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The MEDITS trawl survey specifications in an ecosystem approach to fishery management

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Summary: The MEDITS programme started in 1994 in the Mediterranean with the cooperation among research institutes from four countries: France, Greece, Italy and Spain. Over the years, until the advent of the European framework for the collection and management of fisheries data (the Data Collection Framework, DCF), new partners from Slovenia, Croatia, Albania, Montenegro, Malta and Cyprus joined MEDITS. The FAO regional projects facilitated the cooperation with non-European countries. MEDITS applies a common sampling protocol and methodology for sample collection, data storage and data quality checks (RoME routines). For many years, MEDITS represented the most important data source supporting the evaluation of demersal resources by means of population and community indicators, assessment and simulation models based on fishery-independent data. With the consolidation of the DCF, MEDITS routinely provides abundance indices of target species for tuning stock assessment models of intermediate complexity. Over the years, the survey scope has broadened from the population of demersal species to their fish community and ecosystems, and it has faced new challenges, such as the identification of essential fish habitats, providing new scientific insights linked to the Marine Strategy Framework Directive (e.g. biodiversity, trophic webs, allochthonous species and marine macro-litter evaluations) and to the ecosystem approach to fishery and marine spatial planning.

Keywords: demersal resources; trawl survey; sampling; Mediterranean.

Especificaciones de las campañas de arrastre MEDITS en un enfoque ecosistémico para la gestión pesquera

Resumen: El programa MEDITS comenzó en 1994 en el Mediterráneo, con la cooperación entre institutos de investigación de cuatro países: Francia, Grecia, Italia, España. A lo largo del tiempo, y con la puesta en marcha del programa europeo para la recopilación y gestión de datos pesqueros (Data Collection Framework, DCF), se unieron nuevos socios como Eslovenia, Croacia, Albania, Montenegro, Malta y Chipre. Los proyectos regionales de FAO han facilitado la cooperación con países no europeos. MEDITS aplica un protocolo y una metodología de muestreo comunes, que abarca desde la recolección de muestras hasta el almacenamiento de datos y los controles de calidad de los mismos (programa RoME). Durante muchos años, MEDITS ha sido la fuente de datos más importante para la evaluación de los recursos demersales, mediante indicadores de población y comunidad y modelos de evaluación y simulación, basados en datos independientes de la pesca. Con la consolidación del DCF, MEDITS proporciona rutinariamente índices de abundancia de especies objetivo, que se usan para ajustar modelos de evaluación de stocks. A lo largo del tiempo, los objetivos de las campañas se han ampliado desde las poblaciones demersales a sus comunidades y ecosistemas, afrontando nuevos desafíos, como la identificación de hábitats esenciales para los peces, y proporcionando nuevos planteamientos científicos vinculados a la Directiva Marco sobre la Estrategia Marina (p.ej. biodiversidad, redes tróficas, especies alóctonas y evaluaciones de basura marina), así como la aproximación ecosistémica a las pesquerías y la Planificación Espacial Marina.

Palabras clave: recursos demersales; campaña de arrastre; muestreo; Mediterráneo.

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INTRODUCTION

The aim of scientific bottom trawl surveys is typically to collect data on the distribution of a range of fish species, estimating relative abundance and biological parameters of these species (Hilborn and Walters 1992, Gunderson 1993). The use of quantitative indices obtained is manifold. These surveys are central to the knowledge of the status of commercially important fishery stocks and to forecasting how this status evolves over time (e.g. Trenkel et al. 2007).

In data-rich situations, when both fishery-dependent and fishery-independent data are available, indices of fish population structure by age or length or indices of the whole population are used for tuning age-structured or production stock assessment models. However, for several by-catch species or for stocks that are not the main target of the commercial fisheries, fishery-dependent data are sometimes of poor quality because of incompleteness of the time series, spatial coverage or misreporting (Cotter et al. 2009a). In these data-limited situations, trawl surveys can provide valuable information in terms of quantitative abundance indices, length and/or age structure and biological parameters. Indeed, trawl surveys have gained more attention during the last decade as a primary tool for providing information that is useful per se to the assessment process (e.g. Cotter et al. 2009b).

The MEDITS trawl survey programme in the Mediterranean started in 1994 as a European Commission-funded project in the framework of the cooperation between research institutes from four Member States of the European Union: France, Greece, Italy and Spain (Bertrand et al. 2002). During the following years, the survey was expanded to Slovenia, Croatia, Albania, Malta, Montenegro and Cyprus, finally involving 16 research institutes. Currently, the MEDITS sampling covers 543000 km² with, on average, about 1283 sampling stations per year (Fig. 1; Table 1). Collaboration with non-European countries was facilitated by the FAO AdriaMed regional project and in 2000-2001 by the CopeMed project, for the conducting of two surveys in Morocco.

In 2002, the European countries bordering the Mediterranean made a commitment to carry out MEDITS surveys yearly according to the European Data Collection Framework (DCF). Permanent links are therefore maintained with the relevant bodies at European Union level, such as the Regional Coordination Group of the Mediterranean and Black Sea (RCG_Med&BS) and the Scientific Technical and Economic Committee for Fisheries (STECF). Furthermore, links were also maintained with the General Fisheries Commission for the Mediterranean (GFCM), the FAO regional fisheries management organization.

