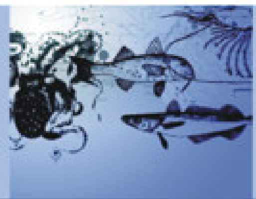

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MEDSUDMED - TECHNICAL DOCUMENTS

Synthesis of information on some target species in the MedSudMed Project area (central Mediterranean)

MEDSUDMED

ASSESSMENT AND MONITORING OF THE FISHERY RESOURCES AND ECOSYSTEMS IN THE STRAITS OF SICILY

MiPAAF

MedSudMed

GCP/RER/010/ITA

Synthesis of information on some target species in the MedSudMed Project area (central Mediterranean)

MedSudMed Technical Documents
GCP/RER/010/ITA/MSM-TD-15

Rome (Italy), November 2008

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 Food, Agriculture and Forestry Policies (MiPAAF).

MedSudMed promotes scientific cooperation among research institutions of the four participating countries (Italy, Libyan Arab Jamahiriya, Malta and Tunisia), for the continuous and dynamic assessment and monitoring of the state of the fisheries resources and the ecosystems in this area of the Mediterranean.

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

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GCP/RER/010/ITA Publications

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

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

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Preparation of this document

This document collates the knowledge available on the biology, ecology and exploitation of four target species recognized by the MedSudMed Project. The document is mainly based on sheets firstly prepared with the support of the Consiglio Nazionale delle Ricerche – Istituto per l'Ambiente Marino Costiero (Italy), the Marine Biology Research Centre (Libya), the Malta Centre for Fisheries Sciences (Malta) and the Institut National des Sciences et Technologies de la Mer (Tunisia).

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ABSTRACT

The present document reviews the knowledge currently available on the biology, ecology and exploitation of *Merluccius merluccius*, *Mullus barbatus*, *Octopus vulgaris* and *Parapenaeus longirostris*, taken from the list of MedSudMed target species. Available knowledge was organized to furnish a synthetic description of these species, 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 and discards). Finally a brief compilation of current fishery legislation and management in each country was made.

Table of Contents

Synthesis of information on some target species in the MedSudMed Project area (central Mediterranean)

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 better identify 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-term activities, entitled "Spatial distribution of demersal resources in the Project area and the influence of environmental factors and fishery characteristics."

Thenceforth, several research activities were planned and organized according to the needs expressed by the research institutions involved in the Project, under the specific output "Results on spatial distribution of fisheries resources and their ecosystems at subregional scale provided by cooperative research activities implemented following an agreed work-plan". Moreover, further to these requests, during the 5th MedSudMed CC (Rome, Italy, 9–10 November 2006), the Project included in the workplan for 2007 the production of synthetic species sheets for demersal species, summarizing knowledge on the target species (taken from the list of MedSudMed target species) in the Project area. The subdivision of the Mediterranean region into Geographical Sub-areas is reported in Annex A.

This document reviews and compiles the scientific information collected on four of the main commercial species of the Straits of Sicily: European hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*), common octopus (*Octopus vulgaris*) and deep-water pink shrimp (*Parapenaeus longirostris*). The document provides a description of each of these target species, 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–MedSudMed Project. The collaboration of several co-authors from four countries has also permitted the retrieval of the scientific works originally published in the national languages, the content of which has been summarized. Furthermore, attention has been given to the so-called grey literature, often of value and relevance but poorly known.

This paper cannot, and does not aim to, be exhaustive either in terms of target species examined or of literature screened: recently, a considerable amount of relevant scientific literature has been published which could not be taken into account in this review. However, it is intended to update the information in the present document periodically in the future and eventually include some other target species.

Merluccius merluccius (Linnaeus, 1758)

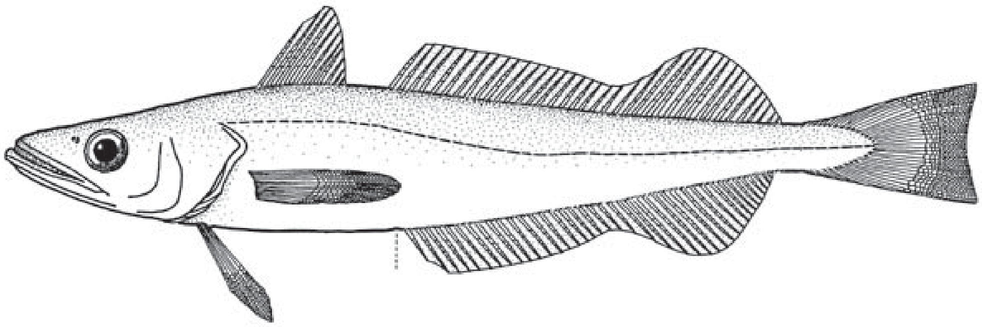


Figure 1 – *Merluccius merluccius* (from Fischer et al., 1987).

Species description

The body of *Merluccius merluccius* (Linnaeus, 1758), commonly known as European hake, is long and cylindrical (Figure 1). The widest part (i.e. maximum body depth) is behind the head. There are two dorsal fins. The first one is short and triangular and the second one is long. The anal fin is similar in shape and size to the second dorsal fin. The pectoral fins are posterior to the ventral fins. The caudal fin has a straight, vertical trailing edge. The colour is slate grey above and lighter on the sides, the belly is whitish (Fischer et al., 1987).

Differences in the vertebral number have been detected between Atlantic and Mediterranean specimens (Cadenat, 1950), as well as among western, central and eastern Mediterranean hakes (Maurin, 1965). Genetic studies have confirmed the former distinction (Pla et al., 1991; Roldán et al., 1998) and results of similar studies in the central Mediterranean are confirming the latter (Lo Brutto et al., 1998).

According to Lloris et al. (2003), at least two subspecies live in the Mediterranean: *Merluccius merluccius merluccius* (Linnaeus, 1758), which inhabits the eastern Atlantic Ocean and the southwestern Mediterranean (pectoral fins longer than ventral ones); and *Merluccius merluccius smiridus* Rafinesque, 1810, which lives in the northwestern Mediterranean (pectoral fins as long as the ventral ones). Other subspecies may occur in other areas of the Mediterranean (Orsi Relini et al., 2002). However, for the purpose of this description, apart from meristics, the division into sub-species will not be considered and references/description will be provided for *Merluccius merluccius* in general.

Meristics

Lloris et al., (2003) give the following meristics for the two recognized subspecies:
Merluccius merluccius merluccius: D1: 9 (10) 11, D2: 35 (38-39) 40, A: 36 (38) 40, P: 10 (14) 15, V: 7; Br. 8 (10) 12; Lat. Lin. 127-156.
Merluccius merluccius smiridus: D1: 8 (10) 11, D2: 35 (38-39) 40, A: 36 (38) 40, P: 10 (14) 15, V: 7; Br. 8 (10) 12; Lat. Lin. 133-143.

Ecology

Geographical distribution
M. merluccius is distributed in the north-eastern Atlantic, from Norway to Mauritania and in the entire Mediterranean; in the Black Sea, the species lives only along the southern coasts (Lloris et al., 2003).

Habitats
M. merluccius is a necto-benthonic fish living at depths between 10 and 1000 m, although it is found mostly between depths of 70 to 400 m. The bathymetric distribution of this species is related to size, the smaller specimens being caught more frequently on the outer continental shelf (50–200 m depths), while the larger ones are mainly distributed along the continental slope (Colloca, 1999). *M. merluccius* prefers muddy bottoms, but it also occurs on other types of bottom (muddy–sandy and sandy bottoms). On the basis of the MEDITS Trawl Survey data (1994–1999), hake was found in GSAs 15 and 16 with an overall frequency exceeding 65% of the hauls, and occurred more often over the shelf (> 80%) than on the slope (about 55% of the hauls) (SAMED, 2002).

Migrations
In daylight, the European hake in the central Mediterranean stays close to the bottom and moves vertically to shallower depths at night. In addition to diel migrations, which affects juveniles (Orsi Relini et al., 1997; Carpentieri et al., 2005), horizontal migrations as a consequence of searching for food have also been reported (Colloca, 1999). The smallest specimens are caught mainly on the outer shelf and over the upper slope (50–300 m depth), while the largest ones are caught along the slope (>200m) (Colloca, 1999; Orsi Relini et al., 2002).

Biological information

Maximum size
According to Lloris et al. (2003) the species reaches a maximum size of 89 cm total length (TL) and a maximum weight of 6 kg in the Mediterranean; however specimens from 14 to 60 cm TL are generally found in the commercial fisheries landings. Considering the northern sector of the Strait of Sicily (GSAs 15 and 16), the observed maximum length is 88 cm TL in females (Fiorentino et al., 2003a) and 58.5 cm TL in males (M. Dimeck, personal communication).

Spawning
In the literature for the Mediterranean, Oliver and Massuti (1995) and Papaconstantinou and Stergiou (1995) have reported an extended spawning period in the Strait of Sicily and adjacent seas.

Although spawning off Tunisia (GSA 12) occurs all the year round, Bouhlel (1973) reported three maturity peaks: in summer, winter and spring, according to the size of the female hake. The largest females (LT > 40 cm) spawn mainly in spring, whereas the smallest (29<TL<39 cm) have two main peaks: one in summer and another in winter.

Bouaziz et al. (1998a), studying samples from Bou-Ismail (GSA 4), reported that the spawning season runs throughout the whole year, even if a peak in summer is evident. According to Levi (1991), mature specimens were collected both in autumn (November) and winter (February) (GSAs 15 and 16).

Information on the northern sector of the Strait of Sicily (GSA 16) indicates that the outer shelf on the western side of Adventure Bank might be a hake spawning area (Fiorentino et al., 2006a). According to the literature, spawning should occur over the outer shelf–upper slope. Aggregation of mature adults was reported on the outer shelf–upper slope of the Adriatic Sea (Zupanovic, 1968), and between 100 and 200 m depth in the Gulf of Tunis (Bouhlel, 1973). In the northwestern Mediterranean (i.e. Catalan sea) Recasens et al. (1998) found that spawners are concentrated between the shelf break and the upper slope (150–350 m).

Length at first maturity
Available estimates of length at first maturity for the Strait of Sicily (Table 1) are fairly close to those given in the literature on the Mediterranean (Oliver and Massuti, 1995; Papaconstantinou and Stergiou, 1995).

Table 1 – Length at 50% maturity ($L_{50\%}$) and curvature parameter (g), by sex, of hake in the Strait of Sicily (*n.a.* = not available).

Author	**GSA**	**Females**		**Males**		**Remarks**
		$L_{50\%}$	g	$L_{50\%}$	g	
Bouhlel (1973)	12, 13	30.5	n.a.	28	n.a.	Empirical estimation
Mugahid and Hashem (1982)	21	24.5 (30)	n.a.	21	n.a.	Empirical estimation
Bouaziz et al. (1998a)	4	30.6	n.a.	21.5	n.a.	By ogive at maturity
SAMED (2002)	15, 16	33.5	n.a.	n.a.	n.a.	By ogive at maturity
Gancitano et al. (2007)	16	37.6	0.288	27.8	0.329	By ogive at maturity

Eggs, larvae and post-larvae
Although it is known from the literature (Lloris et al., 2003) that eggs, larvae and post-larvae of *M. merluccius* are pelagic, no information is available for the Strait of Sicily.
Eggs have been found between 50 and 200 m depth in the Adriatic (Karlovac, 1965). Pelagic larvae in the Mediterranean have been found on the outer shelf–upper slope along the Catalan coast (Sabatés, 1990). More recently, eggs and larvae of hake have been found in winter and spring in the northern Tyrrhenian Sea, and, except in winter, off the Catalan

coast. Eggs and larvae have been preferentially associated with the shelf, peaking in abundance between 100 and 200 m depths (Olivar et al., 2003).

The change from the pelagic to the benthic habitat occurs when young individuals are about 3 cm TL (D'Ancona, 1956).

Recruitment and nursery areas
Despite the presence of very small specimens of 3.5 cm TL (G. Sinacori, personal communication) in catches during the fine-mesh trawl surveys, hake is only considered fully recruited to the fishing grounds at 10 cm TL (SAMED, 2002). In contrast to other areas of the Mediterranean, where two main recruitment pulses are known to occur (Orsi Relini et al., 2002), the analysis of the length–frequency distribution throughout the year suggests that, in GSAs 15 and 16, recruits reach the fishing grounds all year round (SAMED, 2002).

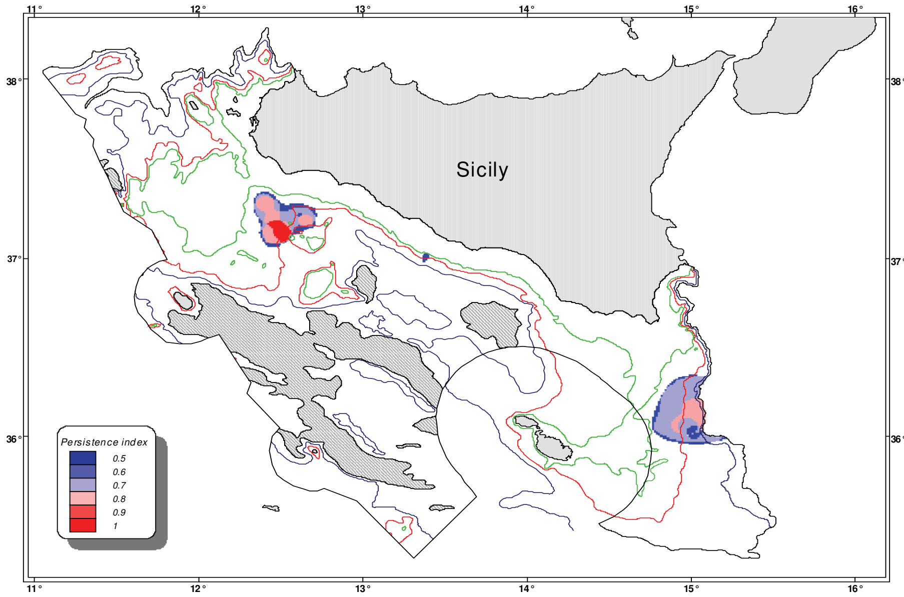


Figure 2. Areas showing stable presence of recruits of *M. merluccius* between 1994 and 1999 in GSAs 16 and 15, excluding the Maltese Fisheries Management Zone (FMZ). The index of persistence ranges between 0 and 1, where 1 indicates stable nursery and 0 absence of nursery (modified from Fiorentino et al., 2003b). A map of the GFCM GSAs is in Annex A.

In the northern sector (GSAs 15 and 16), although some inter-annual variability in the distribution of the nursery areas is evident, two stable nursery areas for hake have been identified, which are related to the presence of meso-scale ocean processes (Fiorentino et al., 2003b). These nurseries are on the eastern sides of the Adventure and Malta Banks, between 100 and 200m depth (Figure 2).

Sex Ratio
Bouhlel (1975a), studying samples from the Gulf of Tunis (GSA 12), has reported that the sex ratio (SR), as number of females out of the total number of sexed specimens, was 0.55 for the smallest individuals (TL<30 cm) and 0.8 for the biggest ones (TL>30 cm). Very

similar results have been found on the northern side of the Strait (GSAs 15, 16), with the proportion of females significantly exceeding that of males mainly at larger sizes (SR≥0.75 at TL>32 cm) (Figure 3) (SAMED, 2002).

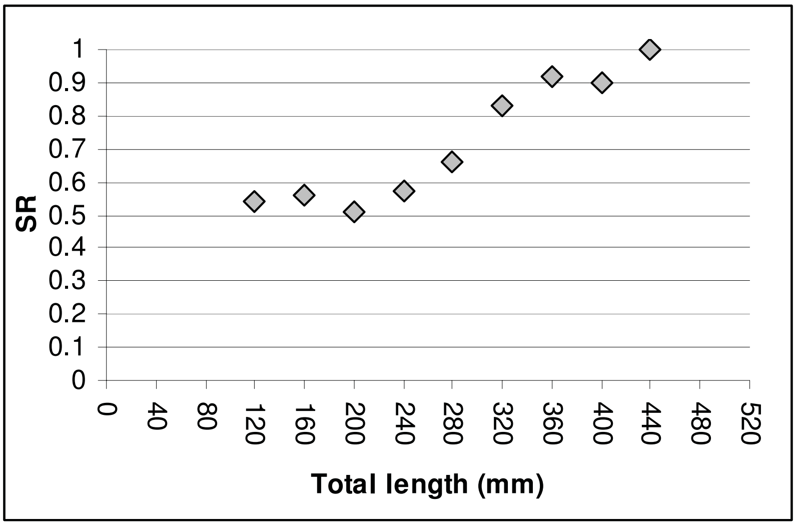


Figure 3. Sex ratio by size of hake in GSAs 15 and 16 (redrawn from SAMED, 2002).

In GSA 16, the sex ratio shows a monotonic significant decrease throughout time, tested by the non-parametric Spearman correlation ($r_s = -0.673$, $p < 0.05$). This result implies a reduction of females in the population since 1994 (Fiorentino et al., 2005) (Figure 4).

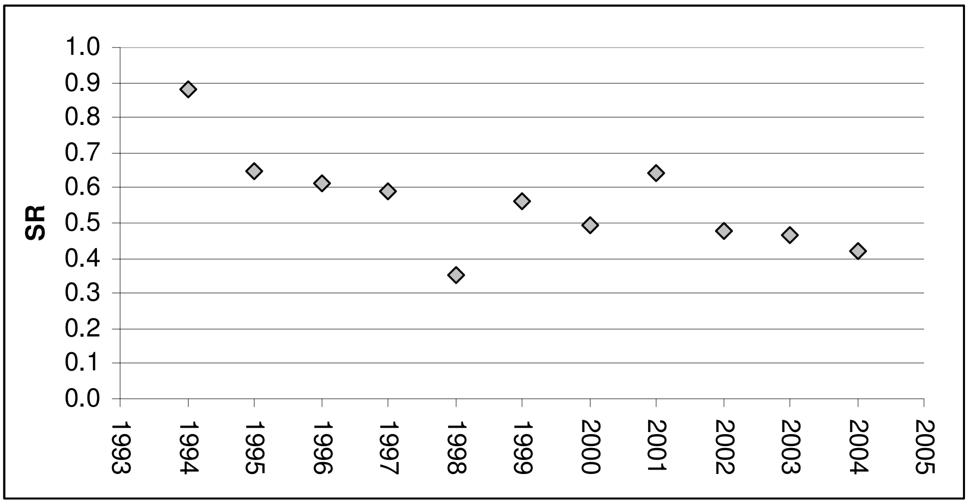


Figure 4. Sex ratio of hake, as the proportion of females in the total number of sexed specimens, in MEDITS Trawl Surveys in GSA 16 (redrawn from Fiorentino et al., 2005).

The significant decrease in the sex ratio could be due to the fishery selectively removing females from the hake stock (see also the subsection on stock assessment here below).
Since individual fish size increases with depth and the sex ratio increases with fish size, a significant increase in the sex ratio with depth has been observed.

Length–weight relationship

The parameters of the allometric length–weight relationships ($TW = a * TL^b$, where TW = Total body weight and TL = total length) are given in Table 2.

Table 2. Parameters of the length–weight relationships of hake in the Strait of Sicily.GSA = Geographical Sub-Area, F = females, M = males; I = immature; a, b = length–weight curve parameters.

Author	**GSA**	**Sex**	**a**	**b**
Bouhlel (1975a)	12	F	0.004	3.20
		M	0.003	3.20
		F+M+I	0.004	3.20
Andaloro et al. (1985)	16	F+M+I	0.006	3.12
Cannizzaro et al. (1991)	15, 16	F	0.007	3.02
		M	0.007	3.02
		F+M+I	0.007	3.04
IRMA–CNR (1999)	15, 16	F+M+I	0.006	3.08
CNR–IAMC (2006)	16	F	0.004	3.17
		M	0.005	3.09
		F+M+I	0.005	3.13
Cherif et al. (2007a)	12	F	0.005	3.11
		M	0.004	3.17
		F+M+I	0.004	3.13

Maximum age and natural mortality

According to Fiorentino et al. (2003a), the maximum estimated age of hake in the exploited standing stock is 15 years. This was established by thin-section otolith readings of the largest females collected in the trawl surveys for over 15 years.

