Overview of the available biological information on demersal resources of the Strait of Sicily

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Abstract

Biological information on the demersal resources of the Strait of Sicily collected during the trawl surveys carried out routinely in the Strait since 1985 is presented. Data concern bottoms of 10 m down to 800 m depth. A total of 143 species or higher taxa, whose density indices (DI; N/km^2) and biomass indices (BI, kg/km^2) are available for the whole study area, are recorded in the IRMA–CNR data base. More detailed information (i.e. size composition, sex ratio, gonad maturity and demographic parameters) are available, although with temporal gaps, for 18 target species: *Helicolenus dactylopterus, Lepidorhombus boscii, Merluccius merluccius*, *Mullus barbatus, M. surmuletus, Pagellus erythrinus, Peristedion cataphractum, Phycis blennoides, Galeus melastomus, Mustelus mustelus, Raja clavata, Scyliorhinus canicula, Aristaeomorpha foliacea, Nephrops norvegicus, Parapenaeus longirostris, Eledone cirrhosa, E. moschata, Illex coindetii.*

1. Introduction

Most of the biological information on groundfish gathered by IRMA–CNR in the Strait of Sicily was obtained within the framework of two main programmes of assessment of demersal resources: the GRUND program, started in 1985 and funded by the Italian government (Relini 2000) and the international programme MEDITS, started in 1994 and supported also by the Europen Union (Bertrand *et al.* 2002).

The aim of this review is to summarize the available information at IRMA–CNR for the main target species in the Strait of Sicily. This information concerns both the average abundance per unit surface (km^2) in kilograms and number, as well as the main length characteristics (range and median length) and most relevant demographic features (growth, maturity and mortality).

2. Material and methods

Data were collected during depth-stratified bottom trawl surveys. The explored bottoms, between 10 and 800 m, were divided into five depth strata (10–50; 51–100; 101–200; 201–500 and 501–800). Most of the campaigns were carried out in spring and autumn, although other seasons were available for some years. Samples were collected with the professional stern trawler "S. Anna" and two standard gears, with a fine mesh in the cod-end (20–30 mm opening) (Levi *et al.* 1998).

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The surveyed area, shown in Figure 1, concerns the Italian side of the mid-line of the Strait of Sicily for the main of campaigns (Area A). Information was also collected in the offshore water (Area B) during the GRUND surveys of 1997, 1998, 2000 and 2001, whereas in 2000, 2001 and 2002, data inside the Maltese Exclusive Fishing Zone were collected together with Maltese scientists, within the framework of the MEDITS programme.