The MEDITS data have been used for joint publications, which have elucidated several aspects related to

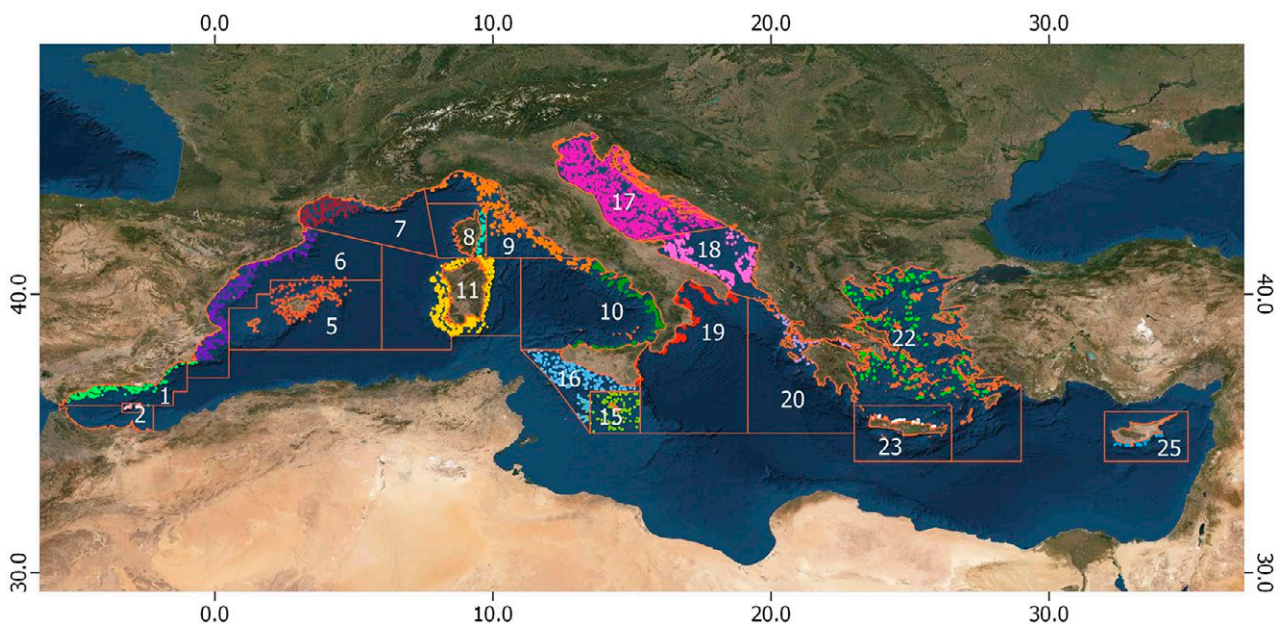


Fig. 1. – Study area of the MEDITS bottom trawl surveys, showing the hauls allocated to the geographical sub-areas established by the General Fisheries Commission for the Mediterranean.

Table 1. – Average number of hauls carried out during the MEDITS bottom trawl surveys by each geographical sub-area (GSA) established by the General Fisheries Commission for the Mediterranean during the period 1994-2001 (before the DCF) and the period 2002-2017. The codes of the MEDITS macrostrata (see Fig. 3) and the relative areas in km² are also shown.

GSA	Macrostrata code	Area (km ²)	Hauls	
			1994-2001	2002-2017
1	111a	11920	34	44
2	111b	833		7
5	115	12656	4	55 ^{ss}
6	112-113	32506	69	85
7	121	13860	67	64
8	131	4562	20	22
9	132	42410	153	120
10	134a-134b	20255	85	70
11	133	26975	120	99
15	135	10580	7	45
16	134c	31386	56	120
17 (W)	211a-211b	60350	86	120
17 (NE)	211c	184	2 ^{oo}	2
17 (CE)	211d	31727	48 ^{oo}	60
18 (W)	221e-221h	15273	72	70
18 (E)	221j	5000		5 ^s
18 (SE)	221i	8735	40 ^{oo}	15
19	221a-221d	16347	74	70
20	222a-222b	16823	31	36
22 (Ar)	223a	24916	22	23
22 (NAe)	224a	68157	65	65
22 (SAe)	225a	55258	38	40
23	225a (06-10)	7343	16	20
25	321a	11106		26 ^{**}
3	114	13841	55 [*]	-

^{oo} since 1996; ^{*} southern Alboran Sea; ^{**} since 2005; ^{ss} since 2007; ^s since 2008.

abundance and biomass indices of demersal species, their length-/age-frequency distribution (by sex and maturity stages) and life history parameters, the latter especially related to total and fishing mortality. Population and community indicators and spatial occupation indices have also been estimated. All these results have provided information among the various GFCM geographical sub-areas (GSAs) of the Mediterranean for a range of target species and thematic areas. The first MEDITS monograph published in 2002 under the title “Mediterranean marine demersal resources: The MEDITS international trawl survey (1994-1999)” (Abelló et al. 2002) is the earliest good example of a joint publication at the wide geographical scale of the northern Mediterranean. Furthermore, studies have been carried out to understand the impact of fishing pressure on the abundance of populations, fish community diversity and structure, as well as to investigate the influence of environmental drivers on shaping the spatial and temporal distribution of fish populations and their communities, thus helping forecast the effects of global changes at a Mediterranean scale. Taxonomic studies, including new reports in the area and descriptions of new species, have also been carried out from samples collected during MEDITS surveys.

A list of relevant publications is provided in the Supplementary Material.

Twenty-five years after the beginning of the MEDITS trawl survey, this second monograph aims to further understanding spatial and temporal patterns of populations and fish community structures and to explore the influence of anthropogenic factors in shaping such patterns.

This paper aims to summarize and update the specifications of the MEDITS trawl survey, focusing on those most relevant to an ecosystem approach to fishery management and on data quality. The latter is pivotal for a sound evaluation of the status of demersal resources and their communities.

A SUMMARY OF THE TECHNICAL SPECIFICATIONS OF THE MEDITS SURVEY

Since the beginning of the project, the standard sampling gear has been the bottom trawl GOC 73 (Bertrand et al. 2002) designed for experimental fishing for scientific purposes in the various conditions encountered in the whole survey area. It has a vertical opening slightly larger than that of the most common professional gears used in the area. Its codend mesh size is 20 mm (stretched mesh) to also allow the catch of juveniles of many species for estimating recruitment indices. Specific studies have been conducted to increase knowledge on the efficiency of the gear (Fiorentini et al. 1996, Fiorentini and Dremière 1996, Dremière et al. 1999, Fiorentini et al. 1999). Both research and commercial vessels are used, depending on the GSA and country, so operational conditions in the GSAs differ.