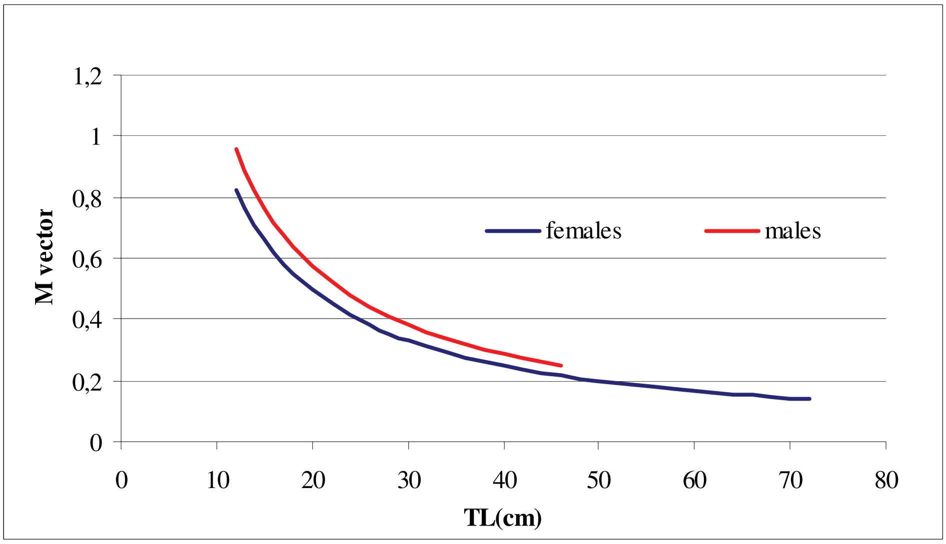


Figure 5. Vector of natural mortality for hake in the Strait of Sicily determined by the Beyer method (Gancitano, personal communication).

On the basis of comparison of the results produced by different methods of estimating natural mortality (Chen and Watanabe; Beverton and Holt Invariants; Alagaraya), M=0.34 for females, M=0.43 for males, have been proposed as reference values for stock assessment purposes (SAMED, 2002).

More recently, Gancitano et al. (2007), using a mean value of natural mortality derived by different methods (Rikhter and Efanov, Pauly, Hoenig, and Beverton and Holt Invariants), adopted a scalar value of M of 0.27 for females and 0.44 for males.

An estimate of the M vector for hake by the Beyer method (Ragonese et al., 2006) was used in length cohort analysis by Gancitano et al. (2007) (Figure 5).

Von Bertalanffy growth function (VBGF)
The Von Bertalanffy growth function parameters, by sex, in different areas of the Strait of Sicily and adjacent seas are given in Table 3.

Table 3. Von Bertalanffy growth function parameters.

Author	**GSA**	**Females**			**Males**			**Remarks**
		L_∞	K	t_0	L_∞	K	t_0	
Bouhlel (1975b)	12	73.00	0.16	–0.80	59.5	0.19	–0.85	Otolith readings + LFD analysis
Andaloro et al. (1985)	16	69.40	0.14	–0;35	57.1	0.16	–0.39	Otolith readings
Bouaziz et al. (1998b)	4	80.64	0.14	–0.44	48.72	0.32	–0.08	LFD analysis
IRMA–CNR (1999)	15,16	70.54	0.18	–0.1	49.37	0.29	–0.01	LFD analysis
SAMED (2002)	15, 16	76.4	0.16	–0.2	44.9	0.28	–0.2	LFD analysis
Gancitano et al. (2007)	16	82.60	0.12	–0.91	52.2	0.22	–0.83	Otolith reading

For comparison, the predicted mean lengths at age of hake, by sex, are shown in Figures 6 and 7. With the exception of the results of Andaloro et al. (1985), hake shows similar growth in populations inhabiting the Strait of Sicily and the adjacent seas.

Excluding the values given by Andaloro et al. (1985), the mean growth rates per month during the first two years range between 0.92 and 1.1 cm for females, and between 0.86 and 1.0 for males. These rates are in line with those reported for juvenile hake in the Mediterranean by Fiorentino et al. (2000).

Recently, results given by otolith readings were considered to underestimate growth, owing to the presence of several checks, which can be confused with annual rings. However, the mean growth rates obtained for the first two years are consistent with those given by De Pontual et al. (2003), based on tagging experiments in the Bay of Biscay (0.84–0.99 cm per month in a size range of 21–40 cm TL).

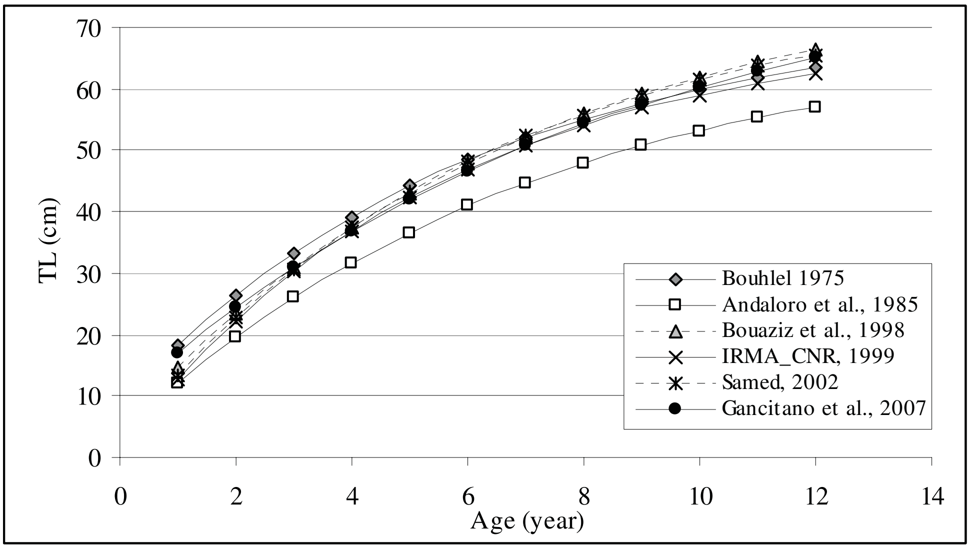


Figure 6. Growth of female hake in the Strait of Sicily (derived from parameters given in Table 3).

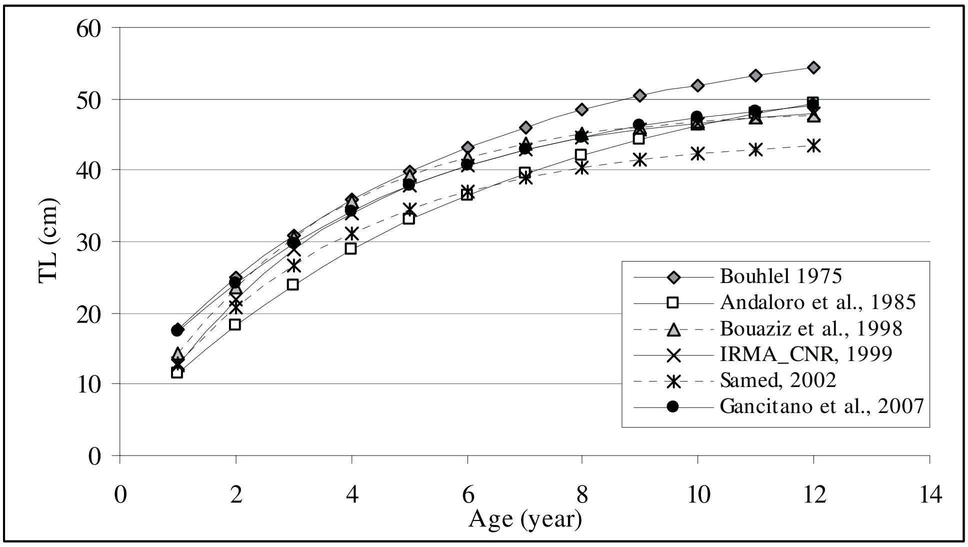


Figure 7. Growth of male hake in the Strait of Sicily (derived from parameters given in Table 3).

Feeding behaviour

According to Bouhlel (1975a) the main prey of hake off the Tunisian coasts (GSA 12) are fishes, such as sardine and anchovy, although hake may also eat crustaceans, such as Norway lobster, *Nephrops norvegicus*, and deep-water pink shrimp, *Parapenaeus longirostris*, and cephalopods, mainly horned and musky octopuses, *Eledone* spp., european squid, *Loligo vulgaris*, and the common cuttlefish, *Sepia officinalis*. Cannibalism has also been reported (Colloca, 1999).

Working on samples from GSA 16, Andaloro et al. (1985) found that the the hake's diet varies according to the fish's size. The smallest fish (4.5–12 cm TL) feed mainly on

Euphausiacea. The main prey of hake between 13 and 24 cm TL is decapod crustaceans, and the preferred food of hake larger than 25 cm TL is fish. Similar feeding preferences depending on size have been observed for other areas of the Mediterranean (see Colloca, 1999).

Stock Units

The stock structure of hake in the Strait of Sicily is still not well known and needs further studies. Levi *et al*., (1994) compared the growth of *M. merluccius* in the Mediterranean and found quite a similar pattern in individuals from the northern side of the Strait of Sicily (GSA15 and 16) and those caught in the Gulf of Gabès (GSA 14). Lo Brutto et al. (1998) have also found no evidence of genetic subdivisions or significant differences in allelic frequencies, between samples near Sicily and those from the mid-line. More recently, Levi et al. (2004) applied electrophoretic, morphometric and growth analyses to test the hypothesis of the existence of a unique stock of hake in the Strait of Sicily, which includes part of the North African continental shelf off the Tunisian coast and the shelf off the southern Sicilian coast. Although the level of genetic variation detected at five selected sampling sites was very low, morphometric analyses and otolith readings revealed some significant differences at a phenotypic level, mainly in females. On the basis of the spatial distribution of spawning and nursery areas compared with the current patterns in the Strait of Sicily, Camilleri et al., (in press) suggested the existence of genetic exchange between hake sub-populations inhabiting GSAs 15 and 16.

Evaluation and exploitation

Biomass and density indices from trawl surveys

The MEDITS Trawl Survey biomass index (kg km^{-2}) showed a reduction in population size from 1994 to 1996, followed by stable, but low, values up to 2001 and by a phase of increase thereafter (Fiorentino et al., 2005) (Figure 8).

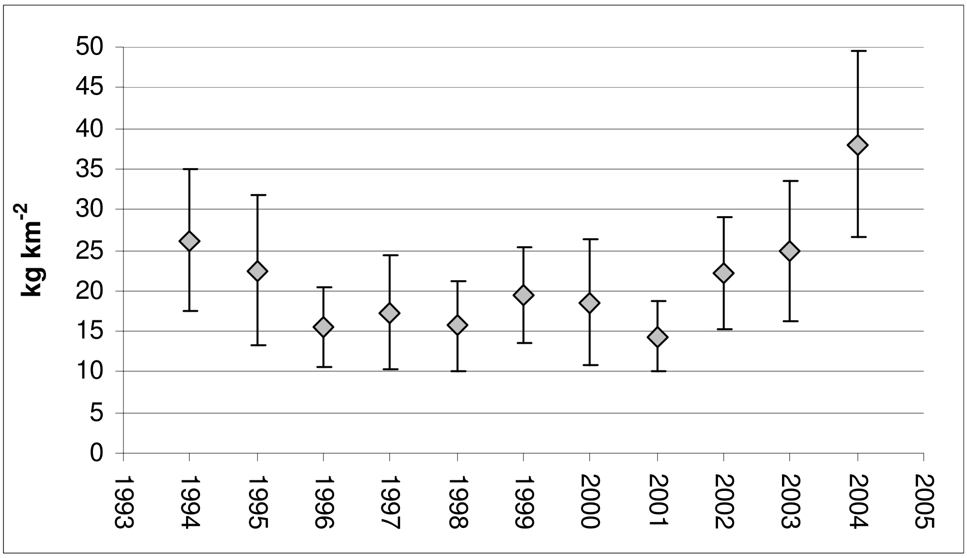


Figure 8. Time-series of *M. merluccius* biomass index (kg km^{-2}, MEDITS Trawl Surveys; 10–800 m depth range) in GSAs 15 (prior to 2000, the MMFZ was excluded) and 16 (redrawn from Fiorentino et al., 2005).

Strength of recruitment

On the basis of a length cohort analysis (LCA) on the yearly landings, a recruitment of about 13,000,000 0-group hake was estimated by Ben Meriem and Gharbi (1996) for the Tunisian coasts (GSAs 12, 13 and 14).

According to Fiorentino et al. (2003b), the estimation of the recruit density (number of recruits km^{-2}) derived from the data of the MEDITS programme (1994–1999) in GSAs 15 and 16, excluding the MMFZ, showed a quite stable hake recruitment. The number of estimated recruits in spring for an area of about 50,000 km^2 was between 3,750,000 and 9,350,000 individuals, on the basis of spring sampling (mean = 7,400,000; s.d. = 1,950,000). Since more than one cohort per year may occur, these values should be considered as underestimates.

Gancitano et al. (2007), on the basis of an LCA on yearly landings (2005–2006), estimated a recruitment at 12 cm TL, using both scalar and vector values of natural mortality. The recruitment numbers varied between 18 (scalar M) and 28 (vectorial M) millions, for females, and, likewise, between 25 and 34 millions, for males.

Stock assessment

Assessments of hake stocks along the Tunisian coast, based on surplus-production models and yield-per-recruit analysis, indicated overfishing (Ben Meriem and Gharbi, 1996). According to the production models, the mean sustainable yield (MSY) of 680–750 t was attained in the early-1980s (1983–1985); a gradual reduction in the fishing effort and an increase in the cod-end mesh size for trawlers, from 38 to 60 mm, was proposed to obtain a long-term gain in the spawning biomass and yield (mainly for artisanal fisheries). According to the assessments based on analytical models applied to trawl survey data, the exploitation rate (E=F/Z) generally indicated an overexploitation of hake ($0.6<E<0.8$) in GSA 16 (IRMA–CNR, 1999). On the basis of the Thompson and Bell predictive model, the increase in mesh size, from 30 (28 mm was the legal minimum mesh size up to the year 2000) to 40 mm (legal minimum mesh size after 2000), should improve both the yield and the income per recruit by about 20 % (Table 4).

Table 4. Simulation of long-term variation in yield (in grams) per recruit (Y/R) and income (in Italian lire = £) per recruit (£/R) with respect to hake in GSAs 15 and 16 in the late-1990s. The effect on yield and income is simulated by a Thompson and Bell model, with a change in the cod-end mesh size from 30 to 40 mm (from IRMA–CNR, 1999).

Current fishing mortality (F)	Y/R(g) “30”	Y/R(g) “40”	Δ%	£/R “30”	£/R “40”	Δ%
0.8	40.7	49.0	+20.3	399	496	+24.2

According to the SAMED programme, the exploitation rate (E) for the hake in GSAs 15 and 16, based on the demographic structure of the stock derived from the MEDITS Trawl

Surveys (1994–1999), ranged between 0.56 (with F = 0.43) for females and 0.64 (with F = 0.78) for males, indicated that the hake stock in the area is overexploited (SAMED, 2002).

Table 5. Main results of length-cohort and Y/R analyses of hake in GSA 16 (Gancitano et al., 2007). Recruitment is in millions of individuals, age is in years, length 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	**Scalar M**		**Vectorial M**	
	Females	**Males**	**Females**	**Males**
Recruits at 12 cm TL	18.281	24.845	28.103	34.330
Mean Z	0.61	1.14	0.62	1.15
Global F	0.57	0.66	0.49	0.58
Exploited critical age	1.1	1.1	1.1	1.1
Virgin critical age	5.9	3.1	7.9	4
Exploited critical length	18	18	18	18
Virgin critical length	46	30	54	34
Current Y/R (in grams)	60.02	36.42	39.08	26.38
Y/R_{max}	74.75	39.46	53.47	29.41
$Y/R_{0.1}$	71.9	37.42	51.47	27.77
Current SSB/R	48.75	7.43	22.82	4.79
Virgin SSB/R	1457.06	252.96	1182.17	240.59
Current SPR	0.03	0.03	0.02	0.02
Factor per Y/R_{max}	0.46	0.55	0.36	0.45
Factor per $Y/R_{0.1}$	0.32	0.34	0.25	0.27

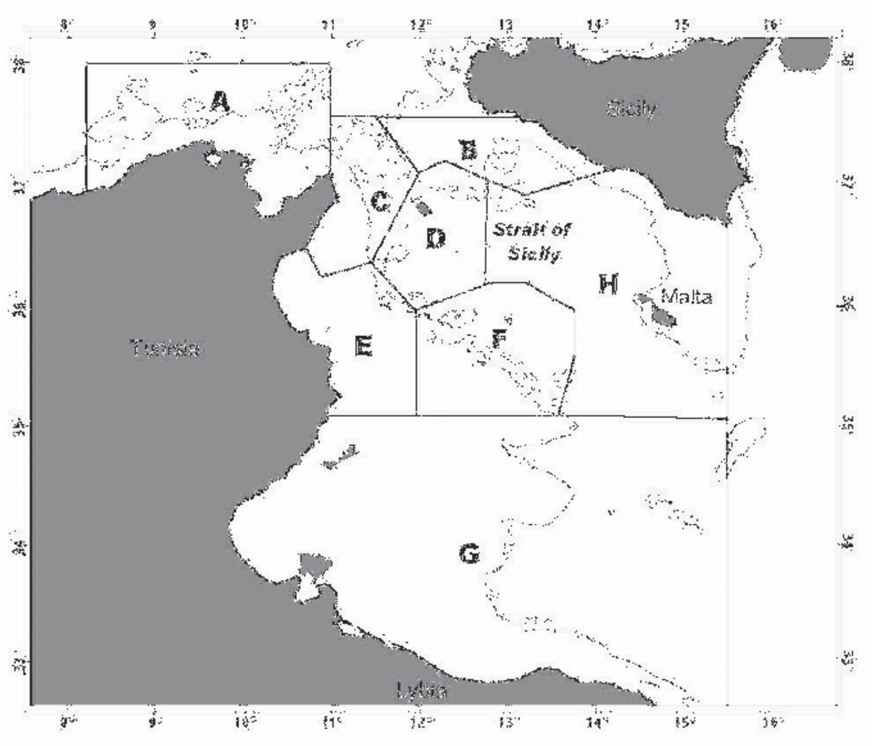
More recently, Gancitano et al. (2007) assessed the hake stock in GSA 16 by length-cohort and yield-per-recruit analyses of length–frequency distributions, by sex, and of the corresponding hake landings in 2003–2005 (mean: 1650 tons; IREPA data). According to the different value of natural mortality used, hake appears to be overfished (Table 5). To reach Y/R_{max} current F should be reduced by values ranging from 54 to 64% for females and from 45 to 55% for males. More severe reduction of current F is advisable if $Y/R_{0.1}$ is chosen as a target reference point. Furthermore, the current SPR, calculated as current SSB/R excluding virgin SSB/R, was only 2-3%, suggesting overfishing especially on recruits. Indeed 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.

Fisheries

Along the Tunisian coast (GSAs 12, 13 and 14), the artisanal fishery (longlines and gillnets) is remarkable, being responsible for about 13 % of the total Tunisian hake catches (Ben Meriem and Gharbi, 1996). In contrast, in the northern sector of the Strait of Sicily (GSAs 15 and 16), the majority of the hake catches (more than 95%) is obtained by bottom trawling, although the species is fished also by longlines and gillnets (Gancitano et al., 2007).

Although hake is not the target of a specific fishery, it is the third species in term of biomass landed in GSA 16 (Fiorentino et al., 2005). Hake is caught by trawling in a wide depth range (50–500m), together with other important species, such as *Nephrops norvegicus*, *Parapenaeus longirostris*, *Eledone* spp., *Illex coindetii, Todaropsis eblanae*, *Lophius* spp., *Mullus* spp., *Pagellus* spp., *Zeus faber, Raja* spp.

