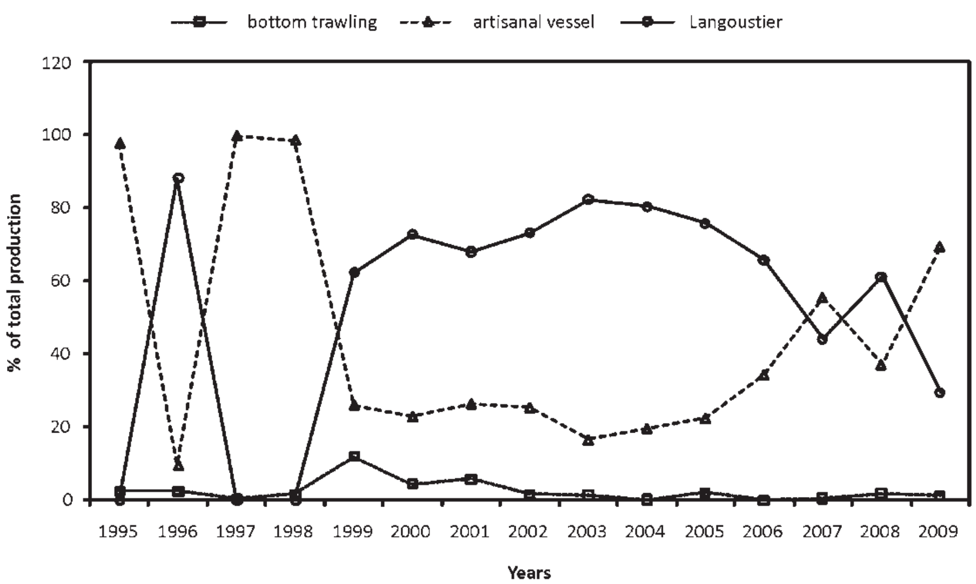


Figure 61. Annual evolution of the percent of the red spiny lobster landing production by gear.

Legislation and Management

P. elephas is signaled in the appendix III of Barcelona convention as species with regulated exploitation and in the appendix III of Berne convention as protected fauna species in the Mediterranean Sea.

All Mediterranean *P. elephas* populations are managed at national level. In Italian and Maltese waters the minimum landing size （MLS) is 90 mm CL. The fishery is closed from January 1st to April 30th (EU Reg. 2006) which covers only one part of the breeding season and berried females are to be returned to the water (Gristina *et al.*, 2002; Gristina *et al.* 2005).

In Tunisian waters, the fishing activity is regulated by an annual closure during the period July-February for territorial water and 15th September-February for international waters, by a MLS of 20cm of total length (TL) corresponding to 70mm CL and by a ban on catching berried females. According to biological studies on this species in Tunisian waters (Gaamour *et al.*, 2009; Rjeibi, 2012), the annual closure in international waters does not cover the peak of the breading season which occurs during August and MLS is smaller than the length at the first functional maturity which is about 80mm CL corresponding to 23cm of TL. The mesh size of outer panels in trammel nets may also be regulated and the minimum size of 70mm was proposed. This last regulation is only considered by the artisanal vessels called “langoustiers” for which red spiny lobster is a target species. However, a considerable quantity of lobsters was caught as bycatch by artisanal vessels (using finfish netting of 40 mm) and by bottom trawling.

Parapenaeus longirostris (Lucas, 1846)

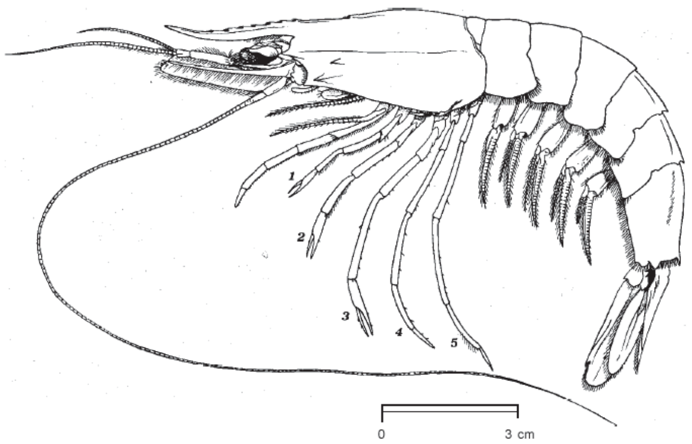


Figure 62. *Parapenaeus longirostris* (from Fischer *et al.*, 1987).

Species description

The deep-water pink shrimp, *Parapenaeus longirostris* (Lucas, 1846), is a large-sized decapod crustacean. On the carapace, there is a long furrow beginning near the eyes and present along the entire length of the carapace. The telson ends with three small, hard, sharp teeth (Figure 62). The carapace is pink–orange, with a reddish rostrum. The female gonads vary in colour, from white to dark green, depending on the stage of maturity (Fischer *et al.*, 1987; Tursi *et al.*, 1999).

Ecology

Geographical distribution
This species has a wide geographic distribution: it is found in the Mediterranean Sea and in the Atlantic Ocean, from northern Spain to southern Angola (Tursi *et al.*, 1999) (Figure 63). Characterized by a gregarious life, it is widespread from the coast of Asia Minor to the Spanish coast, rare on the French coast and the Sea of Marmara (Fischer *et al.* In Holthuis, 1987). It is also found in the Eastern (from Angola to Portugal) and Western Atlantic (from Guianas to Massachusetts).

Habitats
P. longirostris is a demersal species inhabiting sandy–muddy bottoms of the bathyal zone. It can be found at depths ranging between 20 and 700 m, but it is more abundant between 70 and 400 m depths (Fischer *et al.*, 1987). In the Atlantic Ocean, *P. longirostris* is captured between 40 m and 700 m depth, with a maximum abundance between 150m and 300m (Maurin, 1965; Maurine and Carriers, 1968). In the Mediterranean Sea the greatest abundance of *P. longirostris* are recorded between 100 and 300 m depth (Nouar, 1985; Holthuis, 1980; Arzel *et al*., 1992, Audouin, 1965). The Strait of Sicily, together with the seas around Greece, is the Mediterranean region with the greatest abundance of this species (Levi *et al.*, 1995; Abellò *et al.*, 2002). Relatively lower *P. longirostris* abundance is observed in the Gulf of Lion, in the Alboran Sea, (Nouar, 1985; Maurin, 1962), in the

Aegean Sea and off the coast of Gaza Strip and West Bank (Nouar, 1985). In 1954 Heldt (1954) reported the first record of *P. longirostris* off the Tunisian coast. In Tunisia this species can be found both in the North, East and South (Azouz, 1971; 1972) sub-regions, but it is only exploited by commercial fisheries in the north and north-east Tunisia.

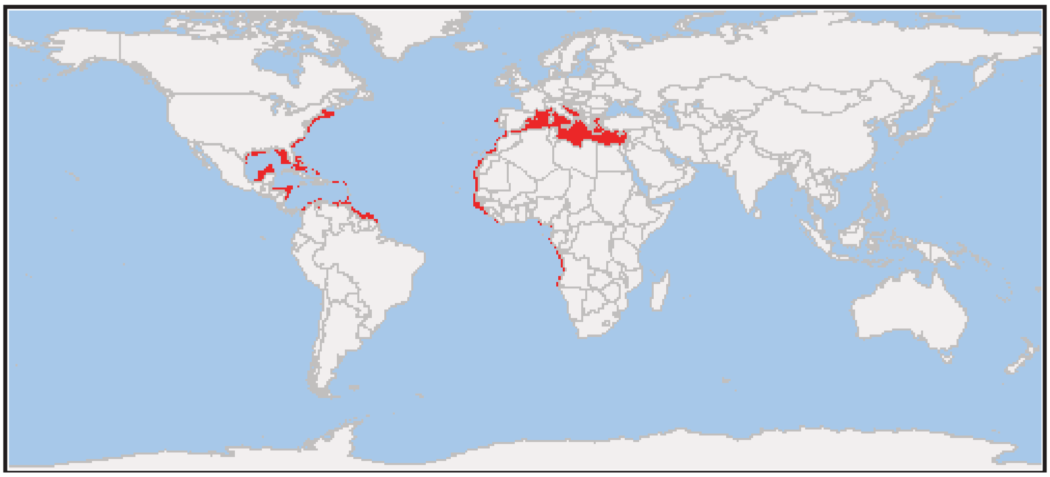


Figure 63. Geographical distribution of *Parapenaeus longirostris* (Holthuis, 1980)

Migrations
P. longirostris shows a bathymetric distribution related to size: the smaller specimens are caught more frequently on the outer continental shelf (50–200 m depth) (Ardizzone *et al.*, 1990; Spedicato *et al.*, 1996; D'Onghia *et al.*, 1998), whereas the larger ones are mainly distributed along the upper slope down to 500 m depth (Chaouachi and Ben Hassine, 1998; De Ranieri *et al.*, 1998; Lembo *et al.*, 2000).

Biogical information

Maximum size
Levi *et al.* (1995) reported *P. longirostris* with a carapace length (CL) up to 41.5 mm in the commercial landings of the offshore trawler fleet fishing in the Strait of Sicily in 1989–1990. A very close maximum size (42 mm CL for females and 35 mm CL for males) was found by Chaouachi and Ben Hassine (1998) along the northern and eastern coasts of Tunisia (GSAs 12 and 13). However, specimens from 20 to 30 mm CL for males and from 25 to 35 are generally found in the commercial fisheries landings. The maximum observed lengths in GSA 15 and 16, recorded during trawl surveys over 14 years, were 46 CL for females and 41 mm CL for males (G. Sinacori, pers. comm.).

Spawning
According to Levi *et al.* (1995), mature females are found in GSAs 15 and 16 all year round, although maturity peaks have been observed throughout the year: one wide peak from November to February and another in April (Figure 64). The lowest percentage of mature females appears in June–July, but continuous spawning seems to occur. Ben Meriem *et al.* (2001) reported that *P. longirostris* reproduces all year long, with a peak in June–July and a

minimum in winter. The evolution of the maturity index (MI = ovary weight/CL) is indicated in Table 30.