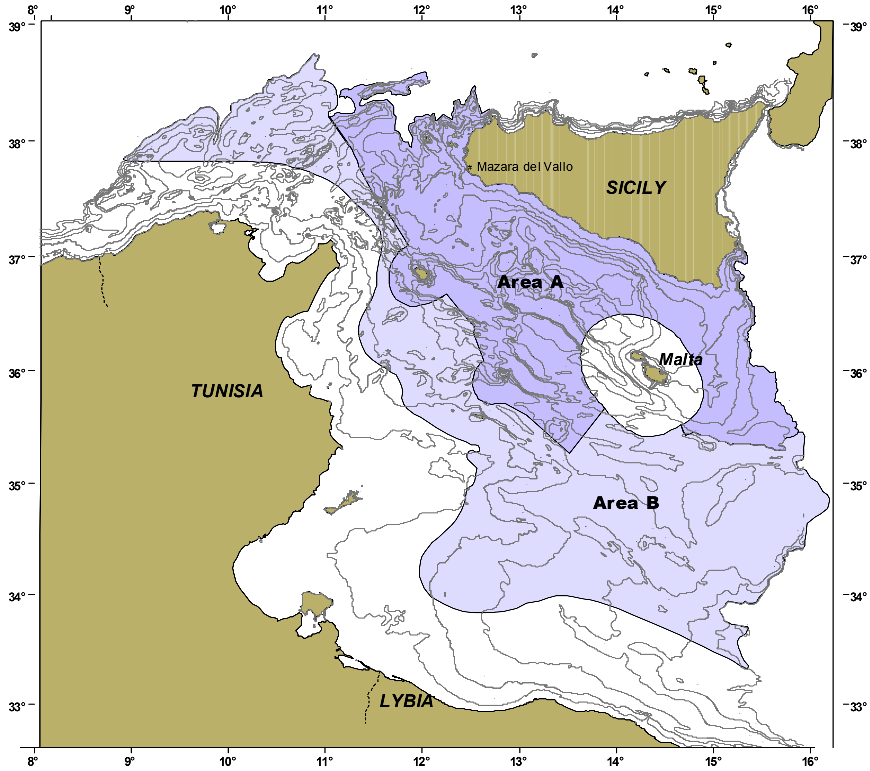

Figure 1. Strait of Sicily. Area investigated within the framework of the GRUND and the MEDITS programmes. The area A, bound by the mid-line is distinguished from the offshore water (area B).

Data were processed to obtain abundance indices in terms of number (Density Index, DI, kg/km^2) and biomass (Biomass Index; BI, kg/km^2) per square kilometre of the whole catch and biological information on the target species (length–frequency distributions, sex ratio, maturity stage, age composition, growth, mortality, etc.). Abundance indices are routinely estimated by stratum, but those referring to the shelf (10–200 m; i.e. 1st, 2nd and 3rd stratum combined, here defined as shelf index) and slope (201–800 m; i.e. 4th and 5th stratum combined, here defined as slope index) are reported herein for the sake of simplicity. Given the aim of the present contribution, the abundace data reported here were provided by the trawl surveys carried out from 1994 to 2002 during the MEDITS programme. A preliminary trend analysis in the abundance was performed after $\log_e$ transformation of the average density indexes (DI, N/km^2); the level of significance for the straight-line regression was set at $P \leq 0.05$.

The life-cycle parameters, and particularly, growth parameters, by sex and by females and males combined, were generally derived both from length-distribution analysis and otolith readings, based on the classic von Bertalanffy growth model. For some cartilaginous fish, the vertebrae were employed for ageing (see Cannizzaro *et al.* 1995). Length–weight relationships were calculated by the usual allometric model. Sex ratio was expressed as the proportion of females in the total number of individuals sexed, for the whole population and by size-class. Size at maturity was estimated by using the classic ogive. The spawning periods were identified by the analysis of maturity stage and of the gonad-somatic index throughout a year. The recruitment period was established by considering the massive occurrence of small-sized specimens in the samples provided by trawl surveys. Total mortality rates were mainly estimated by the means of the length-converted catch curve, whereas the natural mortalities were assessed by empirical methods, depending on the characteristics of each species. More details can be found in SAMED (2002), IRMA (2003), Fiorentino *et al.* (2003), and in the paper by Fiorentino *et al.* in the present report.

3. Available information

A total of 143 species or higher taxa, whose abundance and biomass indices are available over the study area, is recorded in the IRMA–CNR data base (IRMA 2003). More-detailed biological information, however, is available for a restricted number of species chosen according to both their commercial importance in the Strait of Sicily and their consistent presence in the IRMA–CNR data base for a long time. At the moment, there are 18 target species distributed among the most relevant taxa, as follows:

- **Osteicthyes:** *Helicolenus dactylopterus, Lepidorhombus boscii, Merluccius merluccius*, *Mullus barbatus, M. surmuletus, Pagellus erythrinus, Peristedion cataphractum, Phycis blennoides*
- **Chondrichthyes:** *Galeus melastomus, Mustelus mustelus, Raja clavata, Scyliorhinus canicula*
- **Crustacea (Decapoda):** *Aristaeomorpha foliacea, Nephrops norvegicus, Parapenaeus longirostris*
- **Cephalopoda:** *Eledone cirrhosa, E. moschata, Illex coindetii.*

A synoptic overview of the biomass indices and length features are presented in Table 1, whereas a synthetic, though not exhaustive, inventory of the existing information on their life-history characteristics is presented in Table 2.

Table 1. Synoptic overview of the biomass indices (BI) for the shelf (10–200 m) and slope (201–800 m) and length features for the target demersal species of the Strait of Sicily. Lengths refer to total, carapace and dorsal mantle length for fish, crustaceans and cephalopods, respectively.