Fishing zones and seasons
A rough delimitation of the major fishing grounds for the commercial fisheries in most of the Strait of Sicily is given by Andaloro (1996) (Figure 9). The main fishing grounds, species caught, fishing periods and other relevant information in respect of the Mazara off-shore trawlers fishing hake in the Strait of Sicily are reported in Table 6 (from Fiorentino et al., 2003c).



Fgure 9. Main trawling areas (A–H) in the Strait of Sicily, according to Andaloro (1996). Hake is caught on the outer shelf and upper slope in most of the area.

Very detailed maps of trawl-fishing grounds are available for the Maltese Fisheries Management Zone (FMZ), including a large part of GSA 15 (Figure 10). Most of the Maltese fishing effort by bottom longlining and trammel netting is concentrated within a short radius around the major fishing ports, with large areas being only lightly exploited (Figures 11 and 12).

Table 6. Main fishing-grounds and fishery characteristics of the Mazara offshore trawl fishery catching hake in the Strait of Sicily (from Fiorentino et al., 2003c). See Figure 9 for area identification.

Areas/fishing-grounds/GSA	**Target species**	**Seasons**	**Gears**	**Depth range (metres)**	**Duration of haul**	**Number of hauls per day**
A+C/Ponente/GSA12,13	*Parapenaenus longirostris, Aristaeomorpha foliacea, Nephrops norvegicus, M. merluccius*	All year round	"fondale" trawl net	250-500	3-4 h (day) and 5-6 h (night)	4-5 (day) and 1 (night)
				500-750	4h	up to 5 during 24 h
C+D+E/Kelibia/GSA 12,13,16	*P. longirostris, M. merluccius, N. norvegicus*	All year round, but with a peak in spring	"fondale" trawl net	200-500	3-4 h (day) and 5-6 h (night)	4-5 (day) and 1 (night)
G/Fondaletto-Curva/GSA 14	*P. longirostris, M. merluccius, Mullus* spp.	All year round	"fondale" trawl net	200-500	3-4 h (day) and 5-6 h (night)	up to 4 during 24 h

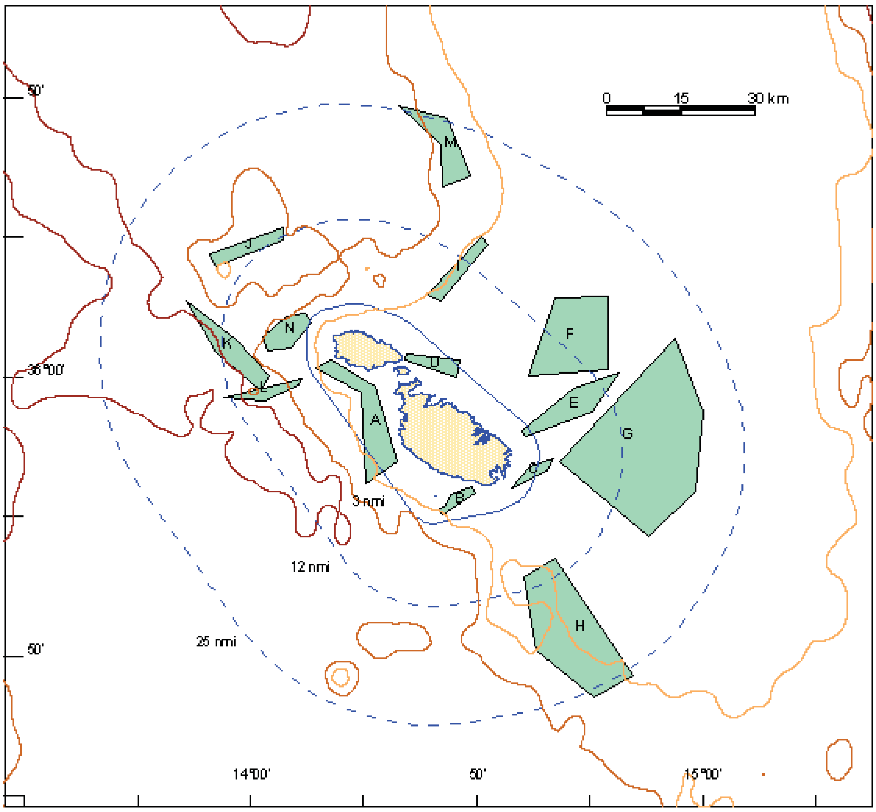


Figure 10. Trawlable areas inside the Maltese Fisheries Management Zone (FMZ) within 25 nautical miles of the Maltese Islands (*A, B, C, D* – protected, trawling forbidden; *E, F, G, H, I* – shelf/shallow water; *J, K, L, M, N* – slope/deep) (from Camilleri et al., in press).

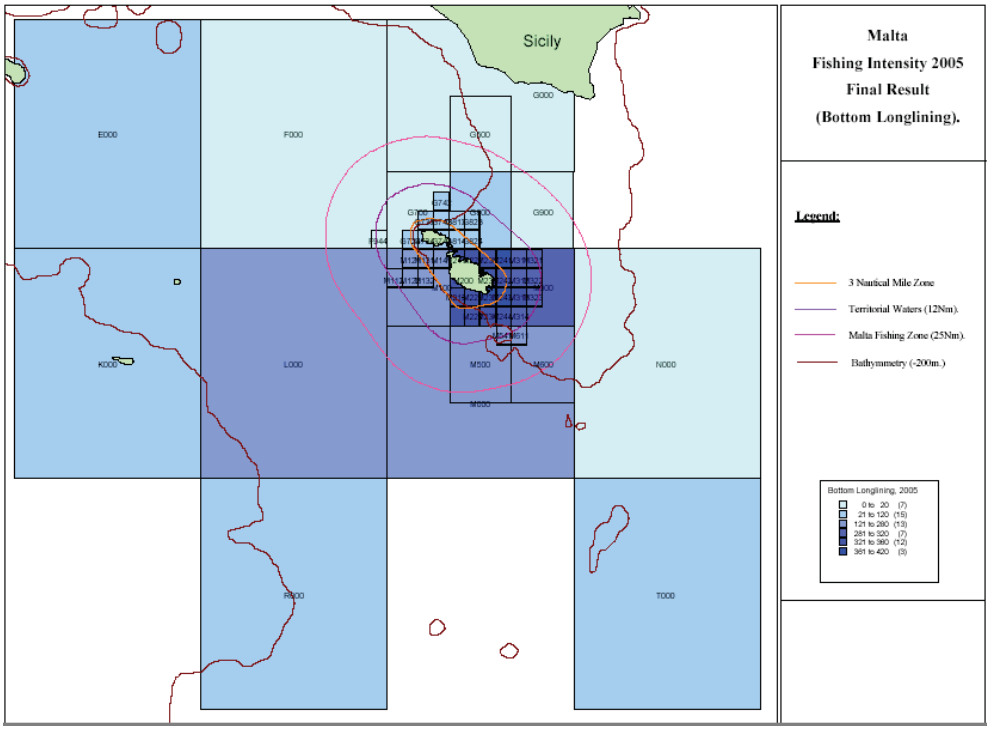


Figure 11. Spatial distribution of Maltese bottom-longlining fishing effort, expressed as number of vessels (standardized according to full-time/part-time fishing activity and vessel length classes) (from Camilleri et al., in press).

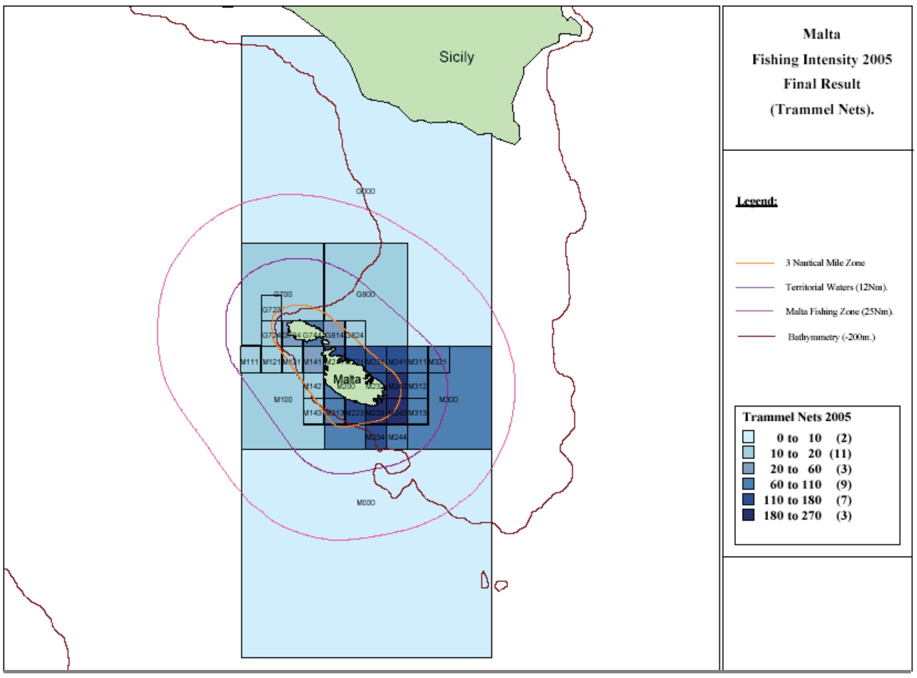


Figure 12. Spatial distribution of Maltese trammel-net fishing effort expressed as number of vessels (standardized according to full-time/part-time fishing activity and vessel length classes) (from Camilleri et al., in press).

Yield

Andreoli et al. (1995) estimated yield of hake landed by commercial trawlers, based on fishing trips of 1–2 days off the southern coast of Sicily (GSAs 15 and 16) in the mid-1980s. Between April 1985 and March 1986, the landings amounted to about 1,440 tons; the following year (April 1986–March 1987), they amounted to 1,238 tons. Considering that overall yield of the trawler fleet was about 9,666 tons in the first year and 8,052 tons in the second, hake landings represented 14–15% of the total yield in the area.

Considering all the Sicilian boats fishing in the Strait of Sicily (inshore and offshore fisheries), 1,995 tons were landed in 2003, and 1,598, in 2006 (from IREPA data). These figures correspond to less than 10% of the demersal landings in GSA 16.

According to Ben Meriem and Gharbi (1996), the Tunisian fisheries yielded about 500 tons of hake in the late-1980s. Trawling off the northern coast (GSA 12) yielded about 49% of the total national catch, while 13 % was caught by artisanal fishing (gillnets and longlines) in the same area. Trawling off the eastern (GSA 13) and southern (GSA 14) coasts yielded 30% and 7%, respectively.

The Maltese hake yield sharply decreased between 1980 (about 40 tons) and 1992 (about 1 ton); thereafter, it has fluctuated around 5 tons. This sharp reduction could be partially explained by the change in the target species of Maltese trawlers, which have fished mainly for shrimps from the mid-1990s onwards (Figure 13).

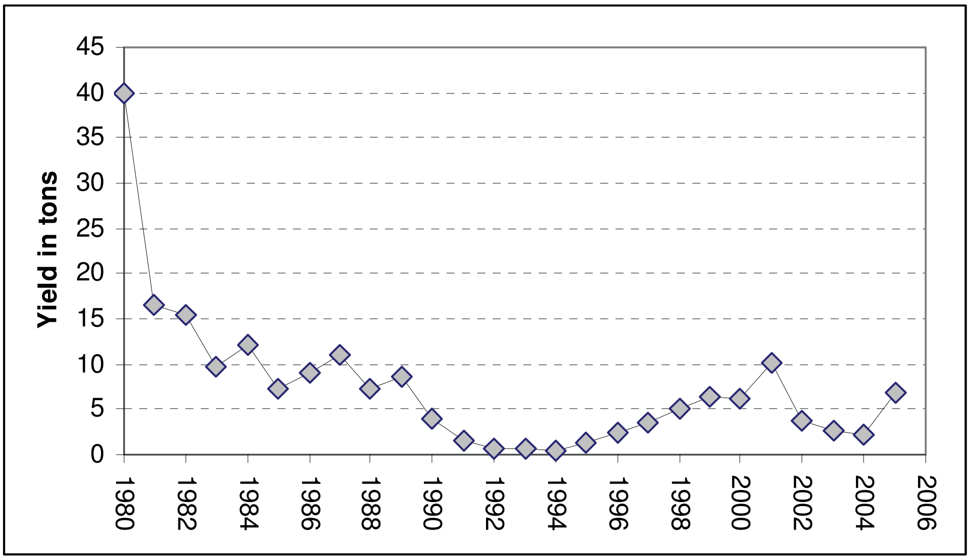


Figure 13. The Maltese hake yield (drawn from data provided by M. Camilleri).

Fishing pattern and discards

Of the fishing gears used in the Strait of Sicily, only trawling has produced relevant amounts of discards of undersized hakes. The discarded fraction of hake is very variable, according to the season and the type of fishery. In the late-1990s, Sicilian trawlers fishing offshore (trips of 15–25 days) have a higher discard of hake (86% by number and 31% by weight) than the inshore trawlers (trips of 1–2 days; 32% by number and 9% by weight) (Anon., 2000). For the distant fisheries, the first modal group (10–12 cm) in the catches is totally discarded. This is due to the intensive use of the work time and the cold-storage space available for high-priced crustaceans. Conversely, trawlers fishing more inshore tend to reduce the discarded fraction to the smallest specimens of the first age group present in the catches (Table 7).

Table 7. Yearly modal length (in centimetres) of the fish in the discarded fraction and in the total landings of hake by typical inshore (Porto Palo in southeastern Sicily) and offshore (Mazara del Vallo in southwestern Sicily) Sicilian trawlers during the late-1990s (Anon., 2000).

Type of fisheries	**Modal length (cm)**	
	Discarded fraction	Total landings
Inshore	9	17-18
Distant	10-12	20

Recent studies on the discarded fraction of trawler catches in GSA 16 during 2006 gave a length at the 50% discard level ranging between 12.9 cm TL (summer and autumn) and 15.0 cm TL (spring) (V. Gancitano, personal communication).

Gears

The Italian trawlers operating in the Strait of Sicily use the same type of trawl net, known as the “Italian trawl net”. Although there are some differences in material between the nets used in shallow water (“banco” net) and those employed in deeper water (“fondale” net), the Italian trawl net is characterized by a low vertical opening (up to 1.5 m), with the main dimensions depending mainly on a vessel’s engine power (Table 8) (Fiorentino et al., 2003c).

Table 8. Main characteristics of the traditional Sicilian trawl nets used in the Strait of Sicily, for a “typical” trawler equipped with a 375–450 kW (≅ 500–600 HP) engine (from Fiorentino et al., 2003c).

Net characteristic	**“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	400-450 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

Legislation and management

At present there are no formal management objectives for hake 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 fish-size limits).

To limit the over-capacity of the fishing fleet, the number of Italian fishing licences has been fixed since the late-1980s. After 2000, in agreement with the European Union's Common Fisheries Policy, the fleet capacity has been gradually decreased. Furthermore, from 1987 to 2005, a 30–45-day closed fishing season has been enforced each year, although in different ways, in order to reduce fishing effort. However, this measure is considered little effective in the protection of hake juveniles.

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

The new EC Regulation 1967, of 21 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 are possible up to 2010.

Concerning the current technical measures, the incongruence between the minimum marketable size of hake (20 cm TL) and the adopted minimum mesh size of 40 mm opening, which corresponds to a size at 50% capture around 13 cm TL (Fiorentino et al., 1998), should be noted.

The adoption of a size at 50% capture compatible with the 20 cm TL (mesh size of 55–60 mm) should have, as a consequence, an important short-term decrease in the yield of small-sized species that are still very appreciated in the Mediterranean countries (Gruppo Metodologie Statistiche, 1998). An effective improvement in hake fishing might be achieved through an integrative technical measure having a similar effect to an increase in mesh size; that is, the protection of hake nurseries. In contrast to red mullet, whose nurseries are on bottoms in the already protected areas within three nautical miles of the coast, the location of hake nurseries in discrete offshore areas on the outer shelf (100–200 m depth) makes nursery protection more complex and, at present, such protection is not enforced (see Figure 2).

Cacaud (2002) reported 20 cm TL as the minimum legal size for *M. merluccius* in Tunisian fisheries. Although the same author reported the existence of minimum sizes for Libyan fisheries, no specific information is available.

It should be noted that, in the Strait of Sicily, in the Maltese Fisheries Management Zone (FMZ), extending up to 25 nautical miles from baselines around the Maltese islands, fisheries 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 and tonnage of 83,000 kW and 4,035 GT, respectively.

Trawlers not exceeding an overall length of 24 metres are authorized to fish in certain areas within the Maltese FMZ (see Figure 10). The overall fishing capacity of the trawlers allowed to operate in the Maltese FMZ must not exceed the ceiling 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 European Commission annually by the Member States concerned.

Mullus barbatus (Linnaeus, 1758)

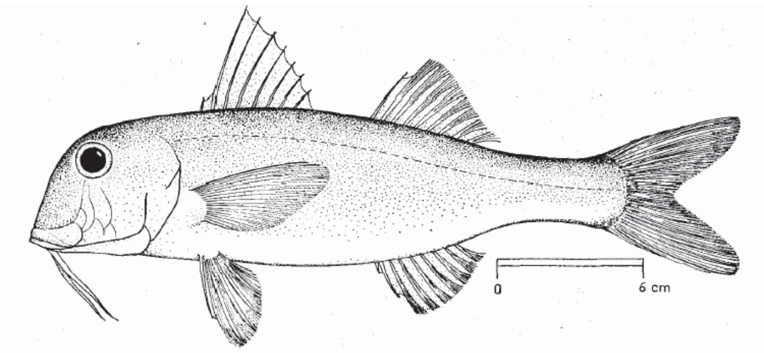


Figure 14; *Mullus barbatus* (from Fischer et al., 1987).

Species description

The body of *Mullus barbatus* (Linnaeus, 1758), commonly known as red mullet, is long, strong and slightly flat laterally. The head is short with respect to the body length; the snout is short as well, with a steep anterior profile. The eyes are positioned near the top of the head. There are two barbels under the mouth; they have a sensory function and are used in searching for prey (Figure 14). The colour is mainly pinkish with the back darker and the belly white. The fins are without any well defined coloration (Fischer et al., 1987; Voliani, 1999).

Meristics
According to Fischer et al. (1987), the numbers of fin rays is as follows: D1: VII-VIII; D2: I+7-8; A:II+6-7; P: 15-17; V: I+5.

Ecoloy

Geographical distribution
Red mullet is distributed in the eastern Atlantic, along the European and African coasts from the North Sea and England to Senegal and also in the Mediterranean and Black Sea (Fischer et al., 1987).

Habitats
Red mullet is a benthic species, frequently found on muddy bottoms at depths between 5 and 250 m (Voliani, 1999). It is also found on gravel, maerl and sandy bottoms. On the northern side of the Strait of Sicily (GSAs 15 and 16), this species was found almost exclusively over the shelf (44 to 69 % of the hauls) (SAMED, 2002).

Migrations
The species has gregarious behaviour. During the summer, juveniles are concentrated very close to shore, whereas, in autumn, they move to greater depths. In some areas, this movement represents a true migration of population from shallow to deeper grounds (Voliani, 1999).

Biological information

Maximum size

According to Voliani (1999), the maximum total length (TL) of red mullet in the Mediterranean is 28–29 cm for females and 23 cm for males, however specimens from 10 to 20 cm TL are generally found in the commercial fisheries landings. In the northern sector (GSAs 15 and 16) the observed maximum length is 27 cm TL for females and 22.5 cm TL for males (G. Sinacori, personal communication).

Spawning

Red mullet reproduction in GSA 13 occurs near the coast, from May to June–July (Gharbi and Ktari, 1981; Cherif et al., 2007b). According to Levi (1991) spawning of red mullet in GSAs 15 and 16 takes place in May. As indicated by Garofalo et al. (2004), two major and clearly separate spawning areas exist on the northern side of the Strait of Sicily (GSAs 15 and 16). They are located over the Adventure Bank, off the southwestern coast of Sicily (GSA 16) and over the Malta Bank, between Sicily and the Maltese Islands (GSA 15), respectively, on the outer shelf (100–150 m depth) (Figure 15). Recent research on the Marine Protected Area of Castellammare del Golfo (northwestern coast of Sicily – GSA 10), where trawling has been forbidden since 1990, has shown that the oldest spawners prefer deeper bottoms (100–200 m depth), whereas the young ones are found in shallower areas (<50m depth) (Fiorentino et al., 2006b).