Table 30. Evolution of the maturity index of *Parapenaeus longirsotris* (Ben Meriem *et al.*, 2001)

Month	Jan. ‘97	Feb. ‘97	Mar. ‘97	Apr. ‘97	May ‘97	Jun. ‘97
Maturity index	3.21	3.24	3.45	3.02	4.16	10.1
Month	Jul. ‘98	Aug. ‘98	Sep. ‘98	Oct. ‘98	Nov. ‘98	Dec. ‘98
Maturity index	4.15	3.47	3.29	4.49	2.11	4.27

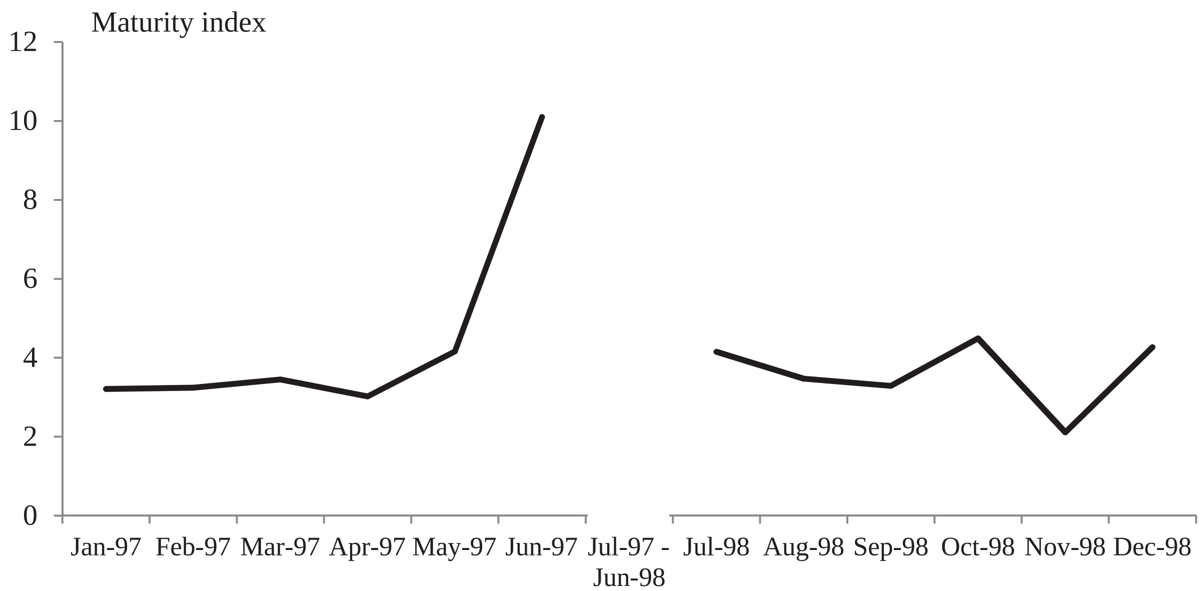


Figure 64. Variation of Maturity index (= ovary weight/CL) in the period January-June 1997 and July-December 1998 (Ben Meriem *et al.*, 2001).

Length at first maturity

The mean size of mature specimens, corresponding to 25 mm CL, was proposed as a proxy for the size at 50% maturity for females in GSAs 15 and 16 (SAMED, 2002). The available parameters of the classical ogive at maturity are reported in Table 31. According to Ben Meriem *et al.* (2001), this species reproduces before the end of its first year of life.

Table 31. Length (in millimetres) at 50% maturity (L50%) and curvature parameters of the ogive at maturity, by sex, of *P. longirostris* in the Strait of Sicily (g – grams; *n.a.* – not available). GSA 12 = Northern Tunisia; GSA 15 = Malta Island; GSA 16 = South Sicily.

Author	GSA	Females		Males		Remarks
		$L_{50\%}$	g	$L_{50\%}$	g	
Ben Mariem et al., 2001	12	20.10	n.a.	n.a.	n.a.	19.1<$L_{50\%}$<20.4 for females
Samed, 2002	15, 16	n.a.	n.a.	15.43	2.03	Trawl surveys 1994-1999
Ragonese et al., 2004	15, 16	24.00	n.a.	19.00	n.a.	Trawl surveys 1994-2002
CNR-IAMC, 2006	16	20.80	0.28	15.60	1.89	Commercial catch (2003-2005)
Gancitano et al., 2013	16	22.74	n.a.	14.27	n.a.	Commercial catch (2006-2011)

Eggs, larvae and post-larvae

The small amount of information available on eggs and larvae is from outside the Strait of Sicily. Dos Santos (1998) found along the southern and southwestern coasts of Portugal the presence of higher densities of deep-water pink shrimp larvae around the 100 m isobath. According to Heldt (1938) the development of larval phases lasts about two months.

Recruitment and nursery areas

Although very small specimens were taken in trawl survey samples, from a minimum size of 5 mm CL (Sinacori, pers. comm.), the size-class at full recruitment to the sea bottom in GSAs 15 and 16, was 17 mm CL for females and 18 mm CL for males (SAMED, 2002). Fiorentino *et al.* (2004) provided a rough geographical mapping of nurseries in GSAs 15 and 16. The annual variability in the positions of the nurseries was low. One important nursery was located off Capo Rossetto, in the western–central part of the area, another on the eastern side of the Malta Bank, close to the 200 m isobath (Figure 65). In Tunisia the small specimens were fished in the Galith Channel (Western-North coast of Tunisia).

A preliminary mapping of the nursery areas of white shrimp in the northern side of the Strait of Sicily has identified two major areas of concentration of recruits (Fiorentino *et al*., 2004), both around 200 m depth: one in the central-western aprt of GSA16; one on the eastern side of the Bank of Malta (GSA15). Persistent areas of high concentration of recruits were found around 200 m depth in the waters off the central part of the Sicilian coast. Other areas can be identified with a certain degree of annual variability in the eastern and western sides of the Adventure Bank. The spatial distribution of juveniles is very similar in the two seasons and in particular the nurseries identified as stable in spring and autumn are fully stackable. Therefore, the area identified is an important nursery of white shrimp in GSA16. It is oriented parallel to the coast and has an area of approximately 700 km^2 (Garofalo *et al.*, 2011). Fortibuoni *et al.* (2010) have definitively confirmed the presence of stable areas of nurseries in the eastern edge of the Adventure Bank (GSA16) and Malta Bank (GSA15). Each of these nurseries is next to a spawning area so as to assume the presence of two different subunits of the local stock of the Straits of Sicily.

Sex Ratio

In GSA 16, the sex ratio derived from the MEDITS Trawl Surveys from 1994 to 2004 remained stable and close to 0.5 (Fiorentino *et al.*, 2005) (Figure 66).

In GSAs 15 and 16, a significant increase in the sex ratio with shrimp size was observed, with the number of males prevailing in the sampled population from 16 to 22 mm CL, whereas females were more abundant at carapace lengths exceeding 24 mm (SAMED, 2002). However, the sex ratio observed in the commercial catch is ranged between 0.57 and 0.67.

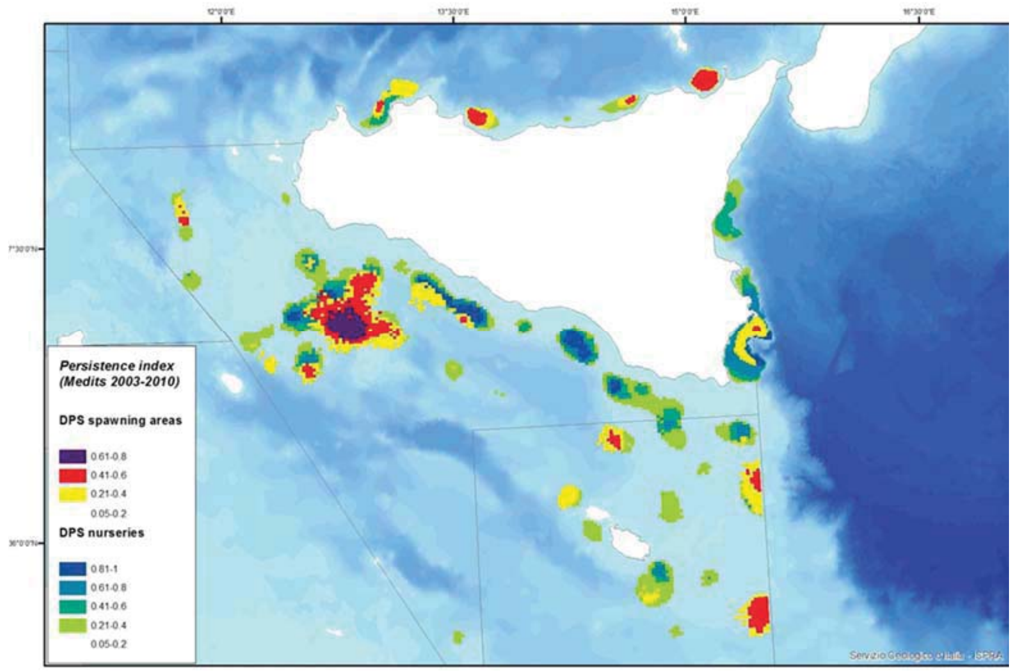


Figure 65. Preliminary mapping of spawning and nursery areas in the northern sectors of the Strait of Sicily (from Colloca *et al.*, 2013).

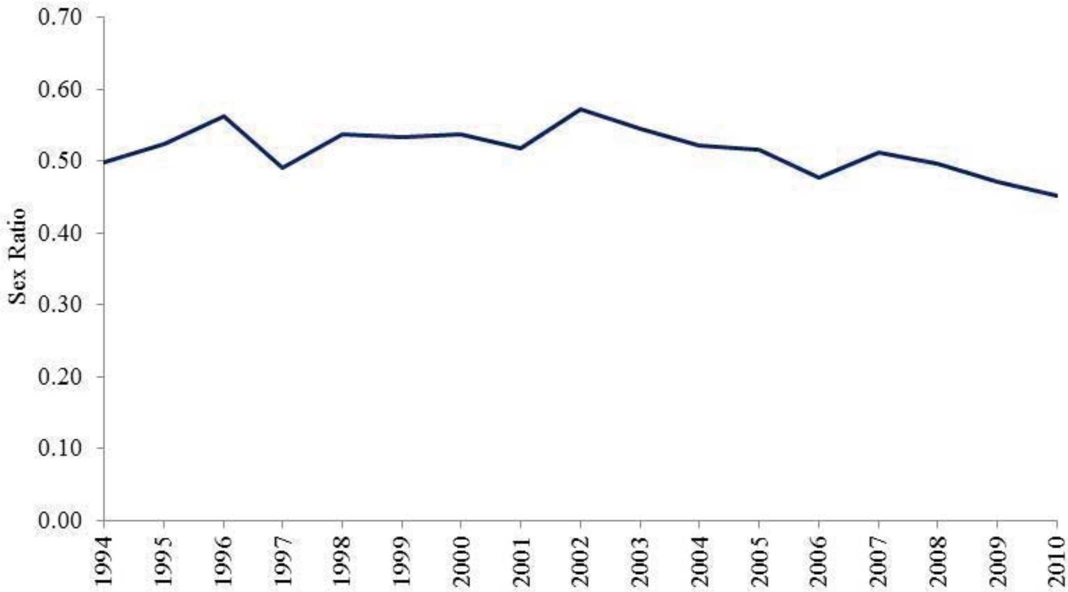


Figure 66. Sex ratio of *P. longirostris* in GSA 16, calculated as the ratio of the number of females to the total number of sexed individuals, from MEDITS Trawl Survey data (redrawn from Gancitano et al. 2013).