Haul duration is 30 minutes on the continental shelf (10-200 m depth) and 60 minutes on the slope (201-800 m depth). The standard fishing speed is 3 knots on the ground, and hauls are allowed only during daytime. Haul performance and gear geometry are usually monitored using the SCANMAR system or, more recently, SIMRAD or MARPORT sensors. Data acquisition is monitored in real time using a laptop and specific software. Effective tow duration was considered as the interval from the time when the gear is stabilized on the bottom and the time when speed is reduced to recover the warp. Vertical and horizontal openings (wings) of the net working on the bottom are expected to range from 2 to 3 m (more commonly 2 and 2.5 m) the former and from 15 to 22 m the latter, the higher values depending on depth. On each haul, the horizontal opening is used to standardize abundance and biomass of catches in relation to the sampled surface.

In addition, probes are used to record water temperature (formerly using Minilog and currently DST Logic CTD sensors) on the bottom during the towing. Intercalibration to exchange knowledge and fine tuning of the application of the common protocols in the field activities have been pursued since the beginning of the MEDITS survey, especially through the exchange of scientists on board the vessels. Furthermore, intercalibration studies have been performed in some GSAs to evaluate vessel effect when a change was needed. For example, this was done between the research vessels *Cornide de Saavedra*, used in GSAs 1 (northern Alboran), 2 (Alboran Island), 5 (Balearic Islands) and 6 (northern Spain), and *Miguel Oliver*, as the former had to be replaced. The intercalibration study was conducted in GSA 6 using parallel hauls and did not show significant differences.

The potential impact of different methods for estimating wing opening on the standardized abundance

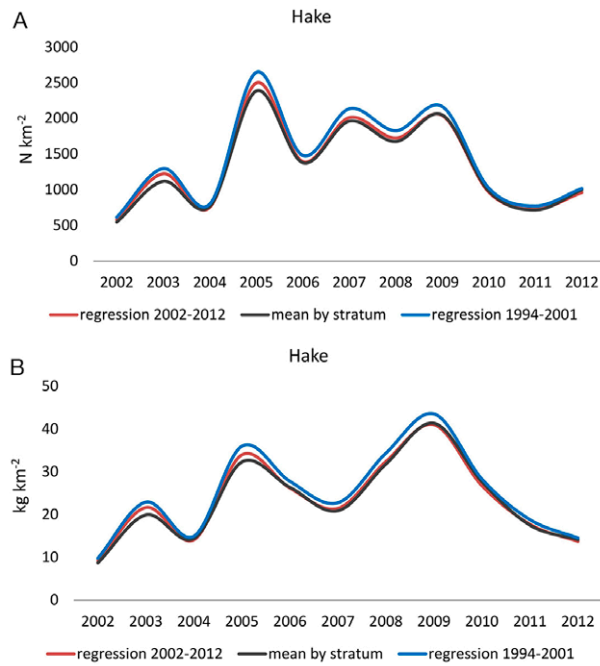


Fig. 2. – Comparison of the abundance indices (A, abundance in $N\ km^{-2}$; B, biomass in $kg\ km^{-2}$ of European hake) as means by stratum, obtained with the values of wing opening per haul estimated from the SCANMAR monitoring system and as results of two logarithmic regressions respectively for the years 2002-2012 and for the years 1994-2001: $WO=14.54+0.651 \times \ln(x)$; $WO=6.7873 \times \ln(\text{depth})+133.94$, where WO is the wing opening and x is depth.

indices (number and $kg\ km^2$) have been tested on a case study in GSA 10 (central-southern Tyrrhenian Sea). Different models were applied to species with different depth distributions, such as European hake (continental shelf and slope), red mullet (continental shelf) and giant red shrimp (slope):

- the mean of the wing opening by depth stratum (median and mode were almost coincident with the

- mean, so only this metric was used) (1)
- a logarithmic equation applied for the period 2002-2012:

$$WO=14.54+0.651 \times \ln(x) \quad (2)$$

- a logarithmic equation applied during the period 1994-2001 before the routine use of SCANMAR system for gear monitoring:

$$WO=133.94+6.7873 \times \ln(x) \quad (3)$$

where WO is the wing opening and x is depth.

The results highlighted that the impact on the estimates of abundance indices (both in number and weight) over 10 years (2002-2012) was, on average, around 2% if Equation (2) was compared with the mean (1) and around 8% if Equation (3) was compared with the mean (1). This higher percentage was observed only for European hake (Fig. 2). Thus, it was considered acceptable to continue to use Equation (3), in continuity with the past, if a device for monitoring the trawl geometry could not be used in a certain GSA in a given year.

The time of the year in which the MEDITS survey is scheduled is late spring-summer (from May to July). The survey follows a depth-stratified random sampling scheme, with haul allocation being proportional to the surface of depth strata, whose limits are 10-50, 51-100, 101-200, 201-500 and 501-800 m. Up to 44 different geographic sectors are also included in the stratification. The sampling strata and the GFCM GSAs are reported in Figure 3.

Indices are calculated following the usual procedure of the stratified mean and variance (Souplet 1996):