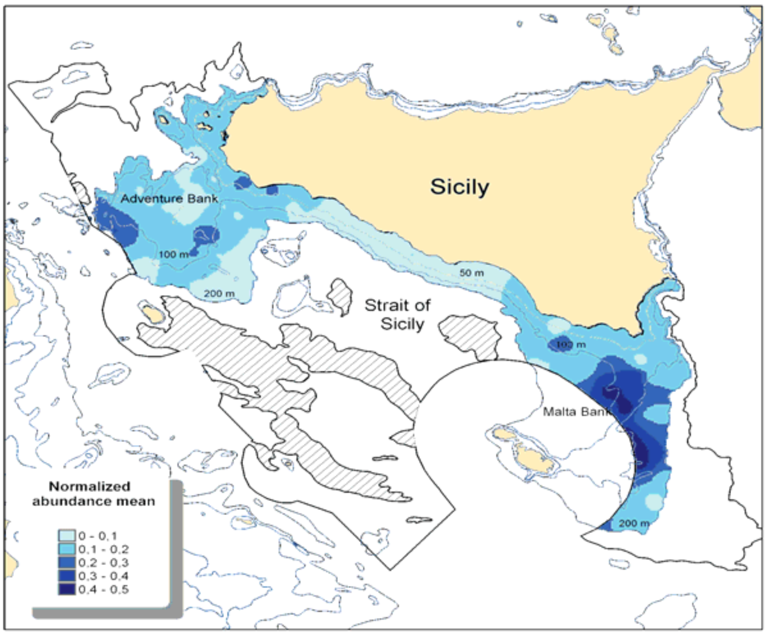


Figure 15. Map of the average distribution of *M. barbatus* spawners. The contour (*solid black line*) of the overall study area and the water depth of more than 800 m (*hatched areas*) are also shown (GSAs 15 and 16) (from Garofalo et al., 2004).

Length at first maturity

The estimation of length at first maturity for the Strait of Sicily (Table 9) agreed fairly closely with what is in the available literature on the central Mediterranean (Voliani, 1999).

Table 9. Length at 50% maturity ($L_{50\%}$) and curvature parameter (*g*) of the ogive at maturity, by sex, of *M. barbatus* in the Strait of Sicily (*n.a.* – not available).

Author	GSA	Females		Males	
		$L_{50\%}$	g	$L_{50\%}$	g
Gharbi and Ktari (1981)	13	15-16	n.a.	14	n.a.
SAMED (2002)	15, 16	15.5	n.a.	n.a.	n.a.
S. Gancitano (personal communication)	15, 16	14.9	1.18	n.a.	n.a.
Cherif et al. (2007b)	12	13.9	n.a.	13.9	n.a.

Eggs, larvae and post-larvae

Eggs, larvae and post-larvae up to 30–35 mm, of *M. barbatus*, are pelagic and live in the surface waters (Montalenti, 1933). According to Sabatés and Palomera (1987), larvae are found only in surface waters (0–1.5 m depth), mainly in areas influenced by river outflow. Larvae were found in the Mediterranean mainly between June and July (Lago de Lanzos, 1980; Sabatés and Palomera, 1987).

Recruitment and nursery areas

Juveniles up to 4–5 cm TL are pelagic, have a blue livery and may be collected several miles off the coast. Above this size, juveniles move to the coastal areas and become demersal. Their livery gradually changes from the juvenile to the adult colours (Voliani, 1999).

As in other areas of the Mediterranean, recruitment in GSAs 15 and 16 occurs over coastal bottoms in summer–early autumn (Levi, 1991; Levi et al., 2003). The smallest specimens registered during trawl surveys in GSA 15 and 16 were 3.5 cm TL (G. Sinacori, personal communication).

Although recruits exhibited a widespread distribution throughout the coastal waters, four main areas showing high abundance and the almost exclusive presence of recruits were found within GSA 16 (southwestern coast of Sicily), between 20 and 50 m depth (Figure 16).

Sex ratio

According to Fiorentino (1999), sex ratio (F/(F+M)) of *M. barbatus* taken during trawl surveys in GSAs 15 and 16 generally differs from 0.5. Males are normally more abundant than females. In the period 1985–1997, a sex ratio lower than 0.5 was found in 14 trawl surveys out of 22.

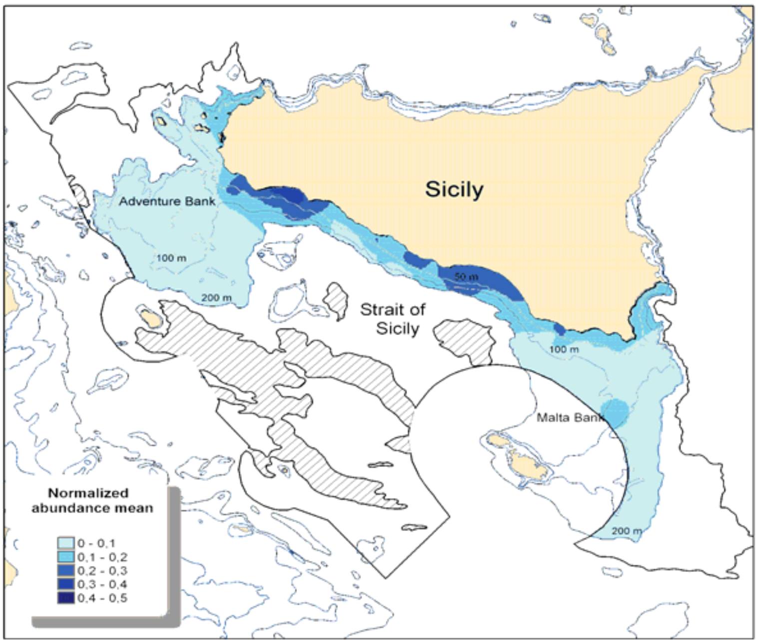


Figure 16. Map of the average distribution of *M. barbatus* recruits in GSAs 16 and 15, excluding the Maltese Fishereis Management Zone (FMZ). The contour (*solid black line*) of the overall study area and the water depth of more than 800 m (*hatched areas*) are also shown (mainly GSA 16) (from Garofalo et al., 2004).

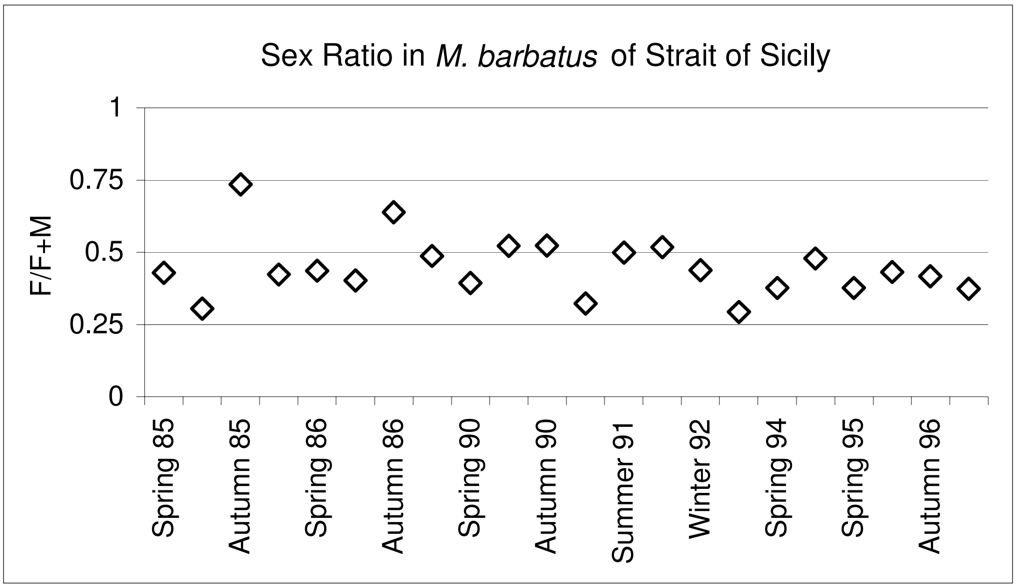


Figure 17. Sex ratio of *M. barbatus* in GSAs 15 and 16, calculated as the ratio between the number of females and the total number of sexed individuals, from GRUND Trawl Surveys (1985–1997) (from Fiorentino, 1999).

Females were more numerous than males only in the autumns of 1985 and 1986. Values of the sex ratio were approximately 0.5 during the winter of 1987, the summer of 1990, the autumn of 1990, the summer of 1991, the autumn of 1991 and the autumn of 1994 (Figure 17). A sex ratio in favour of males was reported in the literature for many areas of the Mediterranean (Voliani, 1999).

In GSAs 15 and 16, the sex ratio in 1994–1999 varied from 0.34 (in 1997) to 0.50 (in 1995), with a mean value of 0.40. The sex ratio increased significantly with individual fish length, from 0.1–0.2 at 100–120 mm TL to 0.9–1.0 at 180–200 mm TL (SAMED, 2002). However, sex ratio values slightly higher than 0.5 were observed in GSA 15 (including the Maltese FMZ) based on trawl survey data from 2002–2007, with an overall mean of 0.55.

More recently, Fiorentino et al. (2005) showed that the sex ratio derived from the MEDITS Trawl Survey data in GSA 16 decreased in 1994 until the late-1990s; then it showed an increasing phase until 2004 (Figure 18).

In the Gulf of Tunis, females are more numerous than males (SR = 0.63) (Cherif et al., 2007b).

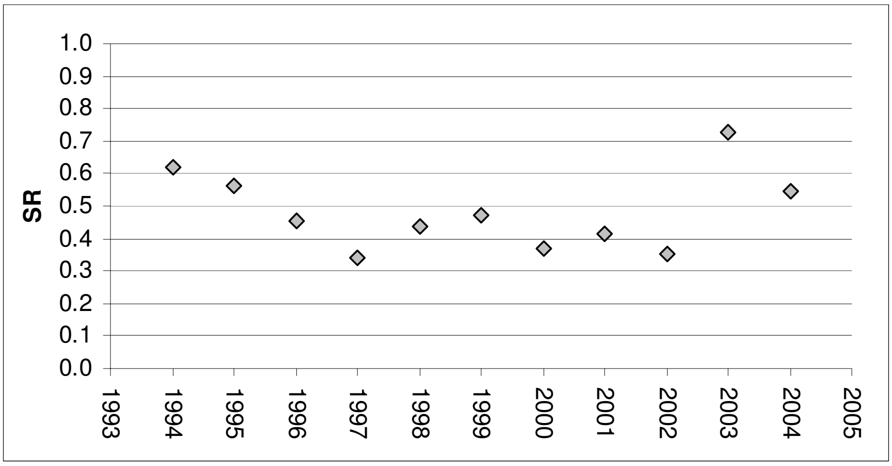


Figure 18. Sex ratio of *M. barbatus* in GSA 16, calculated as the ratio between the number of females and the total number of sexed individuals, from MEDITS Trawl Surveys (redrawn from Fiorentino et al., 2005).

Length–weight relationships

The parameters of the allometric length–weight relationships are reported in Table 10.

Table 10 - Parameters of the length–weight relationships of *M. barbatus* in the Strait of Sicily.

Author	GSA	Sex	a	b	Period
Andaloro and Prestipino-Giarritta (1985)	16	F+M+I	0.0182	2.9972	1982-1983
Cannizzaro et al. (1991)	15, 16	F	0.0174	2.8427	1985-1987
		M	0.0063	3.1826	1985-1987
		F+M+I	0.0103	3.0183	1985-1987
IRMA–CNR (2003)	15, 16	F+M+I	0.0104	3.0444	1996-1998
	16	F	0.0224	2.7695	2002
		M	0.0322	2.6161	2002
		F+M+I	0.0188	2.8249	2002
CNR–IAMC (2006)	16	F	0.0093	3.0316	2003-2005
		M	0.0131	2.9229	2003-2005
		F+M+I	0.0093	3.0596	2003-2005
Cherif et al. (2007a)	12	F	0.0069	3.1222	n.a.
		M	0.0055	3.2158	n.a.

Maximum age and natural mortality

According to Rizzo et al. (2009), the maximum estimated age in years in the exploited standing stock is 10 years for females and 7 years for males. This estimate was provided by thin-section otolith readings of the largest specimens collected in more than 15 years of trawl surveys in GSAs 15 and 16.

On the basis of a comparison of the results produced by different methods of estimating natural mortality (Chen and Watanabe; Beverton and Holt Invariants, Alagaraya), M=1.00 was proposed as the reference value for stock assessment purposes for both females and males in GSAs 15 and 16 (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 11.

Table 11. Von Bertalanffy growth function parameters of *M. barbatus* in the Strait of Sicily (*n.a.* – not available).

Author	**GSA**	**Females**			**Males**			**Combined sexes**			**Remarks**
		L_∞	K	t_0	L_∞	K	t_0	L_∞	K	t_0	
Gharbi and Ktari (1981)	14	20.46	0.50	–0.04	18.09	0.50	–0.18	–	–	–	Scale readings
Andaloro and Prestipino-Giarritta (1985)	16	24.55	0.23	–2.01	23.29	0.16	–2.84	–	–	–	Otolith readings
Levi et al. (1992)	15, 16	–	–	–	–	–	–	27.62	0.15	–2.68	Otolith readings
Djabali et al. (1990)	4	–	–	–	–	–	–	29.65	0.21	n.a.	n.a.
Ben Meriem et al. (1995)	n.a.	–	–	–	–	–	–	26.70	0.51	n.a.	n.a.
IRMA–CNR (1999)	15, 16	23.20	0.64	–0.55	9.91	0.67	–0.66	–	–	–	LFD analysis
SAMED (2002)	15, 16	26.00	0.62	–0.20	20.20	0.64	–0.20	–	–	–	Otolith readings
CNR–IAMC (2007)	16	26.50	0.26	–1.24	20.67	0.49	–0.62	–	–	–	Otolith readings

Feeding behaviour

Red mullet is carnivorous, feeding mainly on small crustaceans, polychaetes and bivalve molluscs. Copepoda, Amphipoda, Mysidacea and Isopoda are the most frequent groups among the crustaceans. Ophiuroidea and Cephalopoda can occasionally be eaten (Gharbi and Ktari, 1979; Andaloro and Prestipino-Giarritta 1985; Voliani, 1999).

Stock Units

Levi et al. (1992), comparing growth curves of *M. barbatus* in the Mediterranean, found significant differences between red mullet growth on the Sicilian side of the Strait of Sicily (GSAs 15 and 16) and in the Gulf of Gabès (GSA 14).

Other evidence supporting the existence of separate stocks of red mullets in the central Mediterranean comes from parasitological observations. A large infestation by a trematode of the genus *Stephanostomum* seriously affected the red mullet fishery in Tunisian waters for several months in 1990. No such occurrence was noted in the fish landed at the Sicilian base-ports of the Strait of Sicily (Levi et al., 1993).

Levi et al. (1995b) proposed another hypothesis on the existence of stock units in the Strait of Sicily, on the basis of the independence of the water masses and the circulation on the Sicilian and African sides of the Strait of Sicily.

Since the red mullet is a typical coastal resource, the peculiarity of the Strait of Sicily (two shelfs – the European and the African – separated by narrow deep bottoms) supports the hypothesis of the existence of different subpopulations in the area.

It is worth noting that studies on the genetic make-up of *M. barbatus* along the Adriatic (Garoia et al., 2004) and the Sicilian coasts (Arculeo et al., 2005) have proved subtle, but a significant genetic differentiation indicates that red mullet may form genetically isolated populations.

Evaluation and exploitation

Biomass and density indices from trawl surveys

Trawl survey abundance indices estimated during the MEDITS programme in GSAs 15 and 16 show a progressive increase in standing stock (Fiorentino et al., 2005) (Figure 19).

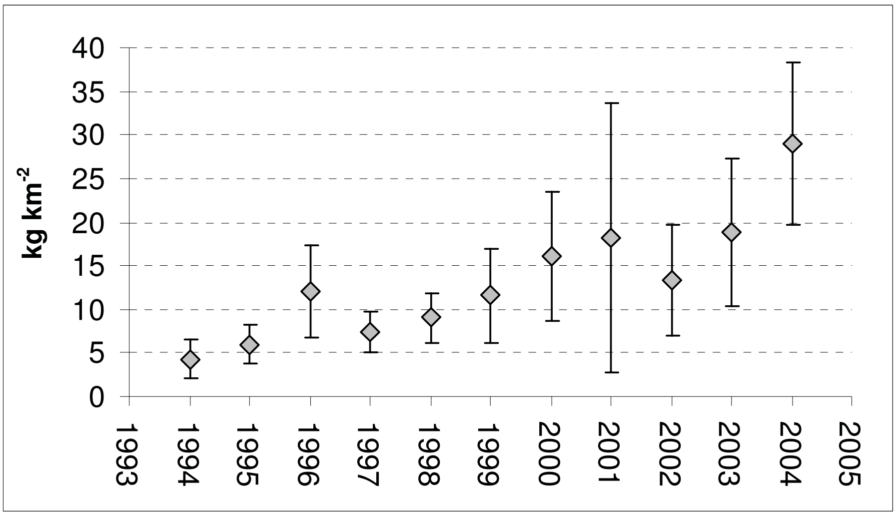


Figure 19. Time-series of *M. barbatus* biomass indices (kg km^{-2}) in GSA 15 (the MMFZ was excluded prior to 2000) and GSA 16 (MEDITS Trawl Surveys; 10–200m depth) (redrawn from Fiorentino et al., 2005).

Strength of recruitment

Levi et al. (2003) investigated the stock–recruitment relationship for red mullet in the Strait of Sicily. On the basis of existing information on the biological cycle of the species, Levi et al. (2003) hypothesized that adults in spring of a given year produce recruits in autumn of the same year. The same authors also explored the influence of sea-surface temperature on the success of the recruitment, finding that, for a given level of spawning stock, higher levels of recruitment corresponded to sea-surface temperatures (SST) warmer than average during the pre-recruitment phase (Figure 20). According to Levi et al. (2003), warm surface seawater is related to a reduced upwelling regime in the area and consequently to a lower level of red mullet eggs, larvae and post-larvae transportation. This condition should support the survival of pre-recruitment phases during their migrations to the coastal nurseries (Figures 15 and 16).

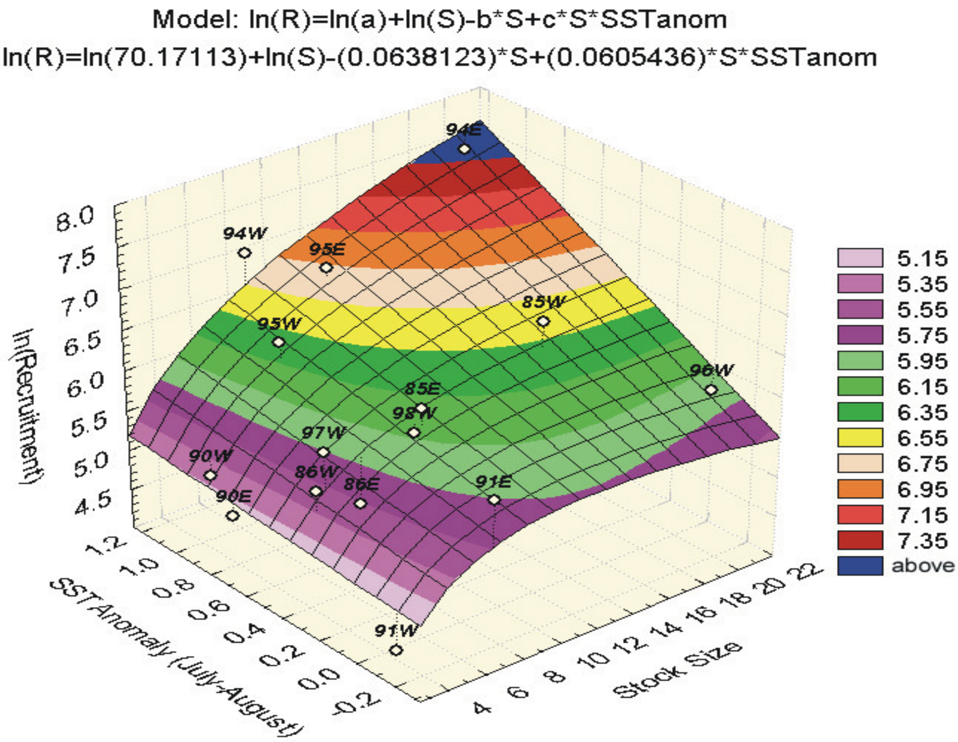


Figure 20. Stock–recruitment relationship of *M. barbatus* in the Strait of Sicily (GSAs 16 and 15, excluding the MMFZ) with respect to sea-surface temperature anomalies in July–August. Recruitment is expressed as number of recruits per km^2 in autumn, SST anomalies as average monthly anomaly over the period July-August from 1961-1990 climatology and Stock Size as biomass of adult per km^2 in spring. Single points are identified in terms of year and geographical sector (W = western side and E = eastern side) (from Levi et al., 2003**.**

Stock assessment

Taking into consideration all the constrains related to the application of Surplus Production Models, Gharbi (1985) assessed *Mullus* spp. (red and striped red mullet together) stocks off the Tunisian coasts (GSAs 12, 13 and 14) using a Schaefer production model. Yield and effort data were from 1971 to 1983 (Figure 21).