Length–weight relationships

P. longirostris generally displays an allometric negative length-weight relationship. The parameters of the allometric length–weight relationships estimated for *P. longirostris* in the Strait of Sicily are reported in Table 32.

Table 32. Parameters of the length–weight relationships of *P. longirostris* in the Strait of Sicily.

Author	GSA	Sex	a	b	Period
Levi et al., 1995	15, 16	F+M+I	0.0061	2.2664	1989-1990
IRMA–CNR, 1999	15, 16	F+M+I	0.0029	2.4961	1996-1998
CNR-IAMC, 2006	16	F	0.0027	2.5194	2003- 2005
“	“	M	0.0025	2.5398	“
“	“	F+M+I	0.0025	2.5436	“
Ben Meriem and Hadj Mbarek, 2009	12	F	0.0023	2.5180	1997-1998
“	“	M	0.0031	2.4101	“
“	“	F+M+I	0.002	2. 556	“

Maximum age and natural mortality

According to Ardizzone *et al.* (1990), the life cycle of *P. longirostris* lasts two years, with the possibility of some larger specimens entering a third year, and is characterized by high rates of growth and mortality. However, Levi *et al.* (1995) made the first estimate of the natural mortality of the species in the Strait of Sicily on the basis of the regression of estimated values of total mortalities (Z) on the annual total number of fishing days. The results by Levi *et al.* (1995) showed a value of M=0.17, which is compatible with a life cycle of a long-living species.

More recently, on the basis of a comparison netween results produced by different methods of estimating natural mortality (Chen and Watanabe; Beverton and Holt Invariants, Alagaraya), values of 1.04 for females and 1.15 for males were proposed as reference values for stock assessment purposes in GSAs 15 and 16 (SAMED, 2002). These latter estimates of natural mortality are compatible with longevities of 4–4.5 years. Also, Ben Meriem (unpublished data) indicate a value of natural mortality equals to 1.03, which is very close to that found in SAMED, 2002.

Von Bertalanffy growth function (VBGF)

The Von Bertalanffy growth function parameters, by sex, available for different areas of the Strait of Sicily are reported in Table 33.

Feeding behaviour

Tursi *et al.* (1999) reported that *P. longirostris* feeds on a wide variety of preys. During the hunting phase it eats small fish, cephalopods and crustaceans, whereas, during the digging phase, it searches in mud for prey, such as polichaetes, bivalves, echinoderms and, above all, foraminifers.

Table 33. Von Bertalanffy growth function (VBGF) parameters of *P. longirostris* in the Strait of Sicily (*n.a.* – not available). GSA = GFCM Geographical Sub-area; Wp = Winter Point, which indicates the period of the year (expressed as fraction of the year) when growth is lowest; C = factor which expressing the amplitude of the growth oscillations according to the seasonalized version of VBGF as reported in Pauly (1987).

Author	**GSA**	**Females**			**Males**			**Combined sexes**			**Remarks**
		L_∞	**K**	**t_0**	**L_∞**	**K**	**t_0**	**L_∞**	**K**	**t_0**	
Levi et al., 1995	15, 16							30.5	0.63	-0.19	Seasonalised with WP=0.1, C =1.0 1989-1990
Ragonese et al., 2004	15, 16	40.9	0.71	n.a.	34.3	0.73	n.a.				Autumn 1996-1998
SAMED, 2002	15, 16	43	0.68	-0.20	38	0.75	-0.20				Spring 1994-1999
CNR-IAMC, 2006	16							37.1	0.53	-0.46	2003-2005
CNR-IAMC, 2007	16	34	0.7	-0.16	28.5	0.68	-0.48				2003-2006
Ben Meriem (unpublished data)	12	42.41	0.66	0.216	32.82	0.73	-0.13	37.6	0.695	-0.17	1997-1998.

Stock units

The stock structure of the species in the Strait of Sicily is not well known. Levi *et al.* (1995) have hypothesized a flux, from east to west, of eggs, larvae and juveniles of *P. longirostris* carried by the Levantine Intermediate Water (LIW) current. More recently, the existence of at least two sub-populations on the northern side of the area (GSAs 15 and 16) was advanced by Camilleri *et al.* (2008) and Fortibuoni *et al.* (2010). This idea is based on the occurrence of local spawning and nursery areas that are connected by the Atlantic Ionian Stream flow (0–150 m depth range), which is considered to be the current in which the larvae and juveniles develop.

In 2013 Lo Brutto *et al.* (2013) provided a first study on the genetic structure of the deep-water rose shrimp in the central and eastern Mediterranean Sea, including the northern sector of the Strait of Sicily. Using radioactive and mitochondrial markers, the genetic distance and assignment methods assessed a significant and gradual differentiation from the Tyrrhenian, Adriatic, Strait of Sicily, to the Aegean area, along a west-east axis (clinal pattern). Athough some homogeneity was evident within the different population of the Mediterranean, a degree of isolation was found between different areas. The differences observed are consistent with existence of physical breaks, such as fronts (Figure 67).
Altough some minor differences were found between samples from the western and eastern side of the Strait of Sicily, for stock assessment purposes deep water rose shrimp is still considered as a single stock (Fiorentino *et al.*, 2008).

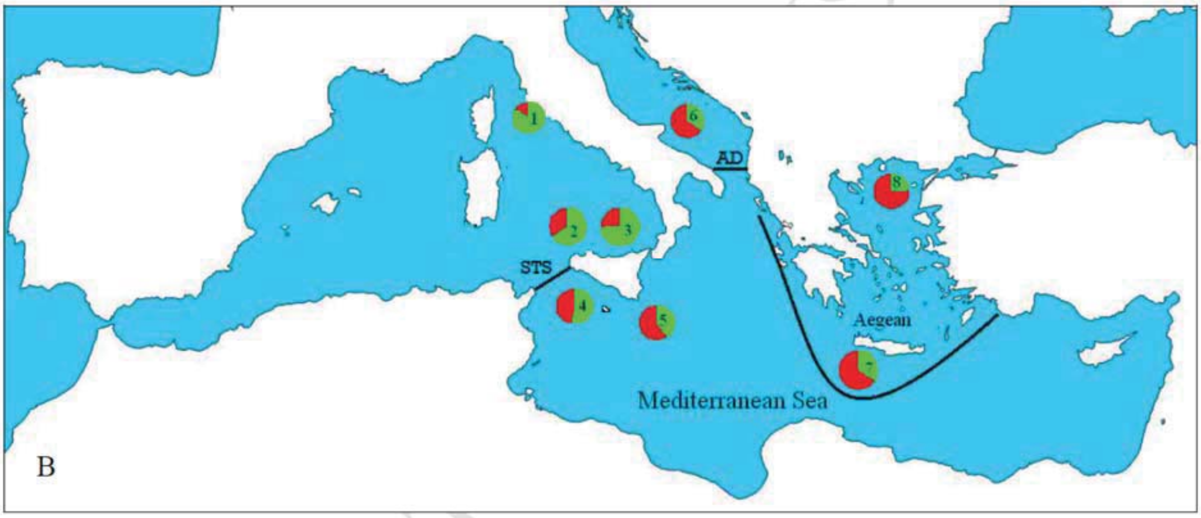


Figure 67. Distribution of the two Amplified Fragment Length Polimorphism (AFLP) clusters of *P. longirostris* population sub units and the main oceanographic fronts and boundaries (STS, Siculo Tunisian Strait; AD, Adriatic barrier; Aegean or Levantine isolation) affecting genetic pattern of the deep-water rose shrimp (from Lo Brutto *et al.*, 2013).

Evaluation and exploitation

Biomass indices from trawl surveys

Trawl-survey abundance indices estimated from the data of the MEDITS Trawl Surveys in GSA 16 showed a cyclical pattern, with the highest peak detected in 2009. Obvious monotonic trend can be observed in the time series (Gancitano *et al.*, 2013) (Figures 68). An analogous trend was found in the GSA 15 although a shorter time series of data is available (Figure 68). Moreover, similar fluctuations were observed in Tunisian data from trawl surveys for the period 2000-2010 (Ben Meriem pers. comm.).

Lamboeuf *et al.* (1995) assessed the LIBFISH Trawl Surveys (1993–1994) with respect to the demersal resources off the Libyan coast (GSA 21); they reported a small standing stock of *P. longirostris* (about 173 tons). This small amount could be due to the limited sampling of bottoms deeper than 200 m. These data were recently re-analysed by Rawag *et al.* (2004) that provided results on *P. longirostris* and *Penaeus kerathurus* (Figure 69). Off the Libyan coasts (GSA 21) *P. longirostris* was found only off Benghazi (eastern sector) and from the Gulf of Sidra (Gulf of Syrta) to the Libyan–Tunisian border (western sector GSA 21) on bottoms deeper than 100 m. The camarote prawn, *Penaeus kerathurus*, was recorded exclusively in the western sector of GSA 21 and at depths less than 100 m.