$$I = \sum_{i=1}^N W_i \bar{x}_i$$

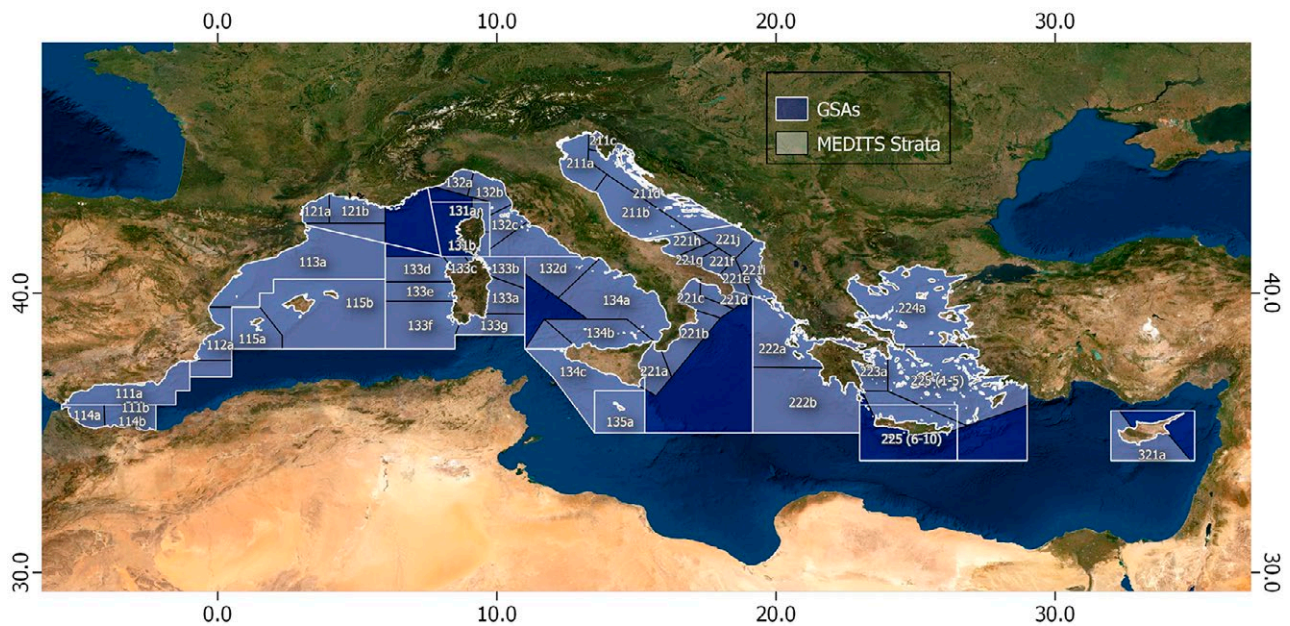


Fig. 3. – Map of the Mediterranean showing the geographic strata (black lines) considered in the MEDITS bottom trawl surveys allocated to the geographical sub-areas (GSAs; white lines) established by the General Fisheries Commission for the Mediterranean.

Table 2. – List of the taxonomic categories used in the MEDITS bottom trawl surveys with code specification and year of introduction and use. The symbol “—” indicates that the taxonomic category is still used.

MEDITS code	Nature	Years
A	Fish	1994-2011
Aa	Fish Agnatha	2014—
Ae	Fish Elasmobranchii	2012—
Ao	Fish Osteichthyes	2012—
B	Crustaceans (Decapoda)	1994—
Bam	Amphipoda	2012—
Bci	Cirripedia	2012—
Beu	Euphausiacea	2012—
Bis	Isopoda	2012—
Bst	Stomatopoda	2012—
C	Cephalopoda	1994—
D	Other commercial (edible) species	1994-2011
Dec	Echinodermata	2012—
Dmb	Mollusca Bivalvia	2012—
Dmg	Mollusca Gastropoda	2012—
Dmo	Mollusca Opisthobranchia	2012—
Dtu	Tunicata (Ascidiacea)	2012—
E	Other animal species but not commercial (not edible)	1994-2011
Ean	Annelida	2014—
Eba	Brachiopoda	2012—
Ebr	Bryozoa	2012—
Ech	Echiura	2014—
Ecn	Cnidaria	2012—
Ect	Ctenophora	2012—
Eec	Echinodermata	2012—
Ehi	Hirudinea	2012—
Emb	Mollusca Bivalvia	2012—
Emg	Mollusca Gastropoda	2012—
Emo	Mollusca Opisthobranchia	2012—
Emp	Mollusca Polyplacophora	2014—
Ene	Nemertea	2014—
Epo	Polychaeta	2012—
Epr	Priapulidae	2014—
Esi	Sipunculida	2012—
Esc	Scaphopoda	2012—
Esp	Sponges (Porifera)	2012—
Etu	Tunicata (Ascidiacea)	2012—
G	Portions or products of animal species (shell debris, eggs of gastropods, selachians, etc.)	2012—
H	Portions or products of vegetal species (e.g. leaves of sea grasses, of terrestrial plants, etc.)	2012—
M	Mammals	2014—
O	Birds	2014—
R	Reptilia (turtles)	2014—
V	#Aquatic plants, macroalgae#	2014—

$$\text{var}(I) = \sum_{i=1}^N \frac{W_i^2 S_{x_i}^2}{n_i} (1 - f_i)$$

R scripts have been developed for estimating population indices. These scripts are available at https://www.coispa.it/index.php?option=com_content&view=article&id=34&Itemid=119&lang=it.

However, since the advent of the DCF, some changes have occurred: i) an increase or a decrease in the sampling intensity from the period 1994-2001 to the subsequent one; ii) a deviation of the survey season from the standard one in certain areas and years; and iii) vessel replacements without the possibility of performing field intercalibration tests. For all these reasons, modelling through GLM, GAM, Delta-GLM and Delta-GAM was suggested, both for the standardization of abundance and biomass indices and for the length-frequency distributions. R scripts have been developed for those purposes and are available at https://www.coispa.it/index.php?option=com_content&view=article&id=34&Itemid=119&lang=it.

SUMMARY OF THE MEDITS BIOLOGICAL SPECIFICATIONS

The focus of the collection of survey data has been on keeping consistency throughout the time, so revisions of the protocols were introduced taking care to avoid disruptions in the time series. These changes are proposed, discussed and adopted in the MEDITS coordination meetings, which are organized annually.

During the last few years more emphasis was directed towards addressing ecosystem questions, while placing the survey in the DCF. Since 2012, the taxonomic categories and lists have been expanded to take into account the needs of the Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC).

All the species larger than 1 cm caught during the MEDITS survey are identified, then total weight and number of individuals are recorded. Alien species are also identified and noted. Currently 43 taxonomic categories are used (Table 2), linked to 1470 observed taxa (at least in one GSA). A full taxonomic list (TM list) is hence routinely updated and is currently available in the online repository (<https://www.sibm.it/MEDITS%202011/>)

Table 3. – Scientific name and code of the target species of the MEDITS bottom trawl surveys, year in which they started to be considered target and MEDITS group in which they were classified. Species belonging to the group G1, according to the MEDITS grouping of species, are in bold. * depending on the species; ** for brevity only the genus is reported (or the group of species in the case of the elasmobranchs), but the single species of the genus or of the group are considered. For further details, see Medits Handbook, Version 9 (Anonymous 2017).