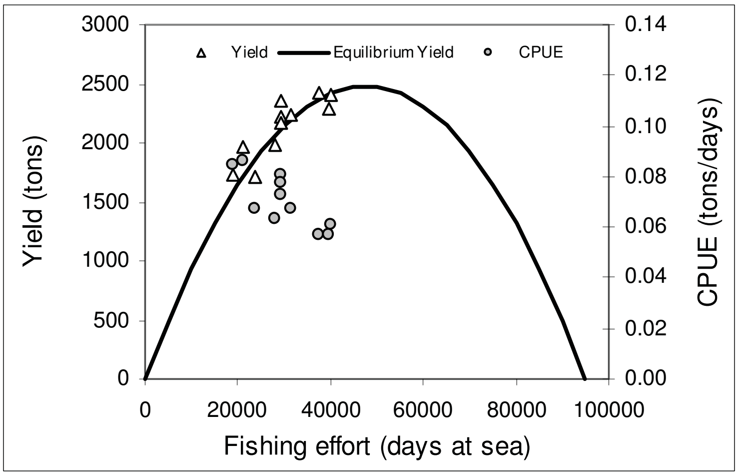


Figure 21. Schaefer surplus-production model of the red mullet and striped red mullet fisheries off the Tunisian coasts according to Gharbi (1985) (CPUE= Catch per unit effort, redrawn from original data).

Analysis showed that, in the early-1980s, *Mullus* spp. were exploited at a level of fishing effort lower than that corresponding to the MSY (f_c/f_{MSY} =0.84) (Table 12).

Table 12. The main parameters of the Schaefer surplus-production model to evaluate red mullet stocks off the Tunisian coasts, according to Gharbi (1985).

a	**b**	**MSY** (tons)	$\mathbf{f_{MSY}}$ (days at sea)	$\mathbf{f_c/f_{MSY}}$
-0.0000011	0.1045	2,482	47,500	0.84

Later, Levi et al. (1993) assessed the state of exploitation of *M. barbatus* on the Sicilian side of the Strait of Sicily (GSAs 15 and 16) using a single-species analytical model based on trawl-survey data. According to the Beverton and Holt relative yield per recruit model, the exploitation rate (E=F/Z) in 1985–87, ranging between 0.66 and 0.73, was higher than E_{max} (=0.59) (Figure 22).

The stock simulation according to a Thompson and Bell model, with fishing mortality (F) from 0.5 to 2 times the current value and keeping gear selectivity constant, showed that the long-term yield (line marked with x) does not change significantly with varying fishing effort (Figure 23).

However, the picture is different in terms of economic gain, since the potential income (line marked with o) doubled if fishing mortality was reduced to 40% of its current value. Further increases in yield and economic value in a long-term scenario could be achieved by changing the cod-end mesh size from 32 to 40 mm opening.

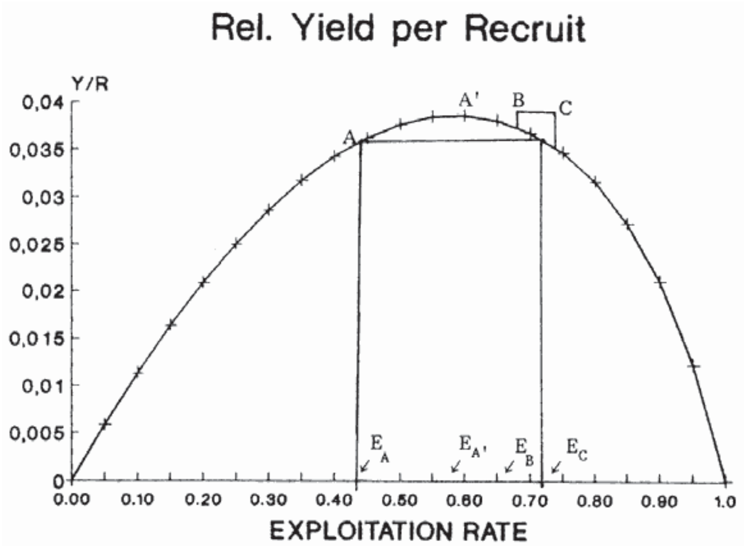


Figure 22. Beverton and Holt relative yield per recruit. *Mullus barbatus.* $L\infty$ = 27.62 cm; M/K = 1.61. B–C 1985–1986 situation; *A'* = maximum relative yield per recruit; *A* =marginal relative yield per recruit. Optima: $E_{A'}$ = 0.59 (E_{max}); E_A= 0.44 ($E_{0.1}$) (from Levi et al., 1993).

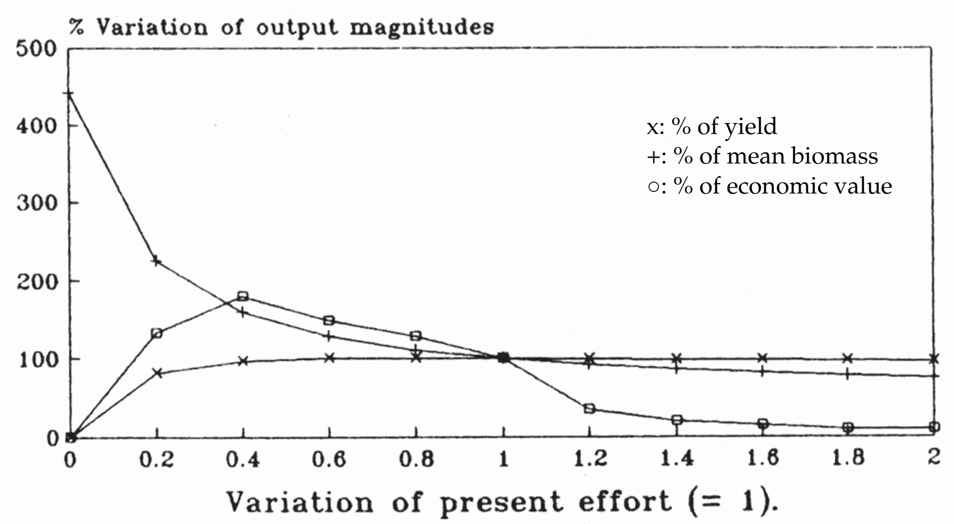


Figure 23. Thompson and Bell forecast model of *Mullus barbatus* in the Strait of Sicily. The ordinate represents the percentage output in terms of yield, mean biomass and economic value; the abscissa represents the level of fishing effort with respect to the present effort (set at 1), corresponding to 1985-1986 data (from Levi et al., 1993).

Comparable results were obtained by stock assessments carried out by the Italian group on demersal-resource evaluation (GRUND Trawl Surveys) in the late-1990s (Table13) (IRMA–CNR, 1999).

Table 13. Simulation, according to the Thompson and Bell model, of long-term variation in yield per recruit (Y/R, in grams) and income per recruit (£/R, in Italian lire) of red mullet in GSAs 15 and 16, changing current mesh size from 30 to 40 mm opening.

Fishing mortality (F)	Y/R(g) "30"	Y/R(g) "40"	Δ%	£/R "30"	£/R "40"	Δ%
0.5	5.8	5.9	+1.9	29	31	+5.5

In more recent literature, the exploitation rate (E) on the red mullet in GSAs 15 and 16, estimated by analysis of the age structure of the stock, based on trawl-survey data (1994–1999), was about 0.56 in both sexes, suggesting a state of light overexploitation (SAMED, 2002).

According to Ben Meriem et al. (1995) and Gharbi et al. (2004), *Mullus barbatus* is fully exploited in GSAs 12 and 13, whereas the stock is overfished in GSA 14. The scientists concerned have recommended a decrease in the current level of fishing effort in GSAs 12, 13 and 14. On the basis of the yield per recruit analysis, changing the mesh size from 38 to 50 mm opening, an increase in the yield should be obtained.

Fisheries
Red mullet (*M. barbatus*) is one of the main coastal demersal resources in the Mediterranean. It is fished by otter trawls, trammel nets and gillnets (Voliani, 1999; Griffiths et al., 2007). Red mullet is caught together with other important species, such as *Mullus surmuletus* (striped red mullet), *Merluccius merluccius* (European hake), *Pagellus* spp. (seabreams, pandoras), *Uranoscopus scaber* (stargazer), *Raja* spp. (rays), *Trachinus* spp. (weevers), *Octopus vulgaris* (common octopus), *Sepia officinalis* (common cuttlefish), *Eledone* spp. (horned and musky octopuses), and *Lophius* spp. (anglerfish).

Fishing zones and seasons
In GSAs 15 and 16, red mullet is caught almost exclusively by inshore trawlers operating on shelf fishing-grounds (notably the coastal-areas of sectors B and H shown in Figure 24).

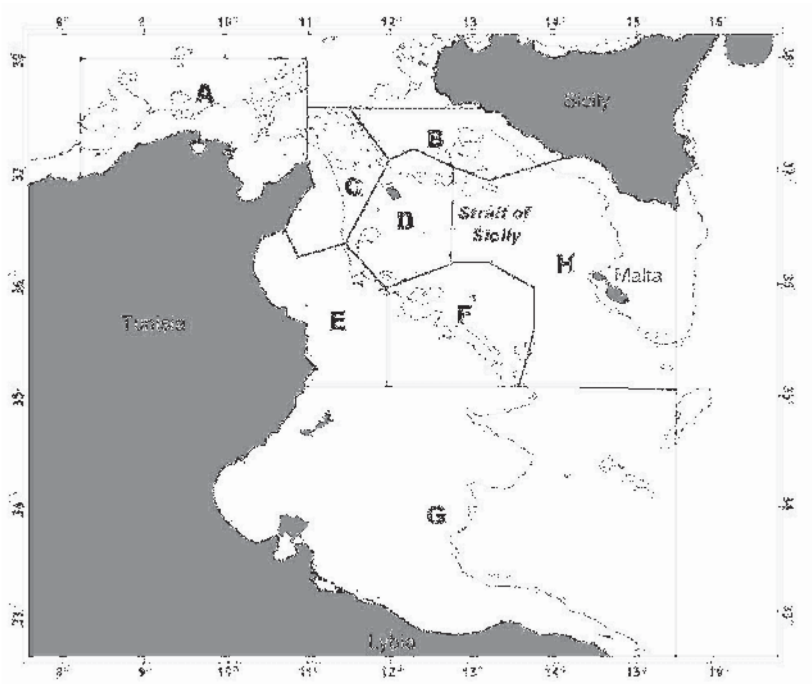


Figure 24. Main trawling areas (A-H) in the Strait of Sicily, according to Andaloro (1996). Sicilian trawlers catch red mullet mainly in the coastal bottoms of the sector B and H.

Detailed maps of trawl-fishing grounds are available for the Maltese Fishereis Management Zone (FMZ), including a substantial part of GSA 15. The most important fishing grounds for *M. barbatus* were the most shallow ones (E, F, G, H and I) (Figure 25) (Camilleri et al., in press).

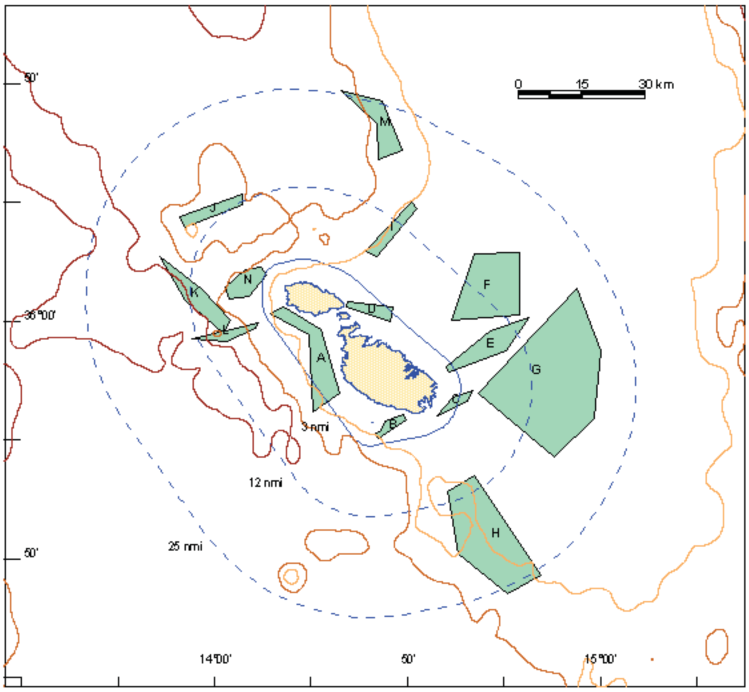


Figure 25. Trawlable areas inside the Maltese Fishereis Management Zone (FMZ) within 25 nautical miles of the Maltese Islands (A, B, C, D – protected, trawling forbidden; E, F, G, H, I – shelf/shallow water; J, K, L, M, N – slope/deep water). The most important fishing grounds for *M. barbatus* were the most shallow ones (E, F, G, H and I) (from Camilleri et al., in press).

Yield

According to Andreoli et al. (1995), the estimated yield of *Mullus* spp. between April 1985 and March 1986 was about 1,100 tons; the following year it amounted to 630 tons. Considering that overall yield of the trawler fleet was about 9,670 tons in the first year and 8,050 tons in the second, *Mullus* spp. landings represented 8–11% of total trawl yield in the area. These landings are sold in and recorded at coastal fish markets, unlike the fish caught by distant water trawlers.

More recent data (IREPA) gave a yield of 5,116 tons of *Mullus* spp. in 2003. In 2006, the yield decreased to 3,050 tons, of which 1,626 tons were attributable to *M. barbatus*.

Off the Tunisian coasts, the average production in the 1990s was around 1,190 tons, 50% coming from the Gulf of Gabès (GSA 14). The artisanal fisheries contributed with 20% for the northern (GSA 12) and eastern (GSA 13) coasts and with almost 5% for the southern (GSA 14) coast (Gharbi et al., 2004).

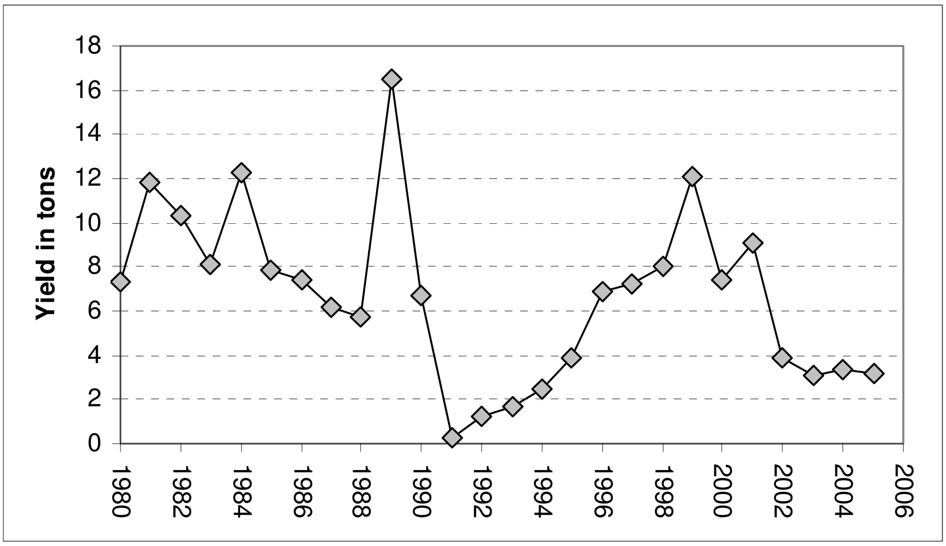


Figure 26. The Maltese yield of *Mullus* spp. (drawn from data provided by M. Camilleri)

Landings of *Mullus* spp. in GSA 15 varied around 10 tons from 1980 to 1985, followed by a decreasing trend to less than 1 ton in 1991, with the exception of 1989, when the highest production (about 16 tons) of the time-series was recorded. From 1992 to 1999 landings increased to 12 tons and thereafter decreased to about 3 tons. This yield remained quite constant up to 2005 (Figure 26).

Fishing and discards

During the 1980s, the estimated landings suggested a fishing cycle with a peak catch in summer, attributable to the trawl fishing along the southern coast of Sicily (only trawlers carrying out 1-day trips between the spring of 1985 and the winter of 1987 were considered) (Fiorentino, 1999). The Sicilian peak occurred earlier than in the other Italian fishery areas, where the main catches were observed in autumn. This difference was attributed to the widespread illegal fishing of recently recruited fish in protected nursery areas within the three-mile coastal zone in the late-1980s.

The discarded fraction of red mullet catches varies with season and type of fishery. Sicilian trawlers fishing inshore have a low-discard fraction, since they normally land all their catch. In summer, the smallest *M. barbatus* landed may be 7–8 cm TL. The biggest trawlers, which undertake 15–25-day trips and fish far offshore, discard red mullet smaller than about 12 cm TL. This discard fraction may be significant during the summer and autumn. The high discard rate is due to the necessity of using the available cold-storage space almost exclusively for high-priced crustaceans. In this situation, the first modal group (9–10 cm TL) in the catches is totally discarded (Anon., 2000) (Table 14).

Recent studies on the discarded fraction of trawler catches in GSA 16 during 2006, given a length at 50% discard, indicated a range between 11.3 (autumn) and 12.0 (spring) cm TL (V. Gancitano, personal communication).

Table 14. Yearly modal length, in centimetres, of the discarded fraction and of the landings of red mullet in the typical inshore (Porto Palo, in southeastern Sicily) and distant (Mazara del Vallo, in southwestern Sicily) Sicilian trawl fisheries (from Anon., 2000).

Type of fisheries	**Modal length (cm)**	
	Discards	Landings
Inshore	No discard	16
Offshore	9 and 15	18-19

Gears
The Italian trawlers targeting red mullet in the Strait of Sicily use the "banco" type of the trawl net called "Italian trawl net". This net is characterized by a low vertical opening (up to 1.5 m) with overall dimensions depending on engine power (Fiorentino et al., 2003c).

Legislation and management

At present there are no formal management objectives for red mullet 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 fish-size limits).

Since 1989 no new fishing licences have been issued in Italy and a progressive reduction in fleet capacity is occurring.

The adoption of a closed fishing season of 30–45 days per year since the late-1980s should have contributed to a reduction in the fishing pressure on demersal resources. However, this measure had little effect in Sicily because the time of the closed trawl-fishing period was not chosen so as to reduce the mortality of juvenile fish due to fishing.

By coupling a closed trawl-fishing period in autumn, when the young red mullets move to deeper water, with the existing prohibition of trawling within three nautical miles of the coast, where the fish recruit in summer (Voliani, 1999), has been shown to produce a remarkable increase in the stock size (Relini et al., 1996; Pipitone et al., 2000).

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

Since 2001 the minimum legal cod-end mesh size for Sicilian trawlers should be 40 mm, following the lifting of a EU derogation allowing a minimum cod-end mesh size of 28 mm for Sicily and Greece. However, till now, this measure has not been implemented.

The new EC Regulation 1967, of 21 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 are possible up to 2010.