Species	Biomass index (BI, kg/km^2)				Length range (mm)	Median length (mm)	Remarks
	Shelf		Slope				
	BI value	year	BI value	year			
Helicolenus dactylopterus	–	–	2.6 17	2001 2002	20–330	120	Occurs both on the shelf and on the slope, but the bulk of the catch was taken on the slope; high discard rate among the long-distance trawlers.
Lepidorhombus boscii	–	–	0.7 1.8	1997 1995	70–380	160	Almost exclusively observed on the slope, always in low quantity
Merluccius merluccius	20.3 37.8	1998 1994	14.5 27.6	1996 1994	40–760	100	Fished in a wide bathymetric depth range; almost disappeared below 500 m; high discard rate for specimens below 15 cm in length; no evident trend
Mullus barbatus	4.5 12.5	1994 1996	0.1 0.2	1997 1998	55–250	140–150	Caught nowadays almost exclusively on the shelf; low discard rate for specimens below 10 cm in length; widespread distribution of recruits, although some nursery areas can be defined. A fluctuating pattern in the BI within the range 6–10 kg was detected
Mullus surmuletus	6.4 15.1	1999 1997	15.6	1996	120–350	180	Occurs mainly on the shelf
Pagellus erythrinus	1.6 9.3	1994 1998	–	–	80–330	120	Fished exclusively on the shelf
Peristedion cataphractum	–	–	0.5 4.4	2001 2002	40–350	190	Fished both on the shelf and on the slope although the highest value of BI occurs on the slope
Phycis blennoides	–	–	5.1 9.4	1995 1996	50–540	110	Mainly found on the slope. Only slight irregular variations of 5–7 kg were evident in the BI
Galeus melastomus	–	–	18.9 28.9	2002 2000	70–530	330	Collected only on the slope and fished over a wide depth range (250–680 m); totally discarded. No trend evident
Mustelus mustelus	4.7 18.6	2001 2000	–	–	–	–	Collected only on the shelf
Raja clavata	4.0 15.2	1995 1999	2.2 8.4	1995 1999	160–890	550	Caught in a wide depth range. Abundance indexes showed an irregular temporal pattern. A sharp decline has been noticed in the most recent surveys
Scyliorhinus canicula	5.0 8.2	2001 2002	–	–	90–490	300	Found both on the slope and the shelf
Aristaeomorpha foliacea	–	–	6.0 20.0	1995 1994	16–74	36	Exclusively caught in the deep waters although occasionally found at lesser depth (150–250 m); almost all sizes are retained (no or very low discard); not considering the 1994 datum, a positive trend was detected. An inversion of the trend has been noted in the most recent surveys
Nephrops norvegicus	0.1	1996 and 1999	2.8 7.3	1997 1996	15–76	31–37	Sought after by fishermen almost exclusively on the upper slope; only a scanty catch is taken on the outer edge of the shelf; no trend
Parapenaeus longirostris	3.9 14.1	1994, 1995 1999	7.4 27.1	1994 1999	9–39	18–23	Wide bathymetric distribution (80–700 m) but fishing grounds located mainly between 100 and 500 m; low discard incidence below CL of 20 mm; some nursery areas were identified. With the only exception of 1997 data, a positive and significant trend was detected for the DI. An inversion of the trend has been noted in the most recent surveys
Eledone cirrhosa	2.1 8.3	1997 1994	1.3 5.3	1995 1994	10–130	80	Juveniles are highly prized
Eledone moschata	9.2 12.6	2002 2000	–	–	20–170	70	A more "coastal" species than the congener; caught exclusively on the shelf
Illex coindetii	5.1 10.0	1997 1999	–	–	30–250	110	In spite of a wide depth distribution, this squid was mainly found on the shelf

Table 2. Inventory of existing information on the life-history characteristics of target species (fish and crustaceans) at IRMA–CNR (data from area A). Weight in grams and length in millimetres (unless otherwise specified). Lengths refer to total and carapace length for fish and crustaceans, respectively. Where applicable, ranges of *a* and *b* values, as well as of length at maturity and of sex ratio, are given. Time unit: year. CI denotes the confidence interval (95%); *F* females, *M* males; *n.a.* not available