Species	Code	Year	Group
<i>Chelidonichthys cuculus</i> (Linnaeus 1758)	ASPI CUC	1998	G2
<i>Chelidonichthys lucerna</i> (Linnaeus 1758)	TRIG LUC	2006	G2
<i>Boops boops</i> (Linnaeus, 1758)	BOOP BOO	2006	G2
<i>Citharus linguatula</i> (Linnaeus, 1758)	CITH MAC	1994	G2
<i>Diplodus annularis</i> (Linnaeus, 1758)	DIPL ANN	2012	G2
<i>Diplodus puntazzo</i> (Cetti, 1777)	DIPL PUN	2012	G2
<i>Diplodus sargus</i> (Linnaeus, 1758)	DIPL SAR	2012	G2
<i>Diplodus vulgaris</i> (Geoffroy Saint-Hilaire, 1817)	DIPL VUL	2012	G2
<i>Engraulis encrasicolus</i> (Linnaeus, 1758)	ENGR ENC	2012	G2
<i>Epinephelus</i> spp. **	EPIN SPP	2012	G2
<i>Eutrigla gurnardus</i> (Linnaeus, 1758)	EUTRI GUR	1994	G2
<i>Helicolenus dactylopterus</i> (Delaroche, 1809)	HELI DAC	1994	G2
<i>Lepidorhombus bosci</i> (Risso, 1810)	LEPM BOS	1994	G2
<i>Lithognathus mormyrus</i> (Linnaeus, 1758)	LITH MOR	2012	G2
<i>Lophius budegassa</i> Spinola, 1807	LOPH BUD	1994	G2
<i>Lophius piscatorius</i> Linnaeus, 1758	LOPH PIS	1994	G2
<i>Merluccius merluccius</i> (Linnaeus, 1758)	MERL MER	1994	G1
<i>Micromesistius poutassou</i> (Risso, 1826)	MICM POU	1994	G2
<i>Mullus barbatus</i> Linnaeus, 1758	MULL BAR	1994	G1
<i>Mullus surmuletus</i> Linnaeus, 1758	MULL SUR	1994	G1
<i>Pagellus acarne</i> (Risso, 1826)	PAGE ACA	1994	G2
<i>Pagellus bogaraveo</i> (Brünnich, 1768)	PAGE BOG	1994	G2
<i>Pagellus erythrinus</i> (Linnaeus, 1758)	PAGE ERY	1994	G2
<i>Phycis blennoides</i> (Brünnich, 1768)	PHYI BLE	1994	G2
<i>Pagrus pagrus</i> (Linnaeus, 1758)	SPAR PAG	2012	G2
<i>Polyprion americanus</i> (Bloch & Schneider, 1801)	POLY AME	2012	G2
<i>Psetta maxima</i> (Linnaeus, 1758)	PSET MAX	2012	G2
<i>Sardina pilchardus</i> (Walbaum, 1792)	SARD PIL	2012	G2
<i>Scomber</i> spp. **	SCOM SPP	2012	G2
<i>Solea solea</i> (Linnaeus 1758)	SOLE VUL	1994	G2
<i>Spicara flexuosa</i> Rafinesque, 1810	SPIC FLE	1994	G2
<i>Spicara maena</i> (Linnaeus, 1758)	SPIC MAE	2012	G2
<i>Spicara smaris</i> (Linnaeus, 1758)	SPIC SMA	1998	G2
<i>Trachurus mediterraneus</i> (Steindachner, 1863)	TRAC MED	1994	G2
<i>Trachurus trachurus</i> (Linnaeus, 1758)	TRAC TRA	1994	G2
<i>Trigloporus lastoviza</i> (Bonnaterre, 1788)	TRIP LAS	1998	G2
<i>Trisopterus m. capelanus</i> (Lacepède, 1800)	TRIS CAP	1994	G2
<i>Zeus faber</i> Linnaeus, 1758	ZEUS FAB	1994	G2
Elasmobranchs**		1999-2012*	G1
<i>Aristeus antennatus</i> (Risso, 1816)	ARIT ANT	1994	G1
<i>Aristaeomorpha foliacea</i> (Risso, 1827)	ARIS FOL	1994	G1
<i>Nephrops norvegicus</i> (Linnaeus, 1758)	NEPR NOR	1994	G1
<i>Parapenaeus longirostris</i> (Lucas, 1846)	PAPE LON	1994	G1
<i>Palinurus elephas</i> (Fabricius, 1787)	PALI ELE	2012	G2
<i>Penaeus kerathurus</i> (Forskål, 1775)	PENA KER	2012	G2
<i>Squilla mantis</i> (Linnaeus, 1758)	SQUI MAN	2012	G2
<i>Eledone cirrhosa</i> (Lamarck, 1798)	ELED CIR	1994	G2
<i>Eledone moschata</i> (Lamarck, 1799)	ELED MOS	1997	G2
<i>Illex coindetii</i> (Verany, 1839)	ILLE COI	1994	G1
<i>Loligo vulgaris</i> Lamarck, 1798	LOLI VUL	1994	G1
<i>Octopus vulgaris</i> Cuvier, 1797	OCTO VUL	1994	G2
<i>Sepia officinalis</i> Linnaeus, 1758	SEPI OFF	1994	G2
<i>Todarodes sagittatus</i> (Lamarck, 1798)	TODA SAG	2012	G2

[principaledownload.htm](#)). The procedure for including a new species in the TM list foresees that the new species's name and sheet is submitted to the person responsible for the TM list who, after checks, proposes a specific code according to the rule of the Nordic Code Centre (NCC-Stockholm).

Currently, the TM list is composed of approximately 1617 codes. Up to 2017, the identified taxa included 385 bony fish, 54 elasmobranchs, 220 crustaceans (decapods), 25 other crustaceans, 60 cephalopods, 93 echinoderms, 115 bivalve molluscs, 98 gastropod molluscs, 54 opisthobranch molluscs, 72 tunicates (mainly Ascidiacea), 28 bryozoans, 90 cnidarians, 42 polychaetes, 50 porifers, 100 aquatic plants and macroalgae and other less numerous groups. 54 taxa

of bony fish and 5 elasmobranchs were recorded in all the GSAs, while for crustacean decapods 10 taxa were observed in all the GSAs (Relini 2015, Relini and Vallarino 2016, Relini and Vallarino 2017).