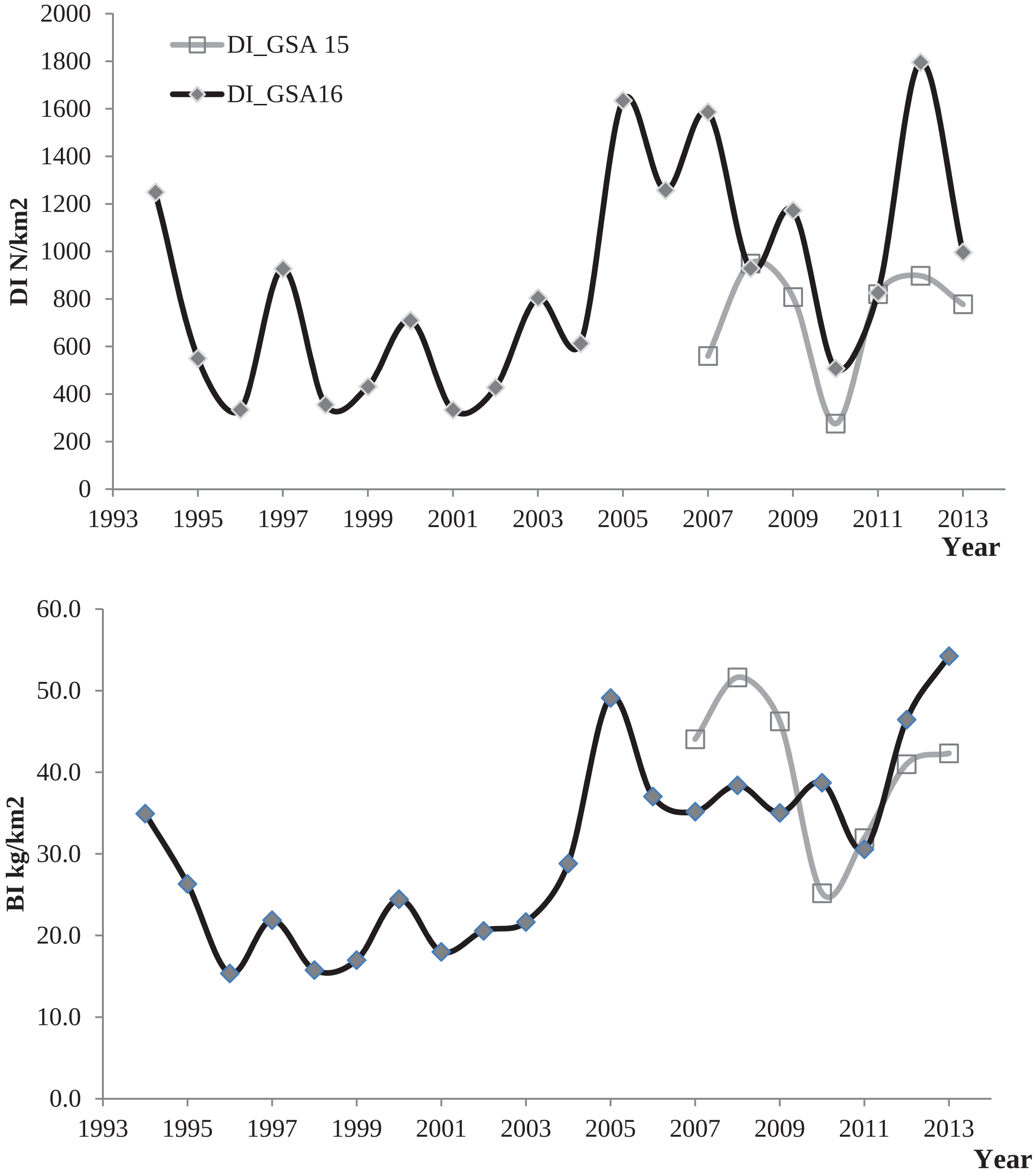


Figure 68. Time-series of *P. longirostris* biomass (kg/km^2) and density (number/km^2) indices (MEDITS Trawl Surveys; 10–800 m depth range) in GSAs 15 and 16 (Redrawn from Ben Meriem *et al.*, 2014).

Strength of recruitment

Density indices (DI) of recruits (individuals less than 18 mm CL) derived from MEDITS Trawl Survey data were used to estimate recruitment strength in GSA 16, assuming that recruitment occurs within the 50–200 m depth range (Gancitano *et al.*, 2103). A cyclic recruitment pattern was evident, with peaks in 1999, 2004 and 2009 (Figure 70).

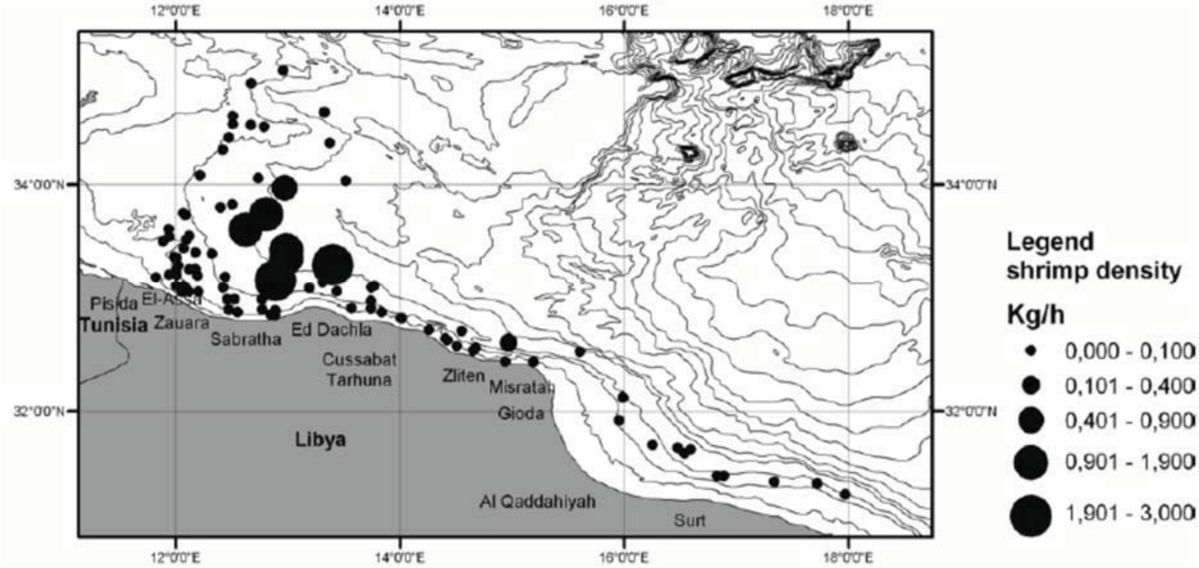


Figure 69. Biomass indices (kg/h) of the shrimps *Penaeus keraturus* (depth<100m) and *P. longirostris* (depth >100 m) combined, off the western coasts of Libya (GSA 21) (LIBFISH Trawl Surveys 1993–1994) (from Rawag *et al.*, 2004).

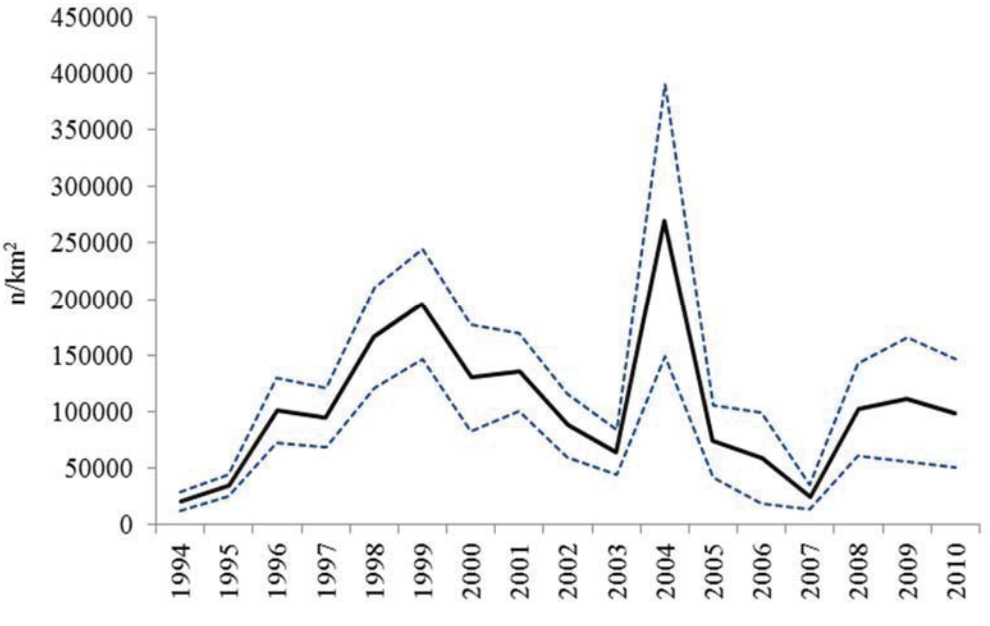


Figure 70. Abundance index of recruitment of *P. longirostris* in GSA 16 derived by MEDITS trawl surveys.

Stock assessment

In the late1980s, the deep-water rose shrimp presented an exploitation rate (E_c=0.8) > than the optimal one (E_{max}=0.67; $E_{0.1}$=0.66; $E_{0.5}$=0.41) (Levi *et al.*, 1995) (Figure 71).

Levi *et al.* (1995) predicted a more efficient exploitation of the resource in the long term as a result of reducing the fishing mortality by about 20% or by increasing the cod-end mesh size from 30 to 40 mm opening (Figure 72).

Overfishing was confirmed (0.65<E<0.75) in the late-1990s with an estimated fishing effort of 46–53% of the present level needed to move the exploitation rate towards that needed to ensure more sustainable fisheries (E_{opt} = 0.35) (Table 34).
Further analysis suggested that an increase of 4–6 % in the yield per recruit and of 25–33% in income per recruit would be obtained if the 40 mm cod-end mesh size was adopted instead of the 30 mm mesh size in use (Table 35) (IRMA–CNR, 1999).

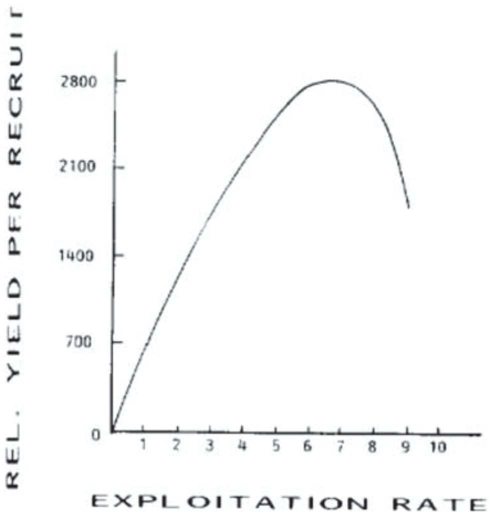


Figure 71. Relative yield per recruit vs. exploitation rate. Calculations with L∞ = 30.5 mm and M/K = 0.27. Emax = 0.67; E0.1 = 0.66; E0.5 = 0.41 and Ec = 0.8 (from Levi *et al.*, 1995).

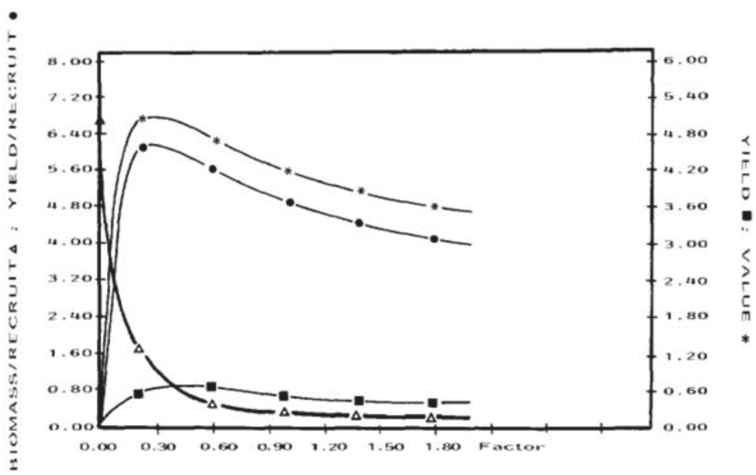


Figure 72. Long-term projection, based on the Thompson and Bell model, of biomass per recruit (in grams), yield per recruit (in grams), yield in weight (in grams) and value per recruit (in Italian lire). *X-axis* coefficient with respect to the present level of fishing mortality (F) (from Levi *et al.*, 1995).