Species	Growth parameters	Length–weight relationship (allometric model: $w=al^b$)	Length at maturity	Sex ratio (F/F+M)	Total mortality (Z)	Natural mortality (M)	Spawning season	Recruitment season
Helicolenus dactylopterus	F+M: L_∞=392; K=0.127; t_0= –1.46	F+M: *a*=0.0000129; *b*=3.05	F=200	0.47	F+M=0.64	F+M=0.31	–	All year round
Merluccius merluccius	F: L_∞=705; K=0.18; t_0= –0.10 M: L_∞=494; K=0.29; t_0= –0.01	F: *a*=0.0000038; *b*=3.12; M: *a*=0.00000461–0.00000408; *b*=3.08–3.10	F=335; M=215–280	0.44–0.52	F=0.78 (CI=0.74–0.83) M=1.34 (CI=1.29–1.39)	F=0.30 M=0.45	All year round	All year round
Mullus barbatus	F: L_∞=235; K=0.60 M: L_∞=202; K=0.65	F: *a*=0.000189–0.0000080; *b*=2.90–3.07; M: *a*=0.0000304–0.00000108; *b*=2.79–3.00	F=150–160 M=140	0.43–0.62	F=2.28 (CI=2.06–2.50) M=2.74 (CI=2.183.29)	F= 1.10 M=1.20	Spring–summer	Summer–autumn
Mullus surmuletus	F: L_∞=290; K=0.48; t_0= –0.84 M: L_∞=250; K=0.50; t_0= –0.20	F: *a*=0.0000209–0.0000100; *b*=2.90–3.04; M: *a*=0.0000166–0.00000670; *b*=2.94–3.11	F=195	0.51–0.58	F=1.68 (CI=1.57–1.79) M=1.85 (CI=1.73–1.97)	F= 0.90 M=0.80	Spring–summer	Summer–autumn
Pagellus erythrinus	F+M: L_∞=380; K=0.18; t_0= –0.71	F: *a*=0.0000438–0.0000288; *b*=2.78–2.85; M: *a*=0.0000347–0.0000221; *b*=2.81–2.91	F=120–130 M=160–170	0.84–0.92	F+M: 0.67 (CI=0.60–0.73)	F+M= 0.40	Spring–summer	Mainly autumn
Peristedion cataphractum	F: L_∞=434; K=0.20; t_0= –0.39 M: L_∞=456; K=0.175; t_0= –0.48	F+M (length in cm): *a*=0.00428; *b*=3.10	F=210 M=230–240	0.54	–	–	Spring–summer	Summer–autumn
Phycis blennoides	F: L_∞=681; K=0.22; t_0= –0.15 M: L_∞=471; K=0.38; t_0= –0.03	F: *a*=0.0000438–0.0000288; *b*=2.78–2.85; M: *a*=0.0000347–0.0000221; *b*=2.81–2.91	F=313	–	F=0.88 M=1.41	F=0.35 M=0.58	Autumn	Spring
Raja clavata	F: L_∞=1265; K=0.098; t_0= –0.51 M: L_∞=1167; K=0.106; t_0= –0.41	F: *a*=0.0000438–0.0000288; *b*=2.78–2.85; M: *a*=0.0000347–0.0000221; *b*=2.81–2.91	F=770–790 M=570–590	0.39–0.49	F (n.a.) M (n.a.)	F (n.a.) M (n.a.)	All year round, with a peak in autumn	n.a.
Aristaeomorpha foliacea	F: L_∞=65.8; K = 0.52; t_0= –0.23 M: *a*=26.3; *b*=3.94 (linear growth; b=slope)	F: *a*=0.00176–0.00210; *b*=2.51–2.56; M: *a*=0.00116–0.00135; *b*=2.65–2.69	F=42 M=30–33	0.43–0.49	F=1.18 (CI=1.09–1.27)	F=0.40	Summer–autumn	Spring
Nephrops norvegicus	F: L_∞=53.0; K=0.14; t_0= –0.5 M : L_∞=62.0; K=0.13; t_0= –0.5	F: *a*=0.000440; *b*=3.133; M: *a*=0.000424; b=3.158; *b*=2.81–2.91	F=30–32	0.40–0.49	F=0.68 (CI=0.63–0.73) M=0.42 (CI=0.40–0.44)	F and M=0.20	Summer–autumn (berried)	Autumn
Parapenaeus longirostris	F: L_∞=40.9; K=0.71; M : L_∞=34.3; K=0.73	F: *a*=0.00244–0.00315; *b*=2.48–2.55; M: *a*=0.00271–0.00406; *b*=2.40–2.50	F=24 M=19	0.57–0.61	F=3.37 (CI=3.30–3.44) M=3.33 (CI=3.17–3.49)	F=1.20 M=1.30	Late summer–late winter	Peak in autumn

4. Discussion and conclusions

The most striking features of the figures reported above consist in their suggestion that there is an overall steady state of the demersal resources in the Strait of Sicily with even some increase in the local index of abundance for some species (i.e., the red shrimp, *A. foliacea*, or the deep-water pink shrimp, *P. longirostris*). That might create some perplexity in non-specialists, fishermen and politicians, given the overfishing generally recognized by scientists and the compliance of the fishermen operating in the Strait of Sicily.