EC Regulation 1626, of 27 June 1994, fixed the minimum marketable size of *Mullus* spp. at 11 cm TL. This minimum length, confirmed by the new EC Regulation 1967, of 21 December 2006, is valid both for Italian and Maltese fishing boats operating in the area.

Cacaud (2002) reported 12 cm TL as the minimum legal size for *Mullus* spp. in Tunisian fisheries. Although the same author reported the existence of minimum sizes for Libyan fisheries, no specific information is available.

It should be noted that, in the Strait of Sicily, in the Maltese FMZ, extending up to 25 nautical miles from baselines around the Maltese islands, fisheries 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 MMFZ is regulated as follows:

(a) fishing within the Management Zone 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 and tonnage of 83,000 kW and 4,035 GT, respectively.

Trawlers not exceeding an overall length of 24 metres are authorized to fish in certain areas within the Management Zone (see Figure 25). The overall fishing capacity of the trawlers allowed to operate in the Management Zone must not exceed the ceiling 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 Management Zone 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 European Commission annually by the Member States concerned.

Octopus vulgaris Cuvier, 1797

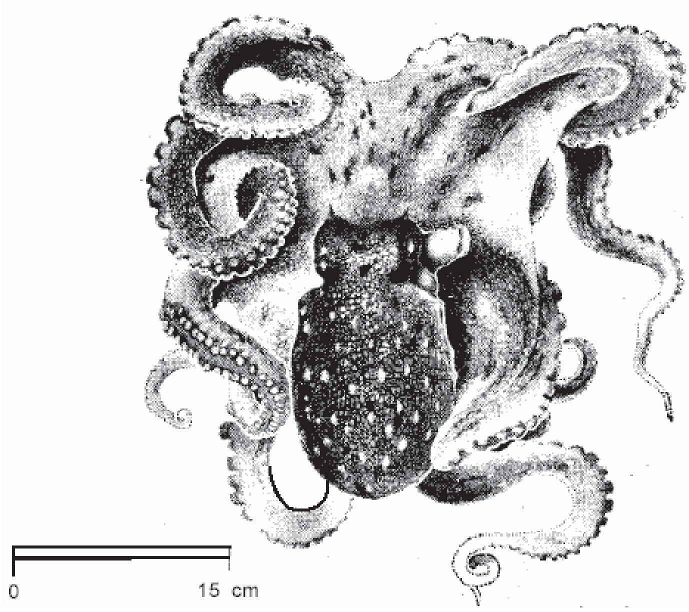


Figure 27. *Octopus vulgaris* (from Fischer et al., 1987).

Species description

Octopus vulgaris (Cuvier, 1797), known as the common octopus, is a medium- to large-sized cephalopod. The mantle is oval and strong; the arms are stout and of about equal length and thickness; the dorsal pair of arms are slightly shorter. The shortened right arm III of males is hectocotylized by the modification of the tip into a very small, spoon-shaped *ligula* (Figure 27). The colour varies from brown–yellowish, red–brownish, brown to greyish (Fischer et al, 1987; Belcari and Sartor, 1999).

Ecology

Geographical distribution
The common octopus has been considered a cosmopolitan species inhabiting temperate and tropical waters for a long time. More recently, taxonomic differences among different areas of the world have been proposed and it is generally recognized that *O. vulgaris* lives only in the eastern Atlantic and in the Mediterranean (Mangold, 1997).

Habitats
This benthic species occurs mainly from the coastline to the outer edge of the continental shelf (depth ≤200 m), although it can be caught at depths exceeding 300 m (Belcari and Sartor, 1999). According to Ragonese and Jereb (1990), in the Strait of Sicily the common octopus is found at depths down to 150 m. It lives in a variety of habitats, such as rocks, sand, mud, reefs and grass beds. The common octopus is usually solitary and territorial, especially in the spawning season. It can burrow into soft substrata during the daytime (Boletzky, 1996).

Migrations
The species undertakes short seasonal migrations. Generally it spends winter in deeper water, where it grows and matures. It then migrates to shallower waters in summer for spawning (Belcari and Sartor, 1999). In the Gulf of Gabès (GSA 14), the breeding is preceded by an inshore migration in autumn, with males preceding females (Ezzedine-Najai, 1992). Close to the coast, these animals find enough light and food (crabs, shrimps and shellfishes) for gonad growth. Then, in early spring, the females isolate themselves in shelters for spawning.

Biogical information

Maximum size
The maximum length registered in the Strait of Sicily (GSAs 15 and 16) is 210 mm dorsal mantle length (DML) for males (Ragonese and Jereb, 1990) and 230 mm DML for females (G. Sinacori, personal communication); however specimens from 80 to 150 mm DML are generally found in the commercial fisheries landings.

Spawning
In the Mediterranean, the reproductive period occurs throughout the year, but especially from January–March to July–October, with one or more peaks of reproduction (Belcari and Sartor, 1999). In the Gulf of Gabès (GSA 14), females spawn from February to September, with a peak between March and July, whereas males are mature all the year round (Ezzedine and El Abed, 2004).

Mating takes place after courtship and can precede spawning by 3–4 months, since immature females can conserve spermatozoa. The fertilization of the eggs is internal; the introduction of the male's *hectocotyli* into the female's mantle cavity ensures that fertilization takes place inside the glands of the oviduct where the spermatozoa are stocked (Belcari and Sartor, 1999). In GSA 14 the potential fecundity, expressed as the number of ova per ovary, ranges between 130,000 and 1,300,000 (Zguidi, 2002). These results agree with those obtained for other Mediterranean populations where the number of eggs laid by a female varies from 100,000 to roughly 500,000 (Belcari and Sartor, 1999).

Length at first maturity
The relevant literature reports that males reach maturity at 65 mm DML, at the earliest, and females, at 130 mm DML (Belcari and Sartor, 1999).

In the Gulf of Gabès (GSA 14), length at 50% maturity ($L_{50\%}$) was 14.5 cm DML, for the female, which is reached during the second year of life. At sexual maturity, females weigh 1,200–1,500 g (Ezzedine-Najai, 1992; Zguidi, 2002).

Eggs, larvae and post-larvae
Females always produce egg strings that are attached to the substrate on rocky shores, in a hole or any sheltered place, generally inaccessible to trawl nets. During the incubation

period, the female ventilates and protects the eggs until they hatch. The females generally die after the eggs hatch.

Figure 28. Newly hatched 24-h-old *O. vulgaris* (INSTM Museum, Salammbô; from Ezzedine and El Abed, 2004)

Hatchlings of about 2 mm DML (Figure 28) live for 30–40 days, or more, in the plankton and when they are approximately 6–7 mm DML they settle on the bottom (Belcari and Sartor, 1999).

Recruitment and nursery areas
According to Belluscio and Ardizzone (1990), recruitment in the central Tyrrhenian Sea occurs from July to September. No information on the recruitment period is available for the Strait of Sicily.

The smallest specimens registered during trawl surveys in GSAs 15 and 16 were 20 mm DML (G. Sinacori, personal communication).

Sex Ratio
According to the available information, the sex ratio does not differ from 0.5 for the population as a whole, with a slight prevalence of females at the biggest sizes (G. Sinacori, personal communication).

Length–weight relationships
Available parameters of the allometric length–weight relationships are reported in Table 15.

Table 15. Parameters of the length–weight relationships of *O. vulgaris* in GSA 16 and in international waters southward of the midline (Area B, see Figure 25). Only data collected during the GRUND Trawl Surveys in autumn were considered. Length was in millimetres and weight, in grams. *F* = female; *M* = male; *I* = immature.

Author	GSA	Sex	a	b
G. Sinacori (personal communication)	16	F	0.0014	2.7195
		M	0.0017	2.6750
		F+M+I	0.0017	2.6813
	Area B	F	0.0010	2.7673
		M	0.0011	2.7419
		F+M+I	0.0012	2.7227

Maximum age and natural mortality

Like most cephalopods, *O. vulgaris* has a very short life-span, of 1–2 years; the males probably live longer than the females (Guerra, 1992).

The common octopus in the Gulf of Gabès (GSA 14) has a life-span between 13 and 20 months, depending on the laying period, and rarely exceeds 2 years (Ezzeddine-Najaï, 1992). Thus, the biggest animals sampled in Tunisian waters (weighing 10 kg) were not necessarily older than 3 years, but they likely found adequate food supplies, which contributed to their rapid growth.

Von Bertalanffy growth function (VBGF)

In the Mediterranean, reported VBGF parameter values were 300 mm for DML_∞ and 0.06 for *k* (monthly) (Guerra, 1979). The growth of common octopus is relatively fast: the species reaches about 150 mm DML at 12 months and > 220 mm DML at 24 months.

In the Gulf of Gabès (GSA 14), the octopus grows quickly and at a nearly constant rate, particularly during the first months of its life (Zguidi, 2002). Two cohorts occur annually: one from the spring spawning, characterized by a high growth rate and a short life-span; another from the summer spawning, distinguished by a lower growth rate and a longer life-span (Ezzedine and El Abed, 2004).

The Von Bertalanffy growth function parameters of *O. vulgaris* for both sexes combined for the Gulf of Gabès (GSA 14) are reported in Table 16.

Table 16. Von Bertalanffy growth function parameters of *O. vulgaris* in the Gulf of Gabès (GSA 14).

Author	GSA	DML_∞	K (yearly)	t_0	Remarks
Zguidi (2002)	14	29.6	0.56	–0.225	*k* is on annual basis

Feeding behaviour
According to the literature, the favourite preys of *O. vulgaris* in the Gulf of Gabès (GSA 14) are decapod crustaceans, molluscs and fishes (Ezzedine-Najai, 1992; Zguidi, 2002) (Figure 29).

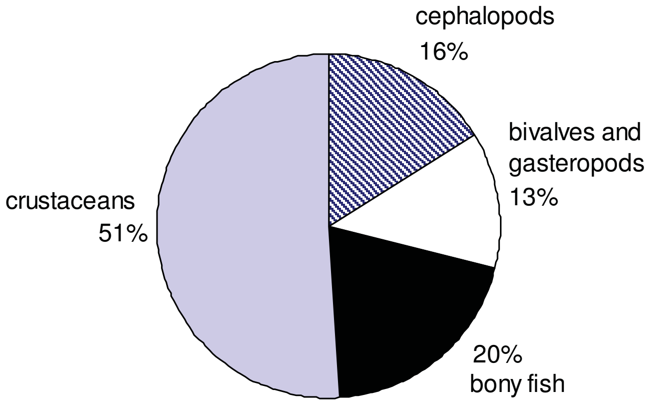


Figure 29. Occurrence of various prey items in the diet of *O. vulgaris* in GSA 14 (redrawn from Ezzedine and El Abed, 2004).

Stock Units
No information is available on the stock structure of *O. vulgaris* in the Strait of Sicily.

Evaluation and exploitation

Biomass indices from trawl surveys

Biomass indices estimated from the data of the MEDITS Trawl Surveys in GSAs 15 and 16 remained stable, at about 10 kg km^{-2}, from 1994 to 1999. Then they fluctuated between 15 kg km^{-2} (2001 and 2004) and 5 kg km^{-2} (2002) (Figure 30).

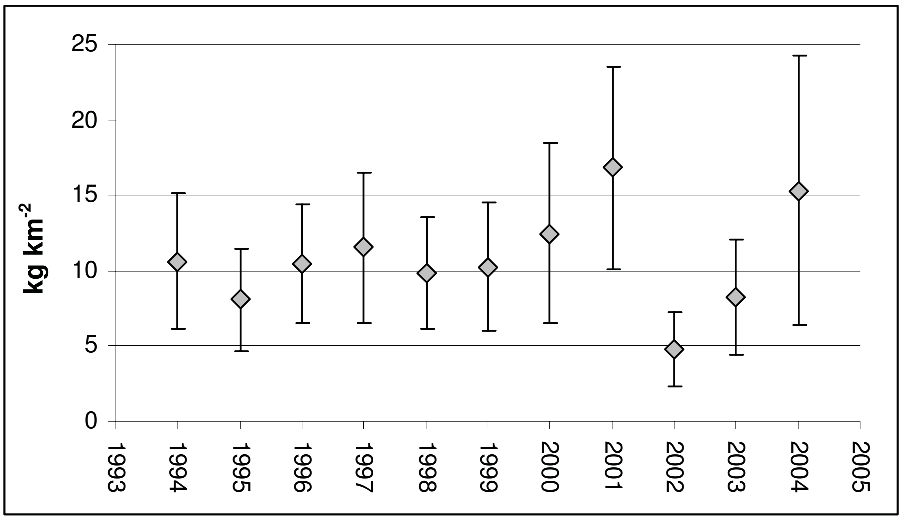


Figure 30. Time-series of *O. vulgaris* biomass indices (kg km^{-2}) in GSAs 15 (the MMFZ was excluded prior to 2000) and 16 (MEDITS Trawl Surveys; 10–200m depth) (redrawn from Fiorentino et al., 2005).

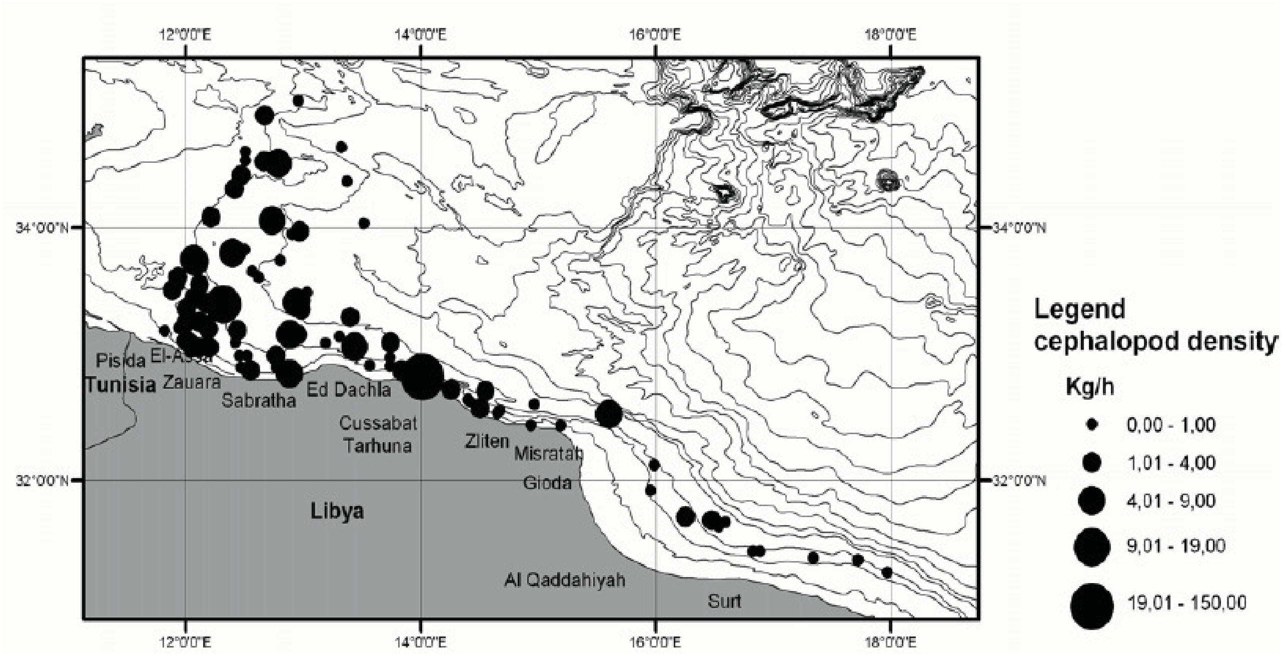


Figure 31. Biomass indices of combined *Octopus* spp. and *Sepia* spp. off the western coasts of Libya (GSA 21) (LIBFISH Trawl Surveys 1993–1994) (from Rawag et al., 2004).

Off the Libyan coasts (GSA 21), joint results are available for *Octopus* spp. and *Sepia* spp. Very high indices of abundance were obtained during the LIBFISH Trawl Surveys (1993–1994) (Lamboeuf et al., 1995) from the Gulf of Sidra (Gulf of Syrta, Western GSA 21) to the Libyan–Tunisian border (western sector) on bottoms deeper than 100 m (Figure 31) (Rawag et al., 2004).

Strength of recruitment

No information on the strength of recruitment of the species in the Strait of Sicily is available. Faure et al. (2000), studying *O. vulgaris* off the Mauritanian coast, outlined the importance of coastal retention as key factor for recruitment success. According to Faure et al. (2000), the frontal zone in the inshore area created in spring by the interaction between high intense upwelling in the offshore area and the wide extent of the Arguin Bank reduces the dispersal of paralarvae, increasing the survival of recruits in autumn/winter.

Stock assessment

Short life-span and high growth rate imply that the common octopus stock has a high turnover rate and a potential capacity for rapid renewal of the stock. In the Gulf of Gabès (GSA 14), the turnover of the standing stock is estimated at 16% of the mean biomass, and the stock was considered overexploited (Zguidi, 2002).

Fisheries

Common octopus is fished in shallow waters with various gears, including trawls, trammel nets, traps, lines and harpoons (Belcari and Sartor, 1999; Griffiths et al., 2007). A typical artisanal fishing method to catch octopus along the Tunisian coasts is by pots attached to longlines.

Fishing zones and seasons

Inside the Maltese Fishereis Management Zone (FMZ), which includes a substantial part of GSA 15, the most important fishing grounds for *O. vulgaris* were the most shallow ones (E, F, G, H and I in Figure 32) (Camilleri et al., in press).

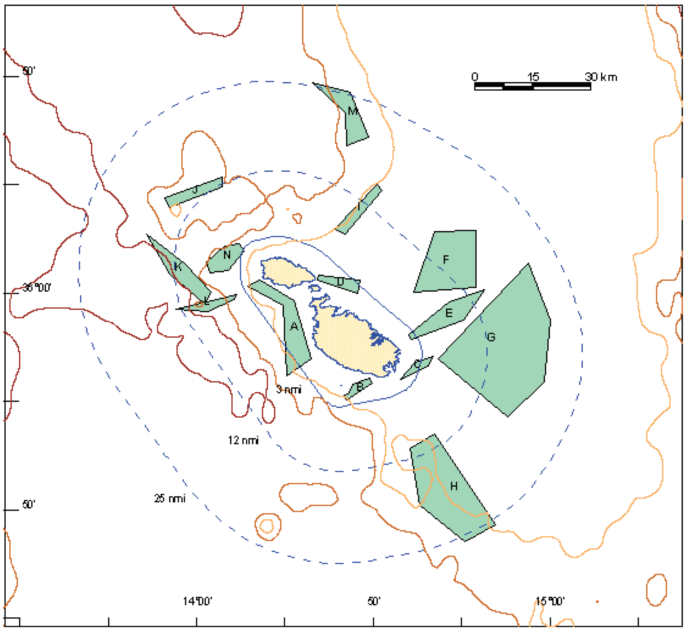


Figure 32. Trawlable areas inside the Maltese Fishereis Management Zone (FMZ) within 25 nautical miles of the Maltese Islands (A, B, C, D – protected, trawling forbidden; E, F, G, H, I – shelf/shallow water; J, K, L, M, N – slope/deep water). The most important fishing grounds for *O. vulgaris* were the most shallow ones (E, F, G, H and I) (from Camilleri et al., in press).

Yield

According to Andreoli et al. (1995), the estimated yield of *Octopus* spp. in GSA 16 between April 1985 and March 1986 was about 94 tons; the following year it amounted to 123 tons. Considering that overall yield of the trawler fleet was about 9,670 tons in the first year and 8,050 tons in the second, *Octopus* spp. landings represented about 1% of the total yield from coastal (inshore) trawling in the area (GSA 16).

Yield of *O. vulgaris* in GSA 16 (all fishing boats combined) was about 650 tons in 2003, of which 370 (about the 57%) were assignable to the artisanal fisheries (from IREPA data).

The common octopus is the most important target species amongst the demersal fishery species in GSA 14. Its landings represent about 83% of the Tunisian production and are destined mainly for exportation, as well as for local consumption (Ezzeddine and El Abed, 2004). In GSA 14 the artisanal fishing provides 90% of the octopus landings. The increase in fishing effort on the southern octopus stock in the coastal zone raised the landings from 2,600 tons in 1975 to 12,000 tons in 1988; after that, production decreased to less than 2,000 tons in 2000 (Figure 33) (Ezzeddine and El Abed, 2004).