Table 34. Percentage reduction in the exploitation rate (E = F/Z) assuming as reference point Eopt = 0.35 in the mid–late-1990s. E values for area A (on the Italian side of the mid-line in the Strait of Sicily) and for area B (on the North African side of the mid-line in the Strait of Sicily) are distinguished as *EA* and *EB*, respectively (from IRMA–CNR, 1999).

EA	EB	% Reduction in current level of E required to reach E_{opt} (0.35)	
		A	B
0.75	0.65	53	46

Table 35. Simulation of long-term variation in yield (in grams) per recruit (Y/R) and income (in Italian lire) per recruit (£/R) with a change in cod-end mesh size from 30 to 40 mm, according to the Thompson and Bell model. Values for area A (on the Italian side of the mid-line in the Strait of Sicily) and B (on the North African side of the mid-line in the Strait of Sicily) are distinguished (from IRMA–CNR, 1999).

Area	F	Y/R(g) "30"	Y/R(g) "40"	Δ %	£/R "30"	£/R "40"	Δ %
A	1.8	2.1	2.3	5.9	20	27	33.3
B	1.4	2.1	2.2	3.6	23	29	24.8

Within the framework of the MedSudmed project, joint stock assessments for the *P. longirostris* were carried out using a common data-set from Italy, Tunisia and Italy (Knittweis *et al.*, 2013). These assessments were performed using length cohort analysis (LCA) (Table 36). The extended survivor analysis (XSA) was also run to assess the state of the stock of *P. longirostris* (Ben Meriem *et al.*, 2012).

The more recent assessment of the state of the stock in GSA 12, 13, 14, 15 and 16 used the commercial catches of the years 2007, 2008, 2009, 2010, 2011 and 2012, by LCA and yield per recruit analysis (Ben Meriem *et al.*, 2013). Current mean F and exploitation pattern were assessed using the steady state LCA on length frequency distributions (LFD) from 2007 to 2012 as well as the average 2007-2012 catches, raised to the total landings. Analyses were performed separately on length frequency distributions of females and males and by keeping fleet segments separate. 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.
The VIT was also used to estimate biomass and to conduct yield per recruit analysis. The latter was done in order to analyze the stock production with increasing exploitation under equilibrium conditions. The biomass and yield per recruit values by sex were combined to obtain a single value for both the sexes by using an average, weighed by sex ratios (0.55 females and 0.45 males). The fishing mortality obtained showed high values of F on largest size although catches include also the juvenile fraction of the stock (Figure 73).

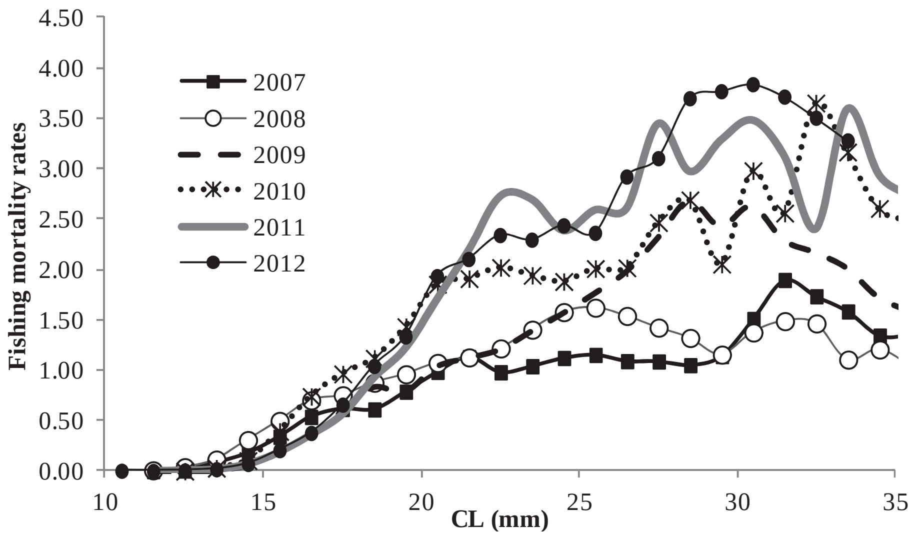


Figure 73. Evolution of fishing mortalities of *P. longirostris* in the Medsudmed area (from Ben Meriem *et al*., 2013).

Table 36. Input parameters of LCA used for Deep Water Rose Shrimp assessment in the Strait of Sicily (mean 2007-2013). Natural mortality (M), as scalar, was 1.05 and 1.20 in females and males respectively (from Ben Meriem *et al*, 2013).

Mean 2007-2012_Female				
Input parameters	**L_∞**	**k**	**t_0**	
	42.705	0.67	0.208	
A	0.0029			
B	2.4818			
F term	2			
Total Yield	5083553937			
% Yield by country	ITA coast	ITA Dist	TUN	MLT
	61.32	19.95	18.56	0.17
Mean 2007-2012_Male				
Input parameters	**L inf**	**k**	**t0**	
	33.56	0.73	-0.13	
A	0.0034			
B	2.4096			
F term	1.37			
Total Yield	2,289,187,940			
% Yield by country	ITA coast	ITA Dist	TUN	MLT
	68.43	15.05	16.31	0.21

The results of the Yield and Spawing Stock Biomass per recruit (average values 2007-2012) are reported in Figure 74. Considering $F_{0.1}$ as Target Reference Point (TRP), the entire stock appears "overexploited". Considering the mean pattern, to increase the value of this TRP is necessary to reduce the current value of F by about 13%. A reduction in the current value of F may not induce a substantial change in the long-term production but would result in a significant increase in SSB (Table 37).

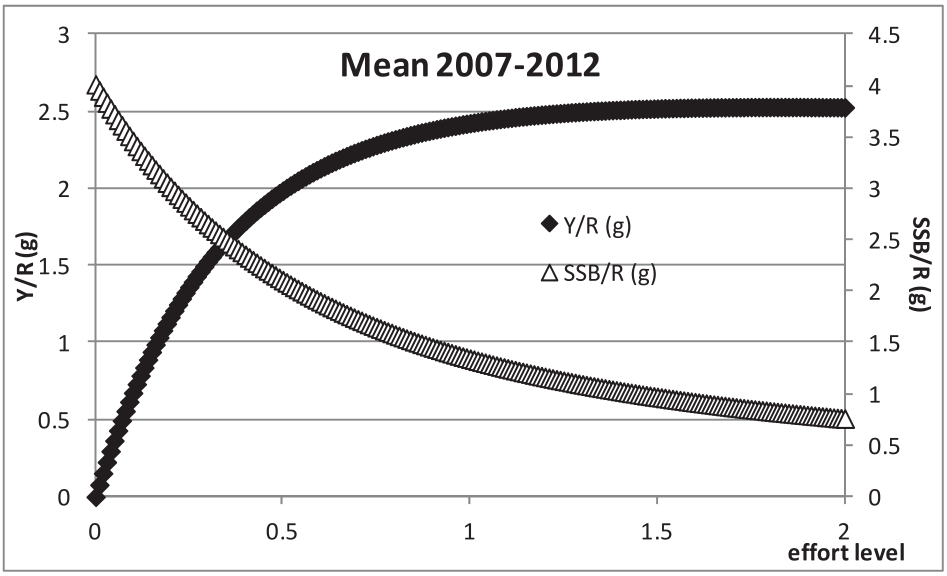


Figure 74. Average Yield (Y/R) and Spawing Stock Biomass (SSB/Y) per recruit of deep water rose shrimp in the Strait of Sicily varying current fishing mortality (Fc) by a multiplicative factor according to LCA (from Ben Meriem et al., 2013).

Table 37. 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 F0.1 is marked in bold (from Ben Meriem et al., 2013).

Year	Factor	F	Y/R	B/R	SSB/R
	0	0	0	4.78	3.88
2007	**1.25**	**1.08**	**2.18**	**2.31**	**1.54**
	1	0.86	2.09	2.46	1.68
	0	0	0	5.14	4.09
2008	**1.05**	**1.14**	**2.49**	**2.41**	**1.46**
	1	1.08	2.46	2.46	1.51
	0	0	0	5.04	4.05
2009	**0.91**	**1.34**	**2.50**	**1.58**	**2.42**
	1	1.48	2.50	2.32	1.43
	0	0	0	5.27	4.08
2010	**0.70**	**1.12**	**2.57**	**2.46**	**1.42**
	1	1.60	2.74	2.03	1.05
	0	0	0	5.10	4.09
2011	**0.54**	**0.97**	**2.42**	**2.50**	**1.59**
	1	1.77	2.64	1.91	1.05
	0	0	0	5.24	4.19
2012	**0.56**	**1**	**2.47**	**2.58**	**1.61**
	1	1.80	2.67	1.89	1.00
	0	0	0	4.97	4.01
Average catch 2007-2012	**0.87**	**1.18**	**2.33**	**2.50**	**1.63**
	1	1.36	2.42	2.18	1.34

In addition to LCA, an assessment based the Extended Survivors Analysis (XSA) was performed on commercial catch of Malta, Tunisia and Italy for the years 2007-2011 calibrated with data from campaigns to sea MEDITS relating to GSA GSA 15 and 16 (partial tuning). No data on discards were available. Annual length frequency distributions from both the commercial and landed campaigns MEDITS were converted into age structures using the package LFDA5. The vector of natural mortality (M) age was calculated by Gislason *et al.* (2008). Some of the outputs of XSA in terms of fishing mortality, spawning stock biomass and recruitment, are reported in Table 38.

It is worth noting that the tuning with the biomass estimation from trawl surveys, resulted in a decrease of the fishing mortalities with respect to the estimates obtained using only the catch values. Furthermore, considering $F_{0.1}$= 1.18, the stock status passed from "in overfishing" (F_c=1.27 in 2011) to "sustainable fishing" (F_c= 0.72 in 2011).

Table 38. Fishing mortality (F), spawning stock biomass (SSB) and recruitment estimates by XSA for *P. longirostris* in 2007 to 2011 with shrinkage set at 0.5, 1 and 2. 0.5 and 2.0 corresponds to the lowest and highest influence of trawl surveys information respectively. The shrinkage corresponding to the reference value chosen is marked in bold (from Ben Meriem et al., 2013).