Among the 14 alien (non-indigenous) bony fish, 12 were recorded in GSA 25 (Relini 2015). The occurrence of 6 alien species of Crustacea decapoda was also recorded, mainly in the eastern Mediterranean (Relini and Vallarino 2016).

Since 2012, the MEDITS reference list of target species has been updated (Table 3) and includes 82 species, of which 32 are elasmobranchs. In addition, the list includes all species of the *Epinephelus* and *Scomber* genera, for which length measurements should be taken.

For all these species and the two genera, total number of individuals, total weight and individual length are collected.

This list of species has been further split in two groups:

- MEDITS G1, which includes 41 species, contains 3 bony fish, 4 crustaceans, 2 cephalopods and 32 elasmobranchs. For these species total number of individuals, total weight, individual length and also biological parameters including sex, maturity, individual weight and age are collected;

- MEDITS G2, which includes 43 species for which the total number of individuals, total weight and individual length are collected.

In 2011, the MEDITS coordination meeting agreed to increase the information recorded during the MEDITS survey, including the monitoring of new biological variables such as the age of bony fish species coded G1 and the individual weight of all the species coded G1.

A length-stratified random sampling was adopted to collect these biological variables, with fixed number of individuals randomly chosen from each length class by sex to take otoliths and individual weight. For details, see the MEDITS Handbook (Anonymous 2017). These biological variables were thus added to the routinely collected information on the macroscopic maturity stage for the main taxonomic groups. All individual measures of the different species are collected following common protocols.

Maturity scales currently used for the main taxonomic groups, Osteichthyes, oviparous and viviparous Elasmobranchii, Crustacea and Cephalopoda were updated at different time steps. A first update of the maturity scales was introduced in 2007, when it was decided to better discriminate the individuals that were maturing for the first time from those that had already reproduced at least once. In addition, this update aimed to better distinguish stages in the maturation and reabsorbing processes. The final goal was to allow, as much as possible, an unbiased estimate of the size at first maturity using either the maturity ogive or mean size at maturing and mature stages. Since 2013, the maturity scale of elasmobranchs was split between oviparous and viviparous species, given the differences of these reproduction strategies.

The validation of the maturity staging has been continuously pursued over the years, with microscopic histological analysis performed by a working group on maturity staging, established in the MEDITS coordination group. At the beginning of 2013, macroscopic photos and descriptions of the full maturity scales of 68 species were collected along with photos of histological sections. This work was also enriched with observations from other seasons carried out in the DCF biological samplings and culminated in the publication of the “Atlas on the maturity stages of Mediterranean fishery resources” (Follesa and Carbonara 2019).

Also for the collection of otoliths, a dedicated working group on ageing protocols was established within the MEDITS coordination group. This work, complemented with the one carried out in the DCF biological samplings, contributed to the publication of the

“Handbook on fish age determination: a Mediterranean experience” (Carbonara and Follesa 2019).

Furthermore, these MEDITS working groups established and maintained links with the ICES Working Group BIOP (e.g. ICES 2017). This allowed a continuous update and, for example, the introduction, for the main taxonomic group, of maturity stage conversion tables between MEDITS maturity scales and other scales if differences emerged. These conversion tables allowed consistency to be maintained in the time series.

ETHICAL ISSUES

The MEDITS protocol prescribes that if a live specimen of a rare species or a species subject to conservation measures is caught, efforts should be made to obtain length, weight and sex data and return the specimen back to the sea unharmed, giving it a chance for survival. The specimens should be returned to the sea preferably within 4-5 minutes.

DATA COLLECTION ON MARINE MACRO-LITTER

In 2013, the MEDITS coordination meeting decided to introduce among the MEDITS activities the samplings of marine macro-litter, to provide data for the descriptor 10 of the MSFD. A common protocol, taking the basis from the one of Galgani et al. (1996), was hence established for the collection of these data on a voluntary basis and it was further improved in 2014 and 2015. Up to 34 different typologies have been identified in the protocol, including 9 main categories related to litter material class and 27 sub-categories related to source and main litter findings (Table 4). This table also shows a comparison with the classification adopted by the ICES International Bottom Trawl Survey (IBTS).

As a result of this activity, the MEDITS group also contributed to the actions of the United Nations Environment Programme (UNEP), the Barcelona Convention of the Mediterranean Action Plan (MAP) for implementing the Regional Plan on Marine Litter Management in the Mediterranean, and the Marine Litter Regional Cooperation Platform. This platform was established by UNEP-MAP as an open-ended group of regional and international partners participating on a voluntary basis and with mandates and activities contributing to the environmentally sound management of marine litter in the Mediterranean (available at <http://web.unep.org/uneppmap/keywords/marine-litter>)

MEDITS DATA QUALITY

The MEDITS protocol also establishes common formats for data storage, which include the following standard files: TA (data on the technical specifications of the hauls), TB (aggregated data on total number and weight by species), TC (aggregated data of the frequency distribution by length, sex and maturity stage by species), TE (individual data of length, weight and age by sex) and TL (data by category and subcategory of marine macro-litter).

Table 4. – Cross-cutting table of the protocol for the collection of marine macro-litter during the MEDITS bottom trawl surveys and the ICES IBTS surveys. Main litter categories, sub-categories and respective codes are shown.

