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Characterization and biogeographic affinity of megazoobenthos in the Central Mediterranean Sea

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Abstract

The Strait of Sicily (SoS) is a key area in the Central Mediterranean Sea characterized by high biodiversity and demersal fisheries productivity. Further, it is traditionally considered the main biogeographic boundary between the Western and Eastern basins of the Mediterranean. Due to the poor knowledge on the benthos composition and distribution in this area, we created the first inventory of megazoobenthos recorded on the trawlable soft bottoms of the North-Western SoS. Samples were collected by bottom trawl surveys between 2003 and 2013 within a depth range of 10–800 m. Overall, 374 taxa with 358 species, belonging to Porifera, Cnidaria, Nemertea, Rotifera, Brachiopoda, Bryozoa, Sipuncula, Annelida, Mollusca, Arthropoda, Echinodermata and Chordata phyla, were found. In addition, the biogeographic affinity of megazoobenthos collected in the SoS to species vulnerable to trawl survey found in other zones of the Central Mediterranean was investigated. Excluding the North Adriatic and the Strait of Messina, moderate affinity values have been recorded within all the biogeographic zones. The benthos species of the North-Western SoS presented the highest affinity with those of the North Tyrrhenian and Ligurian Sea (about 90% of species in common). However, our results show high similarity with species composition of the South-Eastern SoS/South Ionian, North Ionian and Central Adriatic (about 80% of species in common). Our study confirms the role as biogeographic transition zone of the SoS for the Mediterranean biota. Furthermore, the lower affinity with native species of the South-Eastern SoS and the absence of Lessepsian species suggest that the cold waters (due to the permanent up-welling) off the southern coasts of Sicily may act as thermal barrier for regulating species exchange between the Eastern and Western basins. Some concerns about this role of the northern sector of the SoS were discussed in the light of current climate change.

KEYWORDS

benthic invertebrates checklist, biodiversity, biogeography, Lessepsian species, Mediterranean Sea, trawl surveys

1 | INTRODUCTION

The Strait of Sicily (SoS) is a key area in the Central Mediterranean basin characterized by high biodiversity (Altobelli et al., 2017; Coll et al., 2010; Garofalo et al., 2007) and remarkable demersal fisheries productivity (Gristina et al., 2006; Di Lorenzo et al., 2018). In addition, this area has been prioritized for conservation by Oceana (2011) and de Juan et al. (2012) with several sites (e.g. Adventure Bank, Malta Bank and Southern Sicilian Seamounts) identified for their future inclusion in a Mediterranean network of Marine Protected Areas (Altobelli et al., 2017). Furthermore, the SoS plays an important role in the Mediterranean as for its nature and position is traditionally considered the main biogeographic boundary between Western and Eastern Mediterranean sub-basins (Bianchi, 2007; Di Lorenzo et al., 2018).

The definition of boundaries between different biogeographic regions is a complex issue. Since different taxa have different distributions, often a "transition zone" is represented instead of a sharp boundary where a high number of taxa belonging to different phyla are considered (Ferro & Morrone, 2014). Most biogeographic transition zones coincide with zones of change in environmental gradients that play an important role in maintaining the isolation between biotas, and act as ecological barriers limiting the spread of species.

Although most of literature agree in considering the SoS a transition zone, there are different opinions, depending on the approach adopted, on the location of the biogeographic boundary between Western and Eastern Mediterranean. For example, Péres and Picard (1964), based on the benthic bionomy, considered this boundary in the middle Ionian Sea, including Sicily, Calabria and Gulf of Taranto in the Western Mediterranean. Differently Giaccone and Sortino (1974), studying the algae communities, located the border in the middle of the SoS, with the island of Pantelleria belonging to the Western Mediterranean, while the Pelagie Islands (Lampedusa and Linosa) and Malta belonging to the Eastern Mediterranean. Bianchi and Morri (2000), on biogeographic basis, included the whole of