			F0-2		
Shrinkage	2007	2008	2009	2010	2011
0.5	**0.99**	**0.94**	**1.43**	**1.57**	**1.27**
1	1.16	0.99	1.13	0.96	0.82
2	1.10	0.91	0.95	0.79	0.72
			SSB (tons)		
Shrinkage	2007	2008	2009	2010	2011
0.5	**10656**	**7957**	**11261**	**7620**	**9102**
1	10046	8035	12714	9215	10395
2	10236	8373	13730	10253	11171
			Recruitment (millions)		
Shrinkage	2007	2008	2009	2010	2011
0.5	**22825**	**35192**	**27359**	**30721**	**28166**
1	23279	37303	28910	32298	29931
2	23846.00	38915	30094	33246	31105

Fisheries

P. longirostris is exploited almost exclusively by bottom trawlers that operate on the outer continental shelf and upper slope of the south-central Mediterranean throughout the year. According to different areas and depths catches includes a variety of species. On the shallower fishing grounds the main accompanying species are hake (*Merluccius merluccius*), horned and musky octopuses *(Eledone* spp.) (, broadtail short squid (*Illex coindetii*), lesser flying squid (*Todaropsis eblanae*), anglerfish (*Lophius* spp.), red mullet and striped red mullet (*Mullus* spp.), seabreams and pandoras (*Pagellus* spp.), John dory (*Zeus faber*) and rays (*Raja* spp.) (Fiorentino et al., 2008). On deeper grounds deep water rose shrimp is associated to 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.) (Knittweis *et al*., 2013).

Fishing zones and seasons

Deep-water rose shrimp is caught both over the shelf and the upper slope all year round, but landings peaks are observed from March to July (Levi *et al.*, 1995). In Tunisian fisheries the landings peaks are observed from February to July (Figure 75) Traditionally, Sicilian off-shore trawlers concentrate on three main fishing grounds: from North-West to South-East, these are known as “Ponente” (West in the Figure), “Kelibia” and “South Lampedusa”. Each fishing ground is, in turn, further subdivided into distinct fishing banks (Levi *et al.*, 1995) (Figure 76).

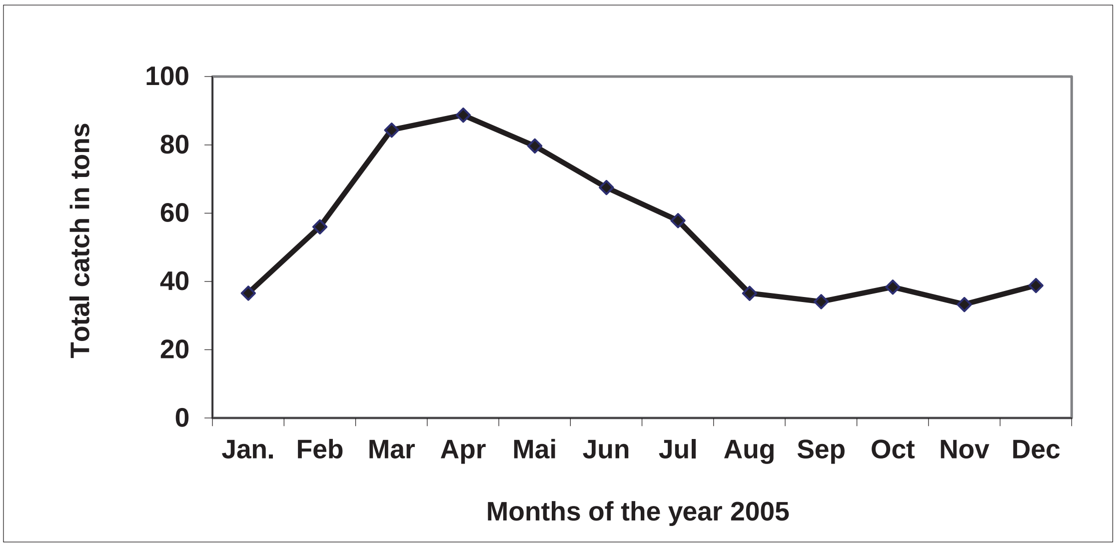


Figure 75. Variations of the avarage yields per month of *P. longirostris* in Tunisian fishery (average from 1995 to 2005) (Annuaires statistiques of DGPA 2005, Tunisia).

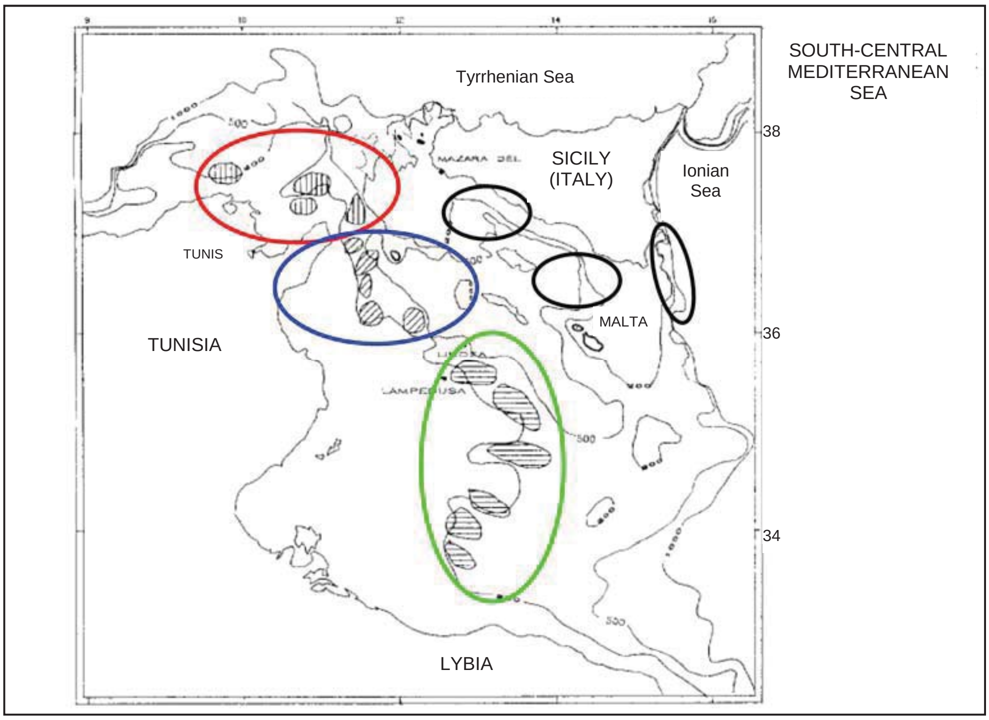


Figure 76. The main fishing areas of *Parapenaeus longirostris* for large (> 24m length overall, coloured lines) and small (12-24 m length overall, black lines) Sicilian trawlers in the south-central Mediterranean (modified from Levi *et al.*, 1995).

Inside the Maltese FMZ, which includes a substantial part of GSA 15, the most important fishing grounds for *P. longirostris* were the deepest ones (J, K, L, M, N in Figure 77) (Camilleri *et al.*, 2008).

Yield

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; GFCM capture production dataset) (Figure 78).

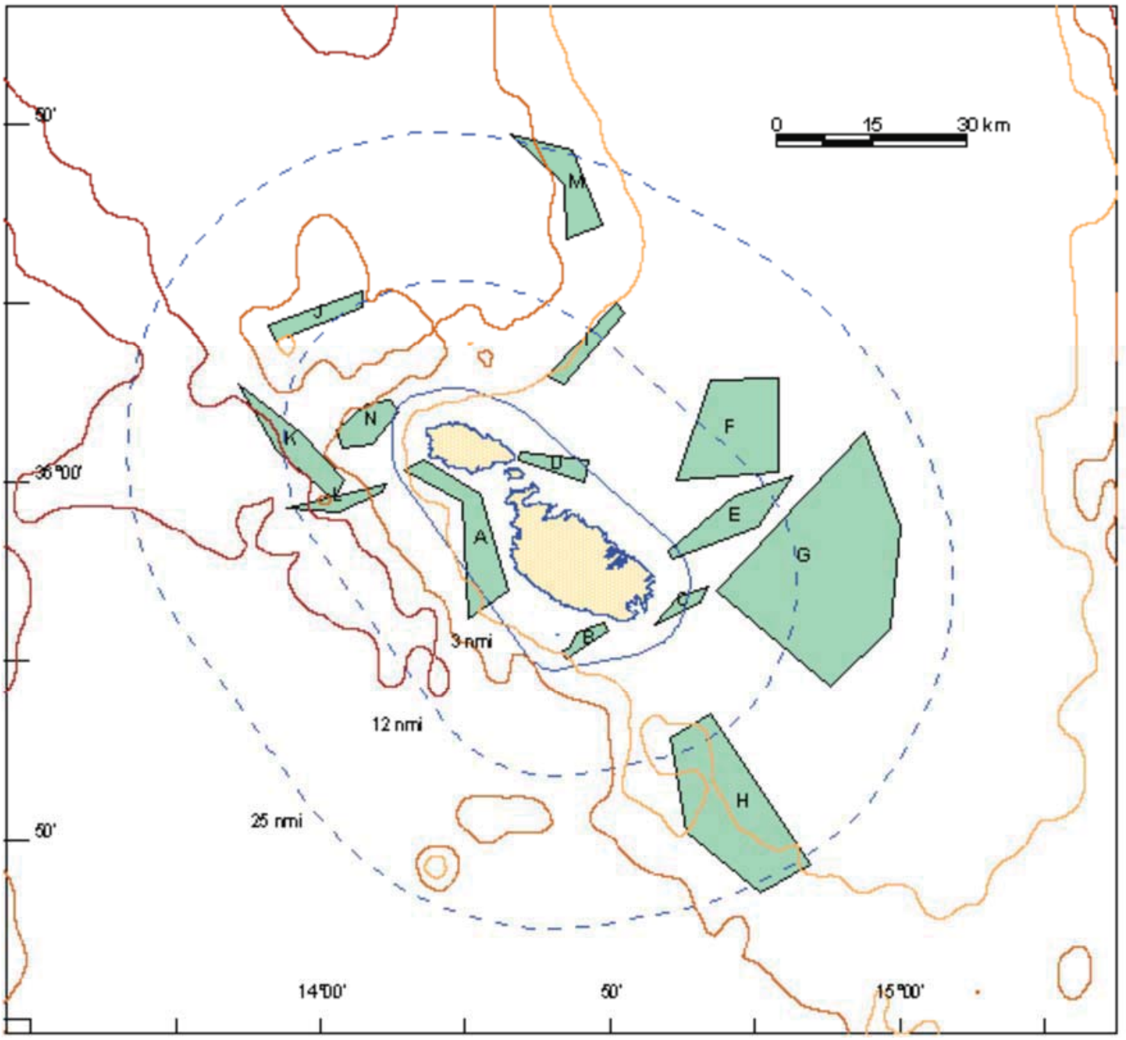


Figure 77. Trawlable areas inside the Maltese Fisheries Management Zone (FMZ) within 25 nm from Maltese Islands (A, B, C, D protected, trawling forbidden; E, F, G, H, I shelf /shallow water; J, K, L, M, N slope/deep water, the most relevant to shrimp fishery) (from Camilleri *et al.*, 2008).