Main categories	MEDITS		IBTS		Main categories
	Sub-categories	Code	Code	Sub-categories	
L1: Plastic	Bags	L1a	A3	Bags	A: Plastic
	Food wrappers	L1c			
	Bottles	L1b	A1	Bottles	
	Sheets	L1d	A2	Sheets	
	Hard plastic objects (crates, containers, ash-trays, tubes, lids, etc.) (specify)	L1e	A4	Caps/lids	
			A9	Cable ties	
			A11	Crates and containers	
	Fishing nets	L1f	B5	Syringes	
			A8	Fishing nets	
	Fishing line	L1g	A5	Fishing lines monofilament	
			A6	Fishing lines entangled	
	Ropes/strapping bands	L1i	A7	Synthetic rope	
			A10	Strapping band	
Other fishing-related items (pots, floats, etc.)	L1h	A12	Others		
		L1j	Others		
L2: Rubber	Tyres	L2a	D4	Tyres	D: Rubber
			D1	Boots	
	Others (gloves, boots/shoes, oilskins, etc.)	L2b	D2	Balloons	
			D3	Bobbins (fishing)	
			D5	Gloves	
			D6	Others	
			B4	Condoms	
			C2	Cans (food)	
	Beverage cans	L3a	C1	Cans (beverage)	
			C8	Others	
Other food cans/wrappers	L3b				
		C5	Appliances		
Medium-size containers (of paint, oil, chemicals)	L3c				
		C6	Car parts		
Large metal objects (barrels, pieces of machinery, electric appliances)	L3d	C4	Drums		
		C7	Cables		
Cables	L3e				
		C3	Fishing-related items		
Fishing-related items (hooks, spears, etc.) (specify)	L3f	C8	Others		
		E2	Bottles		
Remnants from the war	L3g	E3	Pieces		
		E1	Jars		
Bottles	L4a	E4	Others		
		G1	Clothing/rags		
Pieces of glass	L4b	G2	Shoes		
		F5	Others		
Ceramic jars	L4c	B1	Diapers		
		B2	Cotton buds		
Large objects	L4d	B6	Sanitary towels/tampons		
		F1	Wood (processed)		
Clothing (clothes, shoes)	L4a	F4	Pallets		
		F5	Others		
L4: Glass/ceramics	L4b	F3	Paper/cardboard		
		F5	Others		
L5: Cloth (textile)/natural fibres	L4c	B3	Cigarettes butts		
		G3	Others		
Large pieces (carpets, mattresses, etc)	L4b	B7	Others		
		L9			
Natural ropes	L4c				
Sanitaries (diapers, cotton buds, etc)	L4d				
L6: Wood processed (palettes, crates, etc.)	L6				
L7: Paper and cardboard	L7				
L8: Others	L8				
L9: Unspecified	L9				

The Common Fisheries Policy sets out key principles for data quality: e.g. accuracy, reliability and timeliness, avoidance of duplication through improved coordination, safe storage in data base systems and improved availability (EC 2013). To minimize the occurrence of errors, in addition to the standardization of data collection using common protocols at the different steps of the survey implementation, common data checks on the MEDITS standard files were implemented. In 2011, the process of data quality checks was updated and standardized among the MEDITS group to unify the checks independently made by the 18 GSAs participating in the MEDITS survey.

To perform automatically the data check procedure by means of a routine enabling errors to be detected

and facilitating their correction, the RoME routine, an R code for performing multiple and cross checks on MEDITS survey data in TA, TB, TC, TE and TL files, was developed (Bitetto et al. 2019). In version 1.3, RoME was transformed into a package structured in 55 different functions: the run is performed by means of the function `RoME()`. Each function is related to a specific check and is recalled in a specific order to avoid cascade errors. This is also maintained in RoME version 1.4.

This software does not correct the data, but it detects the errors, warning the user that there is the possibility of one or more errors, specifying the type of the error and facilitating correction of the data. The process is based on a loop of checks (errors and warnings) and

feedbacks, so users are able to correct data but they are also advised if some deviations from the protocols occur that are not necessarily classified as errors. This also represents the basis for a data quality assurance and audit for the data to be used in the MSFD (Moriarty et al. 2019) and in the data calls of end users. The analysis carried out at EWG-STEFC level evidenced that the quality of MEDITS data greatly improved when RoME was used before data upload and the Joint Research Centre checks correctly show no error patterns (STEFC 2013). The data checks are performed by RoME simultaneously on the files that can also contain data of more than one year. Further specifications can be found in the RoME Manual, which can be downloaded together with the software at the following link: <https://www.sibm.it/MEDITS%202011/principaledownload.htm>.

Another point which can be a source of bias is related to the gear used during the survey, i.e. whether the technical specifications are in line with the standards adopted for the MEDITS gear. The Multidisciplinary Group on Gear Performance and Standardization of Gear Data Processing (MGGP) was established within the MEDITS coordination group. Regular checks of the MEDITS gears (trawl, rigging and doors) were introduced in 2012, and this protocol of checks was updated in 2014 and further revised in 2015 to fix some technical details. The final version is reported in the MEDITS Handbook, which also includes the work performed by this working group (MEDITS-Handbook, Version 9, Anonymous 2017).

ACCESS TO MEDITS DATA

Access to the MEDITS data is currently controlled by regulation EU 2017/1004 (recast). Data are made available for end users' needs (e.g. STEFC, GFCM) through specific data calls released on an annual basis. Data can also be made available by the relevant countries for specific projects. To facilitate scientific collaborations, each year the MEDITS coordination group agrees common projects, including scientific publications based on the MEDITS data.

In addition, through contacts with the international and national coordinators, a certain number of scientists not involved in the MEDITS project can be invited to the annual MEDITS coordination meetings to present proposals for common projects and discuss the preparation of scientific papers.

MEDITS DATA FOR FISHERIES ASSESSMENT

In the Mediterranean, until the advent of the DCF, trawl survey data were considered the most important—and sometimes the only—source of reliable information for evaluating the status of stocks, fish communities and ecosystems using total mortality estimates (e.g. SAMED; Lembo 2002), assessment models based on fishery-independent data (e.g. SURBA; Needle 2003), simulation models (e.g. ALADYM; Lembo et al. 2009) and population and community indicators (Cotter et al. 2009a).

Under simple formulation and assumptions on natural mortality, MEDITS data allow estimates of total mortality to be made from the structure of the species population at sea, so that guess estimates of the exploitation rate can be obtained, an approach that is also valid in data-limited situations. The SAMED project (Lembo 2002) was a good example, outlining specific methods and approaches and providing an evaluation of several stocks in the Mediterranean (GFCM-SAC 2002). With the consolidation of the DCF, MEDITS data routinely support the stock assessment of the target species, providing relevant abundance indices for tuning the assessment models (for brevity, only the last year reports are here cited; STEFC 2018a, 2018b, FAO 2018).