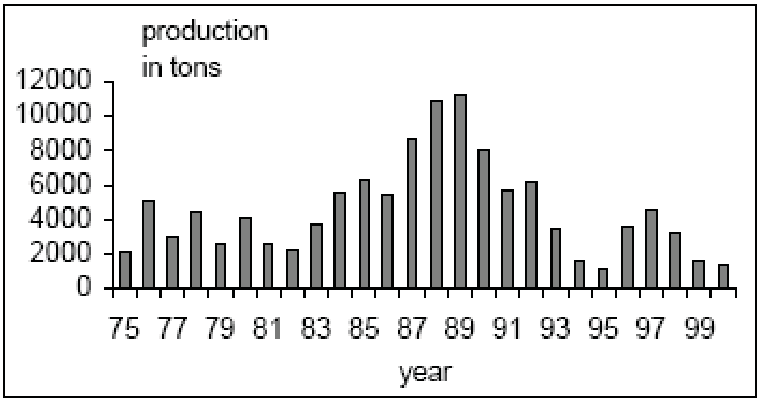


Figure 33. Annual landings of *O. vulgaris* in GSA 14 (from Ezzeddine and El Abed, 2004).

According to Ezzeddine and El Abed (2004), fluctuations in landings might reflect several factors, such as degradation of the sea bed by excessive bottom trawling, changes in the abundance of the octopuses' predators (e.g. groupers and seabreams), and variation in hydrographical regimes.

Fishing and discards

Common octopus is caught by the Sicilian trawlers in GSA 16 together with *Mullus* spp. (red and striped red mullet), *Merluccius merluccius* (European hake), *Pagellus* spp. (seabreams and pandoras), *Trachinus* spp. (weevers) *Uranoscopus scaber* (stargazer), *Sepia officinalis* (common cuttlefish), *Eledone* spp. (corned and musky octopuses) *Lophius* spp. (anglerfish), *Parapenaeus longirostris* (deep-water pink shrimp), *Illex coindetii* (broadtail squid), *Zeus faber* (John dory), and *Raja* spp. (rays).

No fraction of the octopus catches is discarded in GSAs 15 and 16.

Gears

The Sicilian trawlers targeting assemblages of shallow demersal species catch common octopus using the "banco" 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 (Fiorentino et al., 2003c).

Legislation and management

Since 2001, the legal minimum cod-end mesh size for Sicilian trawlers should be 40 mm, as a result of the ending of the UE derogation, which allowed a minimum size of 28 mm for Sicily and Greece. However, up to now, this measure has not been fully implemented.

At present, there are no formal management objectives for common octopus fisheries in the Strait of Sicily. As in other areas of the Mediterranean, the stock management is based on control of fleet fishing power and size (dorsal mantle length) limits.

The new EC Regulation 1967, of 21 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 are possible up to 2010.

No minimum landing size is contained in EC Regulation 1967, of 21 December 2006, in respect of the common octopus and other cephalopods.

The control of management measures, such as the limitation of fishing capacity and of individual size in the landings, is often ineffective and the surveillance of cod-end mesh size is weak. Furthermore, the engines of trawlers are more powerful than the power registered in the fishing licences.

In the Gulf of Gabès, specific regulations for the common octopus fishery were established in 1987 and were amended in 1992 and in 1994. These regulations provide that fishing any octopus weighing less than 1 kg is forbidden from 16 May to 15 October, but allow the possibility of delaying or advancing the opening or the closing dates, respectively. These regulations concern both trawling and artisanal fishing. However, in spite of this legal measure, the annual production has undergone annual fluctuations, with a falling trend since 1990 (Ezzeddine and El Abed, 2004).

Parapenaeus longirostris (Lucas, 1846)

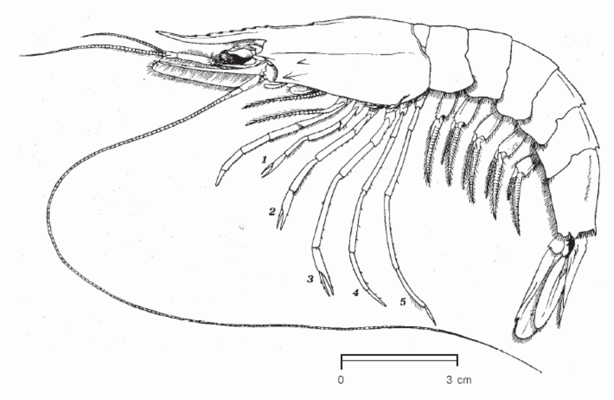


Figure 34. *Parapenaeus longirostris* (from Fischer et al., 1987).

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 and sharp teeth (Figure 34). 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).

Habitats
P. longirostris is a demersal species that can be found at depths between 20 and 700 m, but it is common and abundant on sandy–muddy bottoms between 70 and 400 m depths (Fischer et al., 1987). The Strait of Sicily, together with the seas around Greece, presents the highest abundance of the species in the Mediterranean (Levi et al., 1995a; Abellò et al., 2002)

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. (1995a) 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, personal communication).

Spawning

According to Levi et al. (1995a), mature females are found in GSAs 15 and 16 all year round, although a wide maturity peak extended from November to February and another occurred in April. The lowest percentage of mature females appeared 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.

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 GSAs 15 and 16 (SAMED, 2002). The parameters of the classical ogive at maturity are reported in Table 17. According to Ben Meriem et al. (2001), this species reproduces before the end of its first year of life.

Table 17. Length (in millimetres) at 50% maturity ($L_{50\%}$) and curvature parameters of the ogive at maturity, by sex, of *P. longirostris* in the Strait of Sicily (g – grams; *n.a.* – not available).

Author	GSA	Females		Males		Remarks
		$L_{50\%}$	g	$L_{50\%}$	g	
Ben Meriem et al. (2001)	12	20.20	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	1994-1999
Ragonese et al. (2004)	15, 16	24.00	n.a.	19.00	n.a.	
CNR–IAMC (2006)	16	20.80	0.28	15.60	1.89	2003-2005

Eggs, larvae and post-larvae

The little 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, personal communication), 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 35).

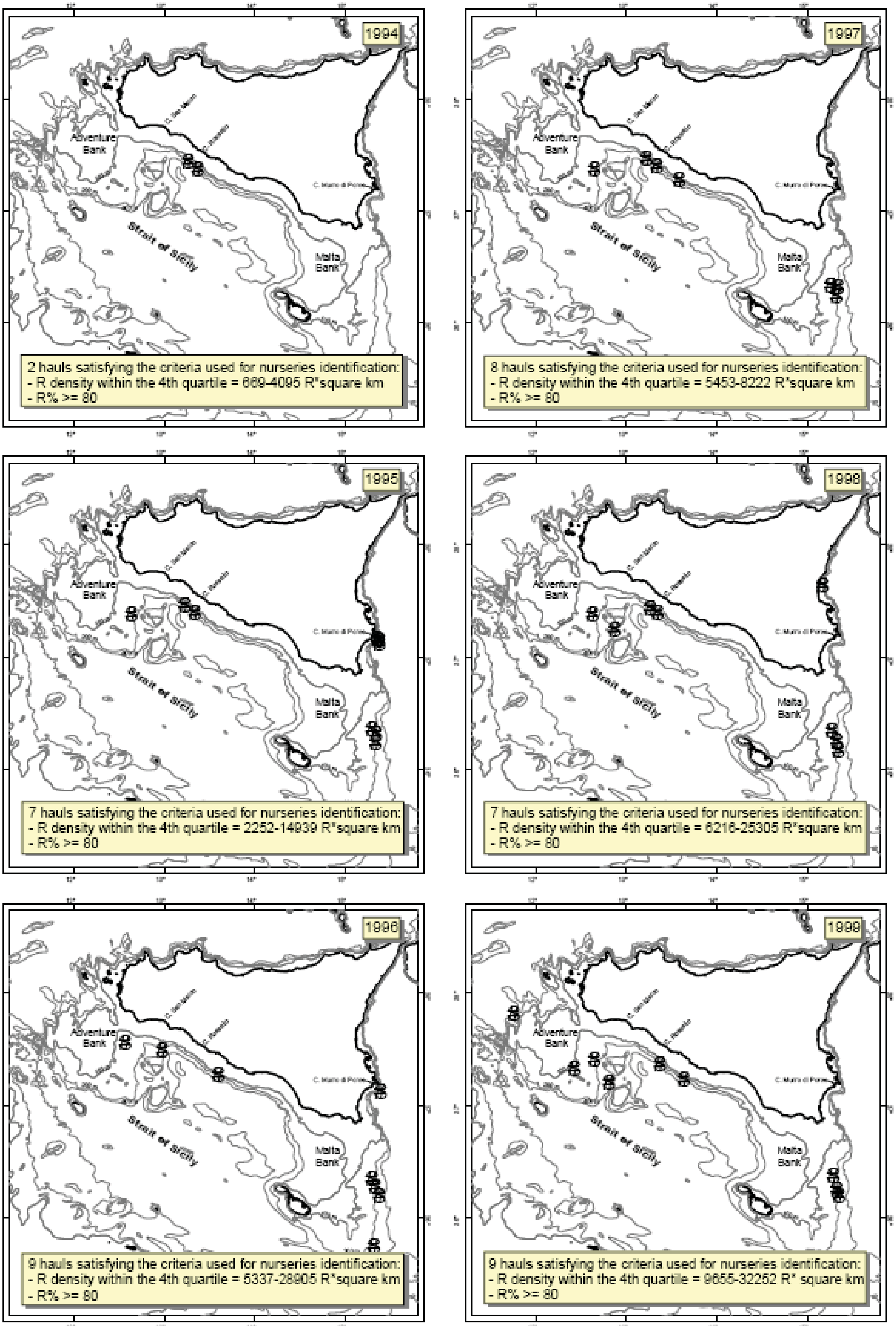


Figure 35. Positions of hauls (**8**) showing presence of recruits of *P. longirostris* during the 1994–1999 MEDITS Trawl Surveys (from Fiorentino et al., 2004).

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 36).

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).

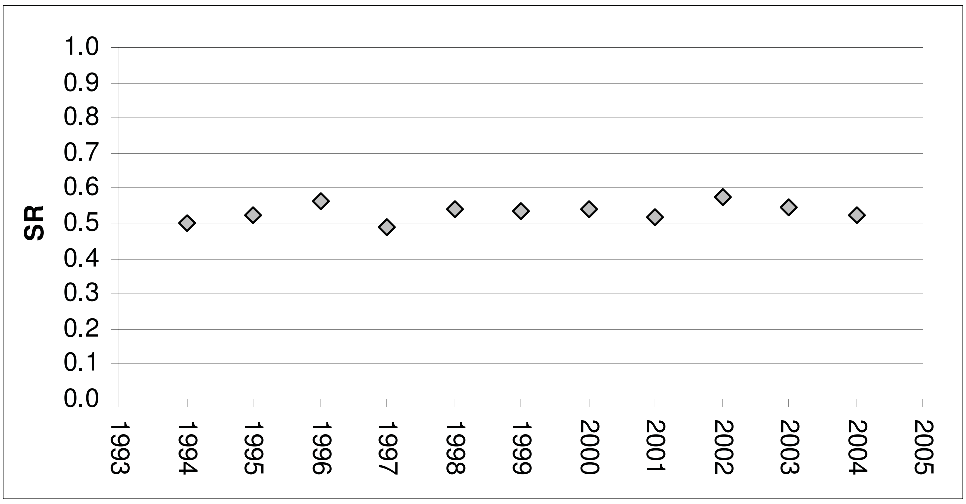


Figure 36. Sex ratio of *P. longirostris* in GSA 16, calculated as the ratio of the number of females to the total number of sexed individuals, from MEDITS Trawl Survey data (redrawn from Fiorentino et al., 2005).

Length–weight relationships
The parameters of the allometric length–weight relationships are reported in Table 18.

Table 18. Parameters of the length–weight relationships of *P. longirostris* in the Strait of Sicily.

Author	GSA	Sex	a	b	Period
Levi et al. (1995a)	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	

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 animals entering a third year, and is characterized by high rates of growth and mortality.

However when Levi et al. (1995a) 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, they reported 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 of 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.

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 19.

Table 19. Von Bertalanffy growth function (VBGF) parameters of *P. longirostris* in the Strait of Sicily (*n.a.* – not available). “Wp” stands for Winter Point, which indicates the period of the year (expressed as fraction of the year) when growth is lowest and “C” is a factor which expresses 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. (1995a)	15, 16	–	–	–	–	–	–	30.5	0.63	–0.19	Seasonalized, with WP=0.1 and 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

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.

Stock units

The stock structure of the species in the Strait of Sicily is not well known. Levi et al. (1995a) 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. (in press). 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. These local sub-populations, one on the Adventure Bank and one on the Malta Bank, are separated by a wide area in which the species' abundance is very low.

Evaluation and exploitation

Biomass indices from trawl surveys

Trawl-survey abundance indices estimated from the data of the MEDITS Trawl Surveys in GSAs 15 and 16 showed an increase in the standing stock from 1994 to 1999, followed by cyclic fluctuations between a maximum of 25 kg km^{-2} to a minimum of 5 kg km^{-2} (Fiorentino et al., 2005) (Figure 37).

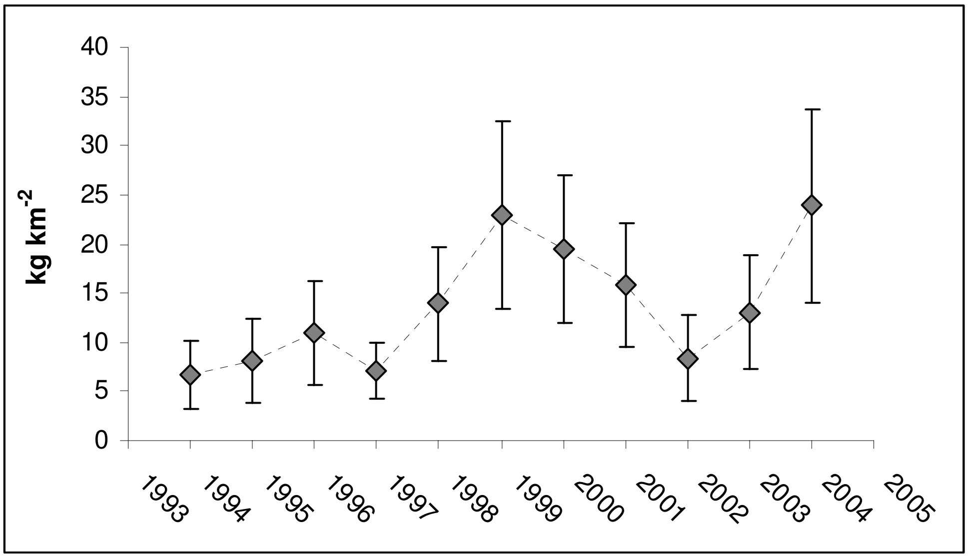


Figure 37. Time-series of *P. longirostris* biomass indices (kg km^{-2}) (MEDITS Trawl Surveys; 10–800 m depth range) in GSAs 15 (the MMFZ was excluded prior to 2000) and 16 (Redrawn from Fiorentino et al., 2005).

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). 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 38).

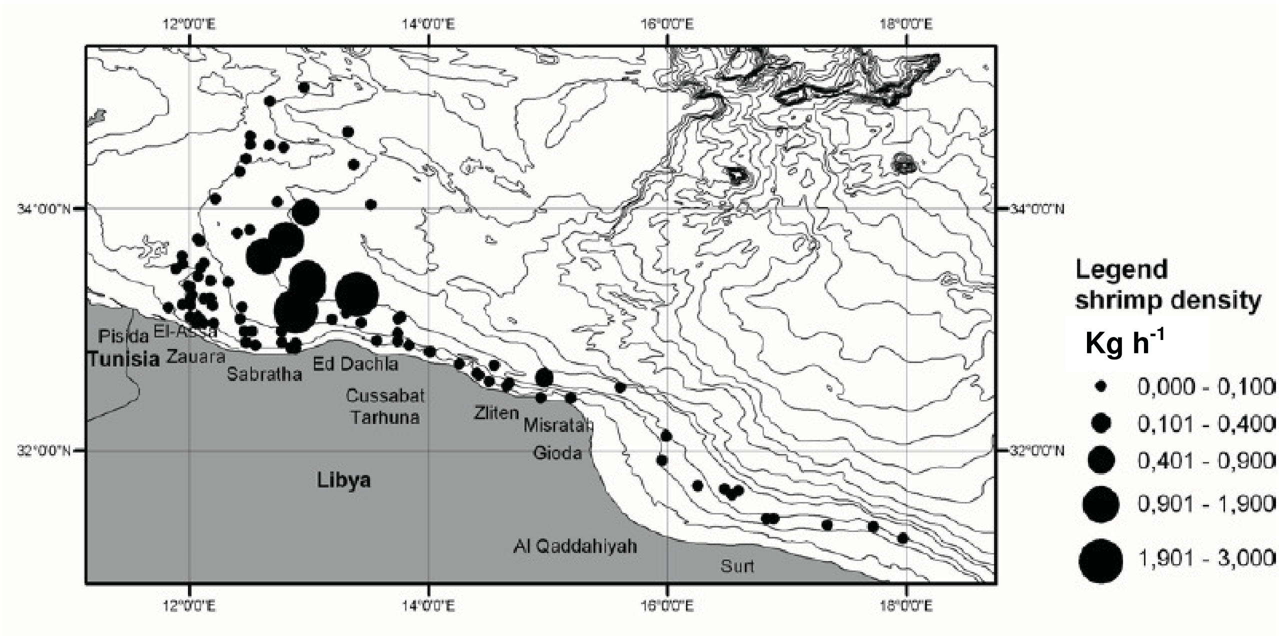


Figure 38. Biomass indices (kg h^{-1}) of the shrimps *Penaeus keraturus* (depth<100m) and *P. longirostris* (depth >100 m) combined, off the western coasts of Libya (GSA 21) (LIBFISH Trawl Surveys 1993–1994) (from Rawag et al., 2004).

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 GSAs 15 and 16, assuming that recruitment occurs within the 50–200 m depth range (an area of 16,500 km^2). The mean value (±sd) of the DI and the absolute number of recruits, from 1994 to 2004, was 1,601 ± 969 individuals per square kilometre and 26.376 ± 15.959 million recruits.

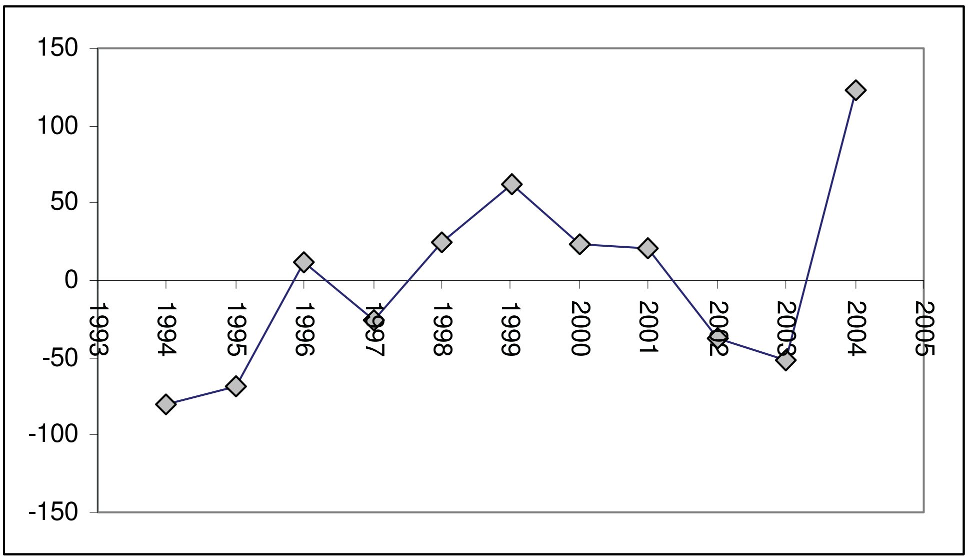


Figure 39. Percentage variation in annual values of recruitment of *P. longirostris* in GSAs 15 and 16. The “0” level stands for the 1994–2004 mean value.