Since most of the deep-water rose shrimp catches are made by long-distance trawlers (fishing trips of 20–30 days), the values above have to be considered as a fraction of the overall production of the Sicilian trawler fleet. The estimated overall annual yield of the Mazara del Vallo offshore trawler fleet in the late-1980s to the early-1990s ranged between 2,360 and 5,180 tons (Levi *et al.*, 1995). The deep water rose shrimp yield of all the Sicilian boats fishing in the Strait of Sicily (inshore and offshore fisheries) at the beginning of the new century varied between 6,665 in 2003 and 8,584 in 2005 (from IREPA data). The estimated overall annual yield of the Tunisian rose shrimp reached a maximum of 2.000 tons in 2006 (Figure 79) (Ben Meriem and Hadj Mbarek, 2009).

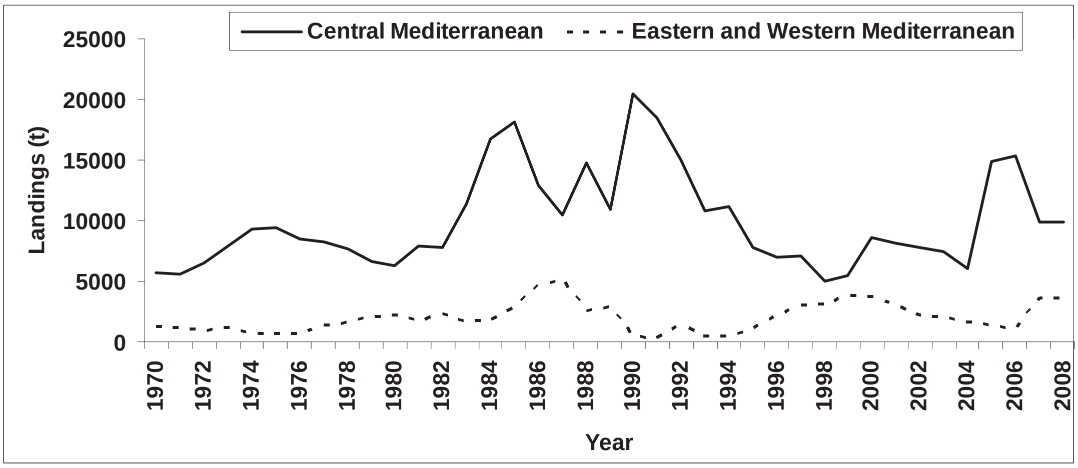


Figure 78. Capture production of *Parapenaeus longirostris* in the Mediterranean Sea from 1970 to 2008 (source: FAO/GFCM). The estimated yield of inshore trawlers fishing *P. longirostris* (1–2 day trips) in GSA 16 between April 1985 and March 1986 was 1,290 tons; the following year it amounted to 1,637 tons,

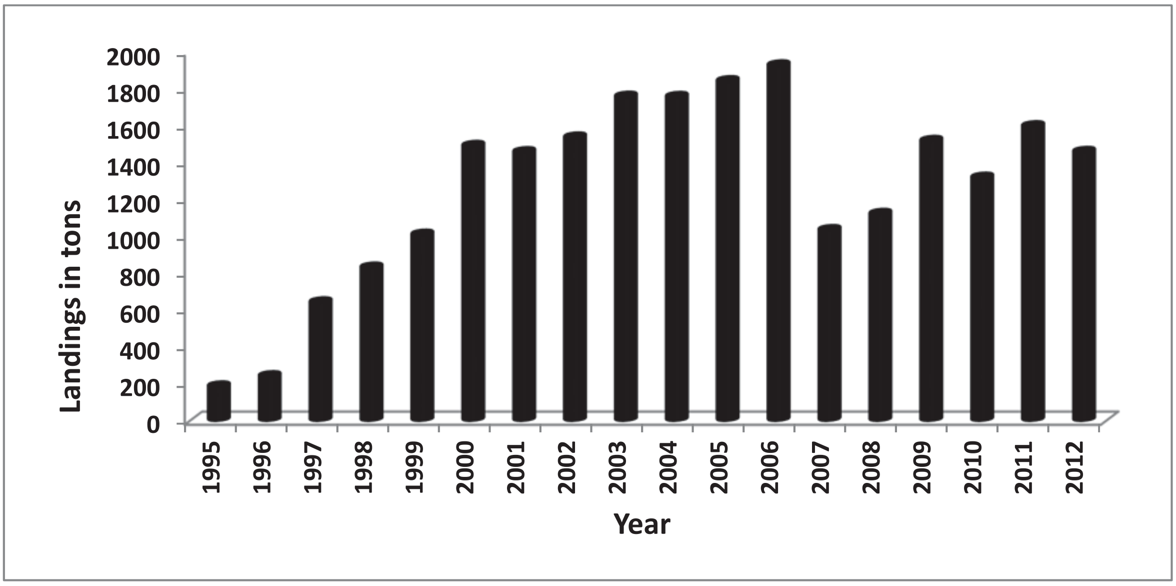


Figure 79. Yield of the Tunisian pink shrimp. (fish statistic of DGPA, Tunisia, 2012)

The analysis of the production by Tunisian regions show that the north provides essential national production of the Tunisian pink shrimp (Figure 80); with an annual average of about 85% of total production. The contribution to this yield by port is indicated in the following figure (Figure 81)

Statistics of shrimp catches in GSA 15 (Maltese trawlers), including red shrimp and deepwater rose shrimp, showed an oscillating trend from 1980 to 2005, with a first maximum in the mid-1980s (about 35 tons), followed by another of similar magnitude in 2003, separated by a minimum in 1993 (about 5 tons) (Figure 82). The very high yield of about 190 tons, in 2001, has been omitted from the graph.

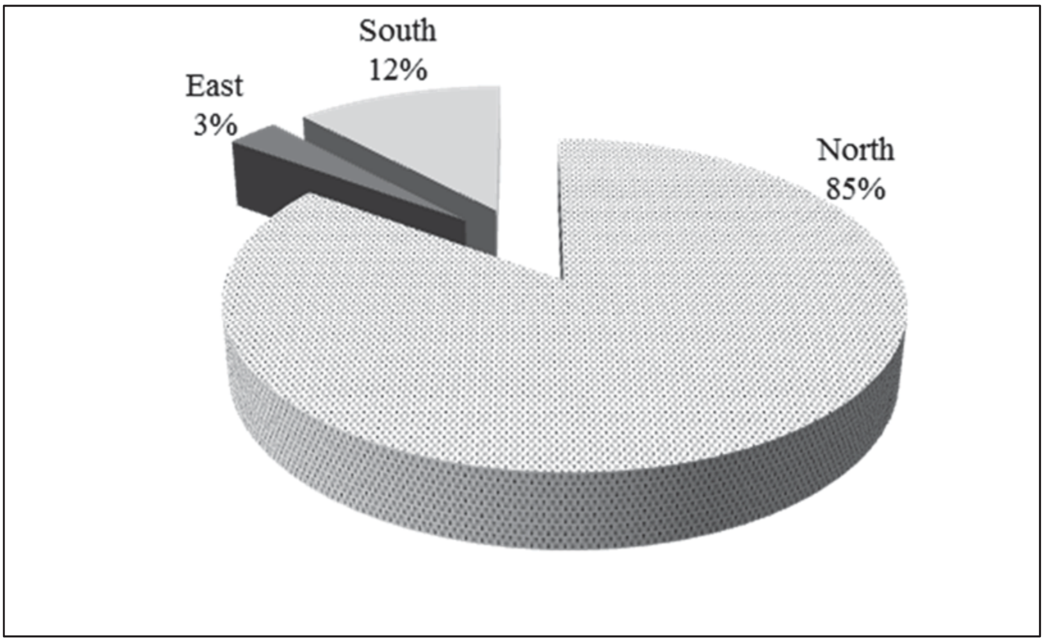


Figure 80. Yield of shrimps (deep-water rose shrimp) by region in Tunisia

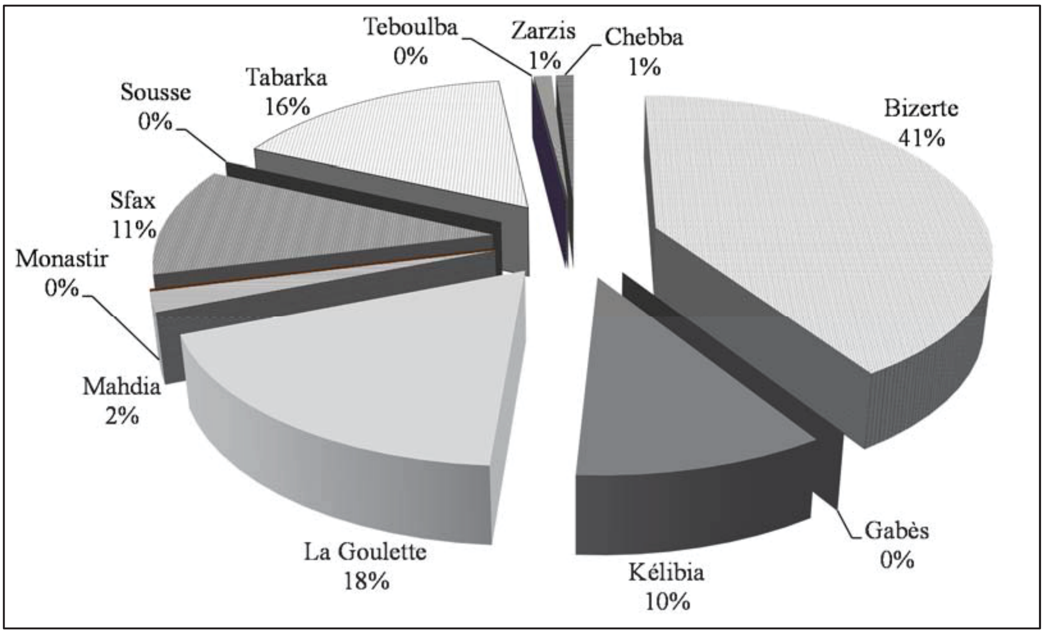


Figure 81. Contribution of the different ports in Tunisia to the total yield of the *P. longirostris.*