Furthermore, MEDITS data have been exploited in several projects to shed light on the localization of essential fish habitats, i.e. nursery and spawning grounds (e.g. Lembo 2010, Giannoulaki et al. 2013, Druon et al. 2015, Colloca et al. 2015), for fish stock identification (Fiorentino et al. 2015), to discover stability or change in biodiversity (e.g. Gaertner et al. 2010, 2013, Granger et al. 2015), to elucidate whether changes in fishing and environmental pressures are propagated bottom-up, top-down, or both (Rochet et al. 2010), to identify regional differences in changes of functional group biomass associated with regional variations of environmental factors (Brind'Amour et al. 2016), to perform a large-scale analysis of cephalopod demersal community (Keller et al. 2017), and to validate forecasts of an integrated ecosystem model at a Mediterranean-wide scale (Moullec et al. 2019).

FINAL REMARKS

The strength of the MEDITS survey so far has been the agreement among the participants to share standardized methods at a Mediterranean level using the same gear, sampling scheme and protocols for collecting, checking and analysing data. However, a shift in the survey time occurred in some situations, and the survey could be not conducted in some years because of administrative issues at national level. Implementing mitigation actions through standardization methods based on GAM modelling is possible, but this process is time-consuming and not always successful. Hence, an effort should be made to avoid disruptions in the time series of surveys as much as possible.

The experience gained in MEDITS in terms of standardization of file formats (TA, TB, TC, TE and TL) and data quality checks can be used to move forward the implementation of a common database/platform to share the effectiveness of open source visual and statistical data checks, keeping internationally available and maintained standard reference lists, sharing data for process and upon end users' requests. In fact, data accessibility and availability for scientific use is also considered a key point in the European Union (STEFC 2018c). The experience gained in MEDITS in terms of data standardization and data quality checks can also be applied to recover time series of past surveys in the different countries, as was already done in the context

Table 5. – Framework of stock categories based on available knowledge for the basis of advice in the ICES area (ICES Advice 2018; <http://www.ices.dk/community/advisory-process/Pages/default.aspx>). The ICES assessment category 3 is based on scientific survey data.

	Stock categories		Advice basis
1	Stocks with quantitative assessments	Stocks with full analytical assessments and forecasts as well as stocks with quantitative assessments based on production models	MSY approach
2	Stocks with analytical assessments and forecasts that are only treated qualitatively	Stocks with quantitative assessments and forecasts which for a variety of reasons are considered indicative of trends in fishing mortality, recruitment and biomass	MSY approach
3	Stocks for which survey-based assessments indicate trends	Stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment and biomass	Precautionary approach, MSY approach being developed
4	Stocks for which only reliable catch data are available	Stocks for which a time series of catch can be used to approximate MSY	Precautionary approach, MSY approach being developed
5	Landings only stocks	Stocks for which only landings data are available	Precautionary approach
6	Negligible landings stocks and stocks caught in minor amounts as by-catch	Stocks for which landings are negligible in comparison with discards and stocks that are primarily caught as by-catch species in other targeted fisheries	Precautionary approach

of the RECFISH project (Ligas 2019) for the GRUND surveys (Relini 2000).

During the last few years, a liaison with the ICES Workshop on Technical Development to Support Fisheries Data Collection (WKSEATEC) and IBTS took place. While progress in the Mediterranean has centred on implementation of standardized data checking routines across surveys, in the Atlantic and Baltic areas efforts converged towards progress in electronic data capture. Moving towards a wider implementation of paperless sampling during the measuring process using either purchased or developed in-house technology is a point to be further developed for the future in all the Mediterranean GSAs involved in the MEDITS project.

A question also rises on the use of data from scientific surveys such as MEDITS. Is the potential of this kind of information fully exploited? The usefulness of the MEDITS trawl survey time series also relies on the possibility of using these data in an assessment framework that allows them to be exploited to produce advice, even in situations in which fishery-dependent data are not available, as is being done in the ICES advice framework (Table 5).

Trawl surveys are also an accurate source of information for understanding the influence of climate change on fish populations, their communities and ecosystems. Many papers so far have tried to disentangle the effects of the anthropogenic pressure caused by fishing from the ones mainly driven by environmental variables linked to climate change, such as sea surface and bottom temperatures, using GAM modelling for example. This is a focus topic in this special issue, to better understand the underlying processes of tropicalization and its potential effect on demersal resources. Thus, it is becoming increasingly important to integrate existing knowledge on environmental drivers, fishing pressure and species interaction in the assessments of ecosystems and fisheries, in line with the ecosystem approach to fisheries management. Many papers in this special issue investigate these relationships.

Unlike in other European seas, where several trawl surveys have been historically conducted, in the Mediterranean MEDITS is the only scientific survey carried out for monitoring stocks of demersal species inde-

pendently of fisheries biological sampling (EC 2016). A second scientific trawl survey, placed in a different time quarter different from the current MEDITS survey could provide useful information to improve and expand the current assessment process and the present understanding of biological processes and dynamics. It can also further assist the implementation of an ecosystem approach to fishery management. Accurate information on cartilaginous fish populations, for example, is difficult to obtain from the commercial fishery, and a single survey cannot be sufficient. This proposal has been put to the STECF (2019). The following aspects could be further improved with the availability of data from a second survey: i) capturing the most relevant biological events for a wide spectrum of stocks (e.g. different spawning seasons), including vulnerable species such as cartilaginous fish; ii) obtaining more accurate estimates of life history parameters (e.g. mortality and growth), in particular of vulnerable species; iii) improving estimates of recruitment indices; iv) obtaining more valuable records for estimating the stock-recruitment relationships; v) improving estimates of seasonal spatial occupation of the different components of the stocks, thus providing key information for a space/season fishery management (e.g. Spedicato 2015); and vi) allowing a more robust evaluation of changes in the population and community indicators.

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SUPPLEMENTARY MATERIAL

The following supplementary material is available through the online version of this article and at the following link: <http://scimar.icm.csic.es/scimar/supplm/sm04915esm.pdf>

List of the papers peer reviewed (with or without impact factor) published between 2002 and 2017 and based on MEDITS data.

The MEDITS trawl survey specifications in an ecosystem approach to fishery management

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Supplementary material

Updated on July 7, 2020

List of the papers peer reviewed (with or without impact factor) published between 2002 and 2017 and based on MEDITS data.

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