Besides the well known problems in obtaining precise and accurate standing-stock estimates, stability does not mean necessarily “good shape”, but only the capability of the investigated resource to withstand a high level of fishing pressure. Although not yet clarified and modelled, the reasons for such resilience likely reflect the interaction amongst spatial complexity, “high compensation” or “robust” stock–recruitment relationships (or recruit migration from less exploited neighbouring fishing grounds) and the adaptability of the fishing fleets, which switch to the most abundant species/fishing grounds year by year. In particular, it is worth underlining Caddy’s (1990) hypothesis of "refugia" which allows a reduced or no longer available parental stock to maintain the standing stock by recruitment.

As matter of fact, the bulk of the trawl catches in the Strait of Sicily is nowadays composed of recruits whose growth is enhanced by the reduced inter-specific competition. Recruits also represent the most abundant specimens (up 90%) in the MEDITS and the GRUND catches. Since recruitment might show spatial and temporal fluctuations, both in the absolute values and in time of occurrence, whereas the experimental survey can cover only a limited temporal window, it is likely that the steady state or trends detected for different species could be correlated with the “good” or “bad” recruitment years enhanced or smoothed out by the synchrony between the biological and the survey calendars.

In practice, experimental data suggest (as does also a comparison of the total and natural mortality values given in Table 2) that all the demersal stocks of the Strait of Sicily fluctuate around the minimum asymptotic level of a Fox-like surplus-production model with a limited possibility to get out of the "trough", given the high efficiency and adaptability of the trawler fleets.

In fact, an historical retrospective indicates that the capacity of fleets fishing in the Strait of Sicily corresponding to the maximum sustainable yield for all demersal species was surpassed during the late 1970s–early 1980s (Levi 1988). As an example of such decline, the hourly catch rate for the pooled demersal resources trawled along the upper slope decreased from about 30–40 kg in the early 1970s to 10–20 kg in the late 1990s (Levi *et al.* 2001). Another example comes from the analysis of the discard rate (a rather good index of the “shape” of a trawl fishery); from 1996 to 2000, the percentage of the total catch of Mazara trawlers discarded decreased from 50% to 20%. This trend became more relevant considering that, in the mid-1980s, discards in the area consisted of about 60–70% of the trawler catches (Levi *et al.* 2001). Further indexes of overexploitation can be found in the rarefaction of the large-size sedentary and slow-growing fishes, such as *Peristedion cataphractum* (Pizzicori *et al.* 1995) and *Helicolenus dactylopterus* (Ragonese and Reale 1995); for the latter species, in particular, it is worth noting the estimated differential between the recent (2 years) and “pristine” (5 years) critical ages (Ragonese and Reale 1992). This scenario is supported also by the ineffectiveness of the management tools applied both by national and regional administrations, among which the most relevant were:

- trawling prohibition within three nautical miles from the coast (law of 14 July 1965, No.963)
- compulsory 45-day trawling ban (since 1983)
- reduction in the fleet size.

It is true that enforcement and control problems, together with other advantages (for example, trawling with a mesh size of less than 40 mm is allowed under Sicilian regional rules), have contributed to the inefficacy of these management actions, and a worse situation could have been attained without them; nevertheless, no effective stock rebuilding has been detected.

Notwithstanding the limitations and drawbacks, the data gathered during the experimental trawl surveys are very precious because they allow a regular and consistent check of the stock status, on the one hand, but (a most important feature) they have also demonstrated some capability to rebuild the resources, thanks to sustained recruitment. The main problem will consist in figuring out a proper management scheme in order to avoid an excessive concentration of the fishing effort where "good" recruitment occurs. The inclusion of the spatial factor in modeling by individualizing unit fishing grounds to be managed on an individual basis might be the challenge for the future.

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