The annual variability of the recruitment strength, in terms of percentage deviation from the 1994–2004 mean value, is shown in Figure 39. A phase of increasing recruitment success occurs from 1994 to 1999, followed by a decreasing trend up to 2003. There was a remarkable increase in the recruitment strength between 2003 and 2004.

Stock assessment

In the late-1980s, the deep-water pink shrimp presented an exploitation rate (E_c=0.8) higher than the optimal ones (E_{max}=0.67; $E_{0.1}$=0.66; $E_{0.5}$=0.41) (Levi et al., 1995a) (Figure 40).

These authors 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 41).

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 20).

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 21) (IRMA–CNR, 1999).

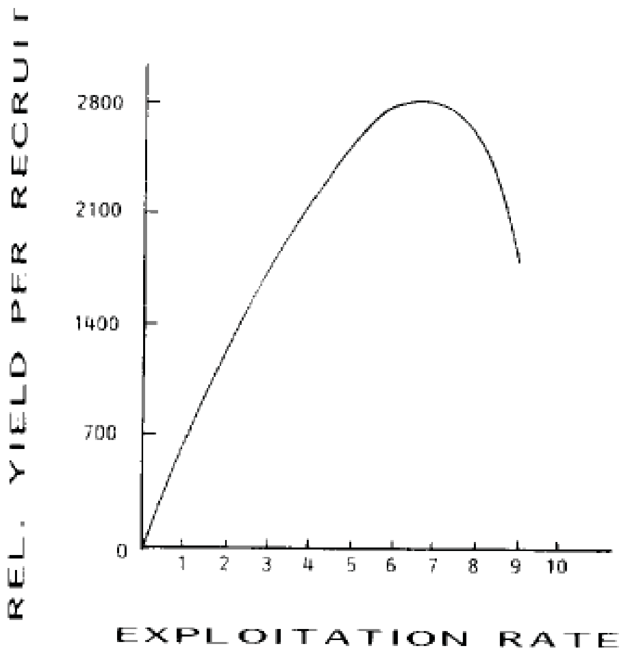


Figure 40. Relative yield per recruit vs. exploitation rate. Calculations with L_∞ = 30.5 mm and M/K = 0.27. E_{max} = 0.67; $E_{0.1}$ = 0.66; $E_{0.5}$ = 0.41 and E_c = 0.8 (from Levi et al., 1995a).

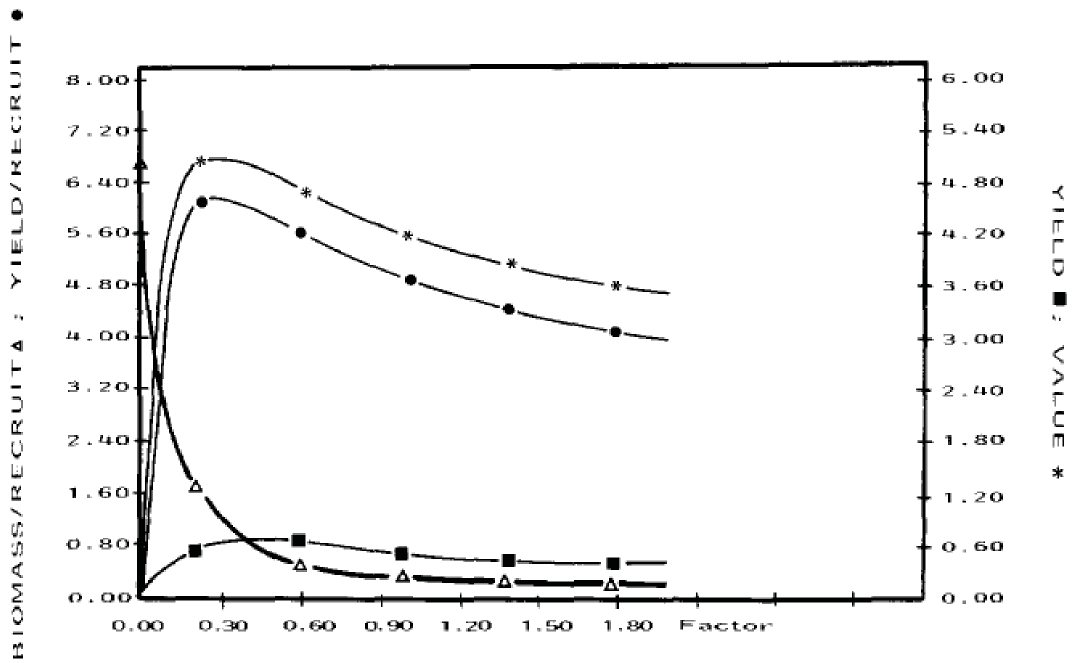


Figure 41. Long-term projection, based on the Thompson and Bell model, of biomass per recruit (in grams), yield per recruit (in grams), yield in weight (in grams) and value per recruit (in Italian lire). *X-axis* coefficient with respect to the present level of fishing mortality (F) (from Levi et al., 1995a).

Table 20. Percentage reduction in the exploitation rate (E = F/Z) assuming as reference point E_{opt} = 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 21. 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

Fisheries

P. longirostris is fished exclusively by otter trawl, together with other species, notably *Nephrops norvegicus* (Norway lobster), *Merluccius merluccius* (European hake), *Eledone* spp. (horned and musky octopuses), *Illex coindetii* (broadtail short squid), *Todaropsis eblanae* (lesser flying squid), *Lophius* spp. (anglerfish), *Mullus* spp. (red mullet and striped red mullet), *Pagellus* spp. (seabreams and pandoras), *Zeus faber* (John dory) and *Raja* spp. (rays) (Anon., 2000).

Fishing zones and seasons

Deep-water pink shrimp is caught both over the shelf and the upper slope all year round, but landing peaks are observed from March to July (Levi et al., 1995a). 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 figrue), “Kelibia” and “South Lampedusa”. Each fishing ground is, in turn, further subdivided into distinct fishing banks (Levi et al., 1995a) (Figure 42).

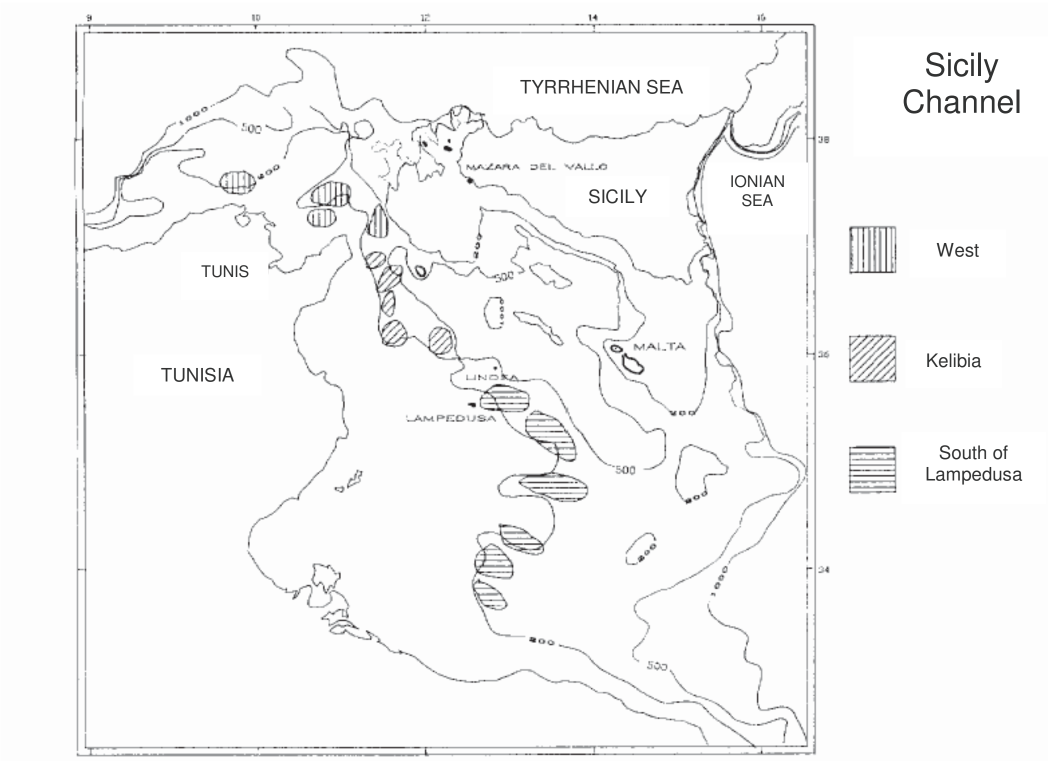


Figure 42. The three main fishing areas for *P. longirostris* in the Strait of Sicily. Each fishing area is divided into several fishing grounds (from Levi et al., 1995a).

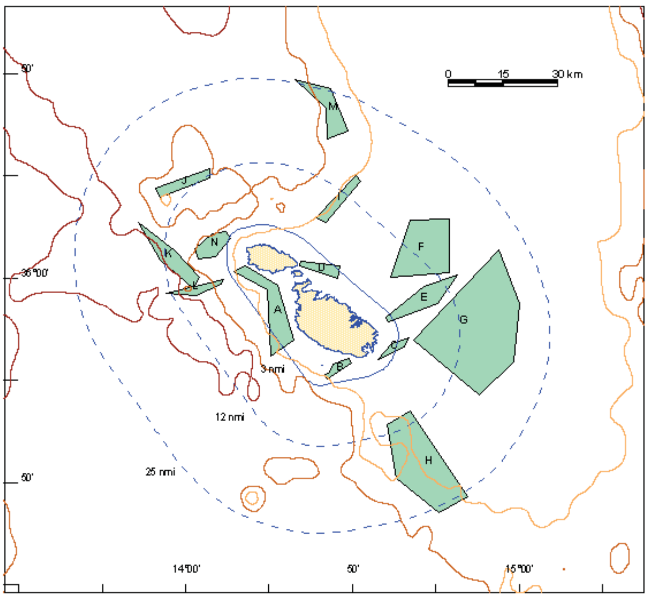


Figure 43. Trawlable areas inside the Maltese Fishereis Management Zone (FMZ) within 25 nm from Maltese Islands (A, B, C, D – protected, trawling forbidden; E, F, G, H, I – shelf / shallow water; J, K, L, M, N – slope / deep water, the most relevant to shrimp fishery) (from Camilleri et al., in press).

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 43) (Camilleri et al., in press).

Yield

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, corresponding to 13–20% of total yield in the area (Andreoli et al., 1995). Since most of the deep-water pink shrimp catches are made by distant 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., 1995a). The yield of all the Sicilian boats fishing in the Strait of Sicily (inshore and offshore fisheries) was 7,402 tons in 2003 and 8,440 in 2006 (from IREPA data). These figures correspond to more than 30% of the demersal landings in GSA 16.

According to Chaouachi and Ben Hassine (1998), trawlers fishing along the northern coast of Tunisia (GSA 12) yielded about 215 tons of deep-water pink shrimp annually (1990–1994), with the fleet based in Bizerta contributing more than 50% of the landings (Figure 44).

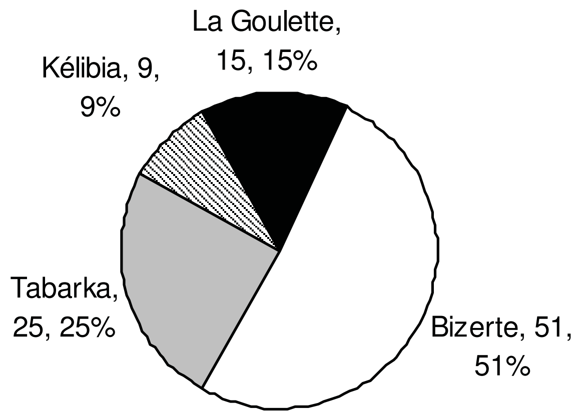


Figure 44. Contribution of the main Tunisian trawling fleets in GSA 12 to the yield of *P. longirostris* in 1990–1994 (redrawn from Chaouachi and Ben Hassine, 1998).

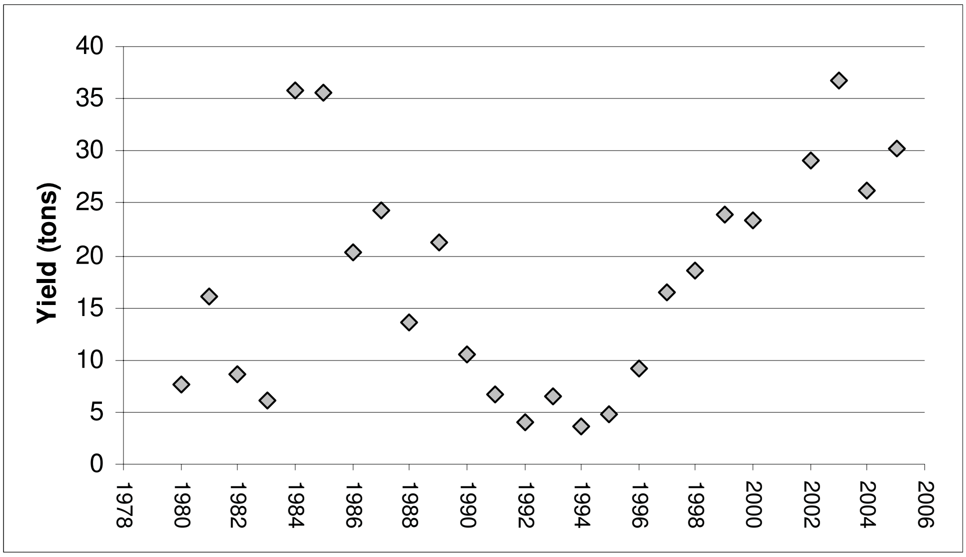


Figure 45. Yield of shrimps (deep-water pink shrimps and red shrimps) by the Maltese trawlers from 1980 to 2005 (drawn from data provided by Camilleri M.).

Statistics of shrimp catches in GSA 15 (Maltese trawlers), including red shrimp and deep-water pink 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 45). The very high yield of about 190 tons, in 2001, has been omitted from the graph.

Fishing and discards

According to Levi et al. (1995a), 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 22). The amount of discards is also variable, being higher in autumn–winter and from catches taken between trawling depths of 150 and 300 m (Anon., 2000).

Table 22. Annual modal length (LC in millimetres) 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).

Type of fisheries	**Modal length (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, personal communication).

Gears

The Italian trawlers targeting deep-water pink 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 23) (Fiorentino et al., 2003c).

Table 23. 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 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	400-450 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

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 late-1980s. 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. However this measure is considered to have been little effective in the protection of juvenile shrimps.

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 21 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.

No information on minimum legal size for *P. longirostris* is available for Tunisia and Libya.

The new EC Regulation 1967, of 21 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 are possible up to 2010.

Available information suggests that the new mesh size should improve the fishing of deep-water pink shrimps (Sobrino et al., 2005; Ragonese et al., 2006). A further improvement in the fishery might be obtained through the protection of *P. longirostris* nurseries (Lembo et al., 2000). Similarly to hake, the shrimp nurseries are located in discrete offshore areas on the outer shelf (100–200 m depth range) (see Figure 35).

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 (see Figure 43). The overall fishing capacity of the trawlers allowed to operate in the Maltese FMZ must not exceed the ceiling 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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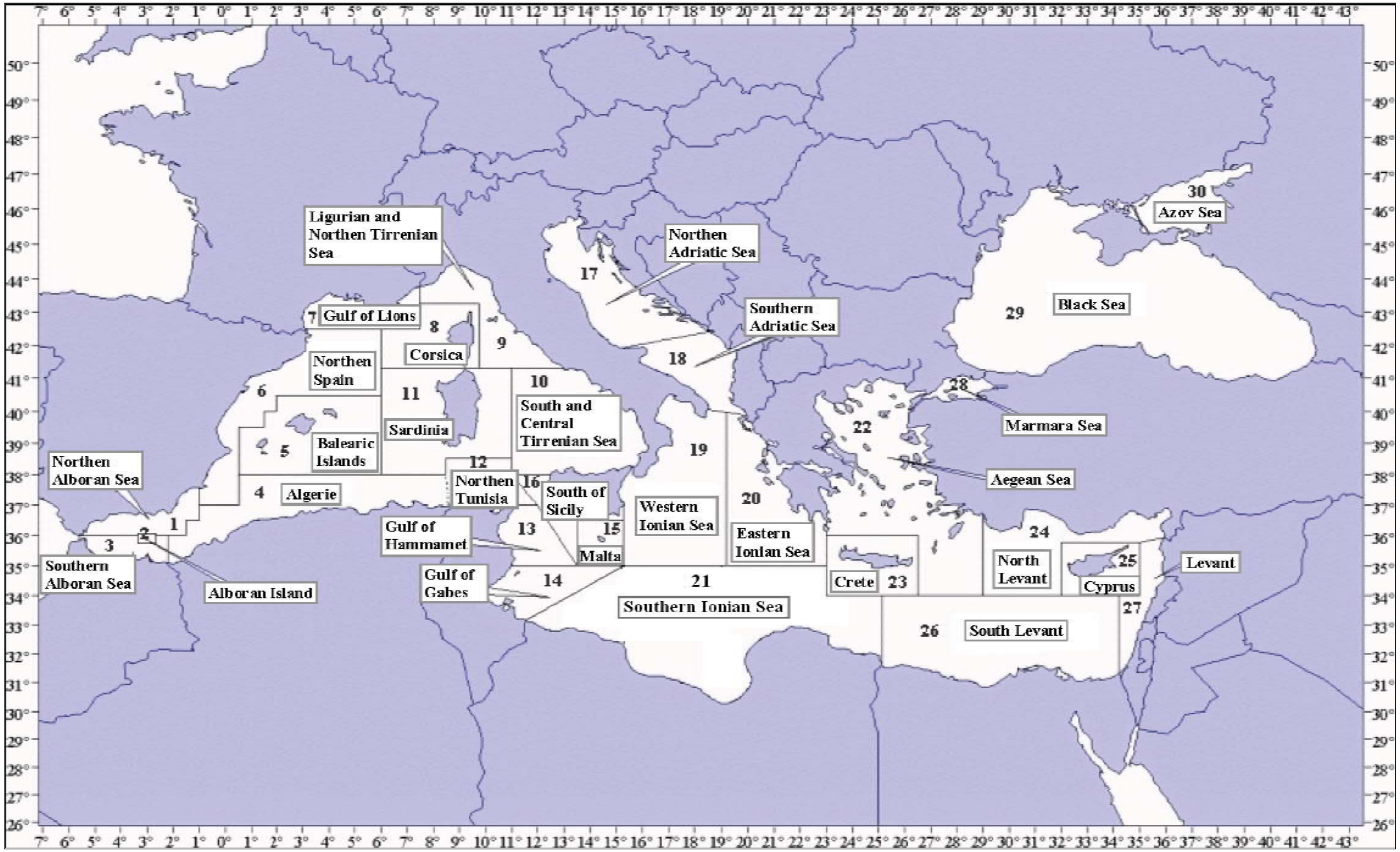
Annex A

GFCM Geographical Sub-Areas (GSAs) according to Resolution GFCM/31/2007/2.



GFCM Geographical Sub-Areas (GSAs) names according to the Resolution GFCM/31/2007/2

1	Northern Alboran Sea	16	South of Sicily
2	Alboran Island	17	Northern Adriatic
3	Southern Alboran Sea	18	Southern Adriatic Sea
4	Algeria	19	Western Ionian Sea
5	Balearic Island	20	Eastern Ionian Sea
6	Northern Spain	21	Southern Ionian Sea
7	Gulf of Lions	22	Aegean Sea
8	Corsica Island	23	Crete Island
9	Ligurian and North Tyrrhenian Sea	24	North Levant
10	South Tyrrhenian Sea	25	Cyprus Island
11	Sardinia	26	South Levant
12	Northern Tunisia	27	Levant
13	Gulf of Hammamet	28	Marmara Sea
14	Gulf of Gabès	29	Black Sea
15	Malta Island	30	Azov Sea

Notes

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