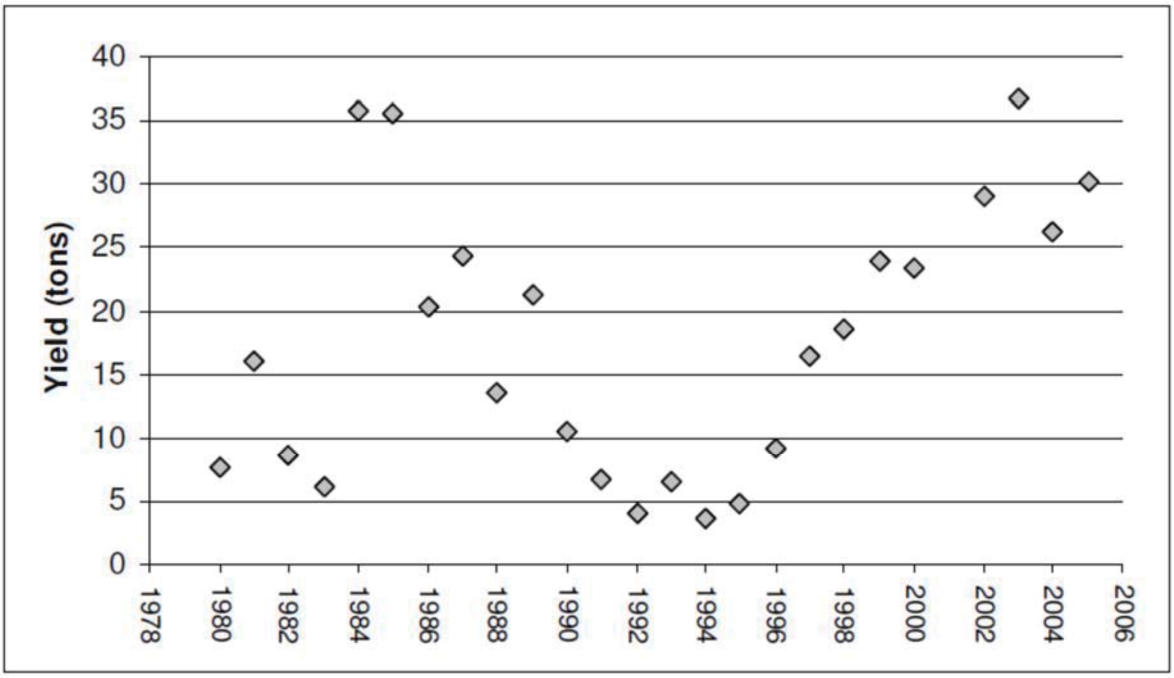


Figure 82. Yield of shrimps (deep-water rose shrimps and red shrimps) by the Maltese trawlers from 1980 to 2005 (drawn from data provided by Camilleri).

The most recent yield values used in stock assement within the MedSudMed Projecct is reported in Figure 83.

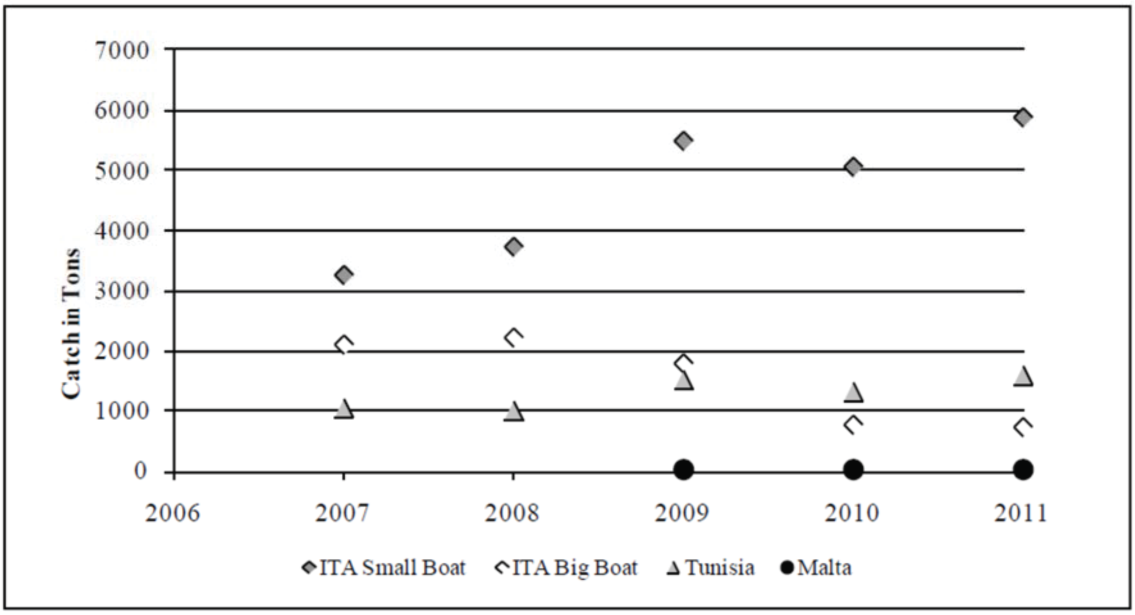


Figure 83. Yield of DPS from 2007 to 2011 in the Strait of Sicily, Central Mediterranean (GSA 12,13,14,15 and 16) (from Ben Meriem *et al.*, 2012)

Fishing and discards

According to Levi *et al.* (1995), the length at 50% capture using a cod-end mesh size of 32 mm mesh size, estimated from the catch curve, was 16.1 mm CL (selection factor = 0.5). More recently, selectivity experiments for the same cod-end mesh size gave an L50% = 13.0 ±0.1 (mm) (selection range = 5.2 and SF = 0.42) (Ragonese and Bianchini, 2006).

The modal individual size in the catch and in the discarded fraction of *P. longirostris* taken by Sicilian trawlers is very variable according to the season and the depth ranges of the various fisheries (Table 39). The amount of discards is also variable, being higher in autumn–winter and from trawling catches between depths of 150 and 300 m (Anon., 2000).

Table 39. Annual modal length (carapace length, CL, in millimeters) of individual *P. longirostris* in the discarded fraction and in the landings of typical inshore (Porto Palo, southeastern Sicily) and distant (Mazara del Vallo, southwestern Sicily) Sicilian trawl fisheries (from Anon., 2000).

Fishery	Modal length (CL, mm)	
	Discards	Landings
Inshore	12	16 and 19
Distant	19	25-26

Recent studies on the discarded fraction of trawl catches in GSA 16 during 2006 gave a length at 50% discard ranging between 14.6 and 17.0 mm CL (V. Gancitano, pers. comm.).

Gears

The Italian trawlers targeting deep-water rose shrimp in the Strait of Sicily use the “fondale” type of the trawl net called “Italian trawl net”. The Italian trawl net is characterized by a low vertical opening (up to 1.5 m), with overall dimensions depending on engine power (Table 40) (Fiorentino *et al.*, 2003c).

Table 40. Main characteristics of the traditional Sicilian trawl nets used in the Strait of Sicily for a “reference” trawler equipped with a 375–450 kW (~ 500–600 HP) engine (from Fiorentino *et al.*, 2003c).

Net characteristic	**Banco net**	**Fondale net**
Length of codend	5-6 m	5-6 m
Length of extension piece	20-21 m	23-25 m
Lastridge rope	Absent	Absent
Circumference of codend	400-450 mesh*40-36 mm	500-600 mesh*28-26 mm
Circumference of extension piece	900-1000 mesh*44-40 mm	400 mesh*50-52 mm

The fleet targeting the pink shrimp in the north of Tunisia has increased in the beginning of the 90s but their number decreased in the late 90. A new entry of some industrial (frozen) trawlers is observed at the beginning of 2000s (Figure 84).

Figure 84. Number of trawlers targeting the pink shrimp in the north region of Tunisia (fishing statistic of DGPA, 2014 Tunisia).

Legislation and management

At present there are no formal management objectives for *P. longirostris* fisheries in the Strait of Sicily. As in other areas of the Mediterranean, the stock management is based on control of fishing capacity (number of fishing licences), fishing effort (days at sea, number of trawls), and technical measures (cod-end mesh size, area closures and size limits).

In order to limit the over-capacity of the fishing fleet, the number of Italian fishing licences has been fixed since the late1980s. Since 2000, in conformity with the European Common Fisheries Policy, a gradual decrease in fleet capacity has occurred. Furthermore, from 1987 to 2005, an annual 30–45-day fishery closure was enforced, although in different ways, in order to reduce fishing effort.

A medium-term management plan for 2008-2013 has been agreed for Italian trawlers targeting rose shrimp in the Strait of Sicily. Italian Management Fishery Plans (IFMP) is based on:

• a reduction of 25% of the current fishing fleet capacity obtained in two steps. The first (12.5%) from 2008 to 2010, and the second (12.5%) from 2011 to 2013.

• a trawling ban of 45 days per year between January and March.

Although included in the medium-term fisheries management plan, no measures of protection of nurseries are currently implemented.

According to Cacaud (2002), the Tunisian authorities can limit the number of boats fishing in a given area and they can impose fishery closures of up to three months, which can be renewed.

The new EC Regulation 1967, of 21st December 2006, fixed for the first time a minimum marketable size of *P. longirostris*, which is of 20 mm CL for the Italian and Maltese trawl fisheries.

In Tunisia, no regulations specifically targeting the rose shrimp fishery are currently in place. However, trawling is not permitted within 3 nautical miles of the coast and at less than 50m depth in GSAs 12-14. Moreover, in GSA 14 a closed season where trawling is prohibited from July-September is in place in order to protect recruits of a large number of species. Although minimum landing sizes exist for a number of crustacean species harvested by the Tunisian fleets, there is no minimum landing size for *P. longirostris*. The minimum legal mesh size used by benthic trawlers in Tunisian waters is 20mm.
The new EC Regulation 1967, of 21st December 2006, fixed 40 mm opening as the minimum mesh size for cod-ends of bottom trawls for EU fishing boats (Italian and Maltese trawlers). With effect from July 2008, mesh size has to conform to a square mesh size of 40 mm opening or a romboidal mesh size of 50 mm opening, although derogations were possible up to 2010.
Available information suggests that the new mesh size should improve the deepwater rose shrimp fisheries (Sobrino *et al.*, 2005; Ragonese *et al.*, 2006). A further improvement in the fishery might be obtained through the protection of *P. longirostris* nurseries (Fortibuoni *et al.*, 2010). Similarly to hake, the shrimp nurseries are located in separate offshore areas on the outer shelf (100–200 m depth range) The fisheries in the Maltese FMZ in the Strait of Sicily, which extends up to 25 nautical miles from baselines around the Maltese islands, are specifically managed on the basis of the control of the fleet capacity.
The access of European Community vessels to the waters and resources in the Maltese FMZ is regulated as follows:
(a) fishing within the Maltese FMZ is limited to fishing vessels smaller than 12 metres overall length using other than towed gears, and
(b) the total fishing effort of those vessels, expressed in terms of the overall fishing capacity, must not exceed the average level observed in 2000–2001, which corresponds to 1,950 vessels with an overall engine power of 83,000 kW and an overall tonnage of 4,035 GT.

Trawlers not exceeding an overall length of 24 metres are authorized to fish in certain areas within the Maltese FMZ. The overall fishing capacity of the trawlers allowed to operate in the Maltese FMZ must not exceed the limit of 4,800 kW and the fishing capacity of any trawler authorized to operate at a depth of less than 200 m must not exceed 185 kW.
Trawlers fishing in the Maltese FMZ hold a special fishing permit in accordance with Article 7 of Regulation (EC) No 1627/94 and are included in a list containing their external marking and their corresponding Community fleet register number (CFR) to be provided to the Commission annually by the Member States concerned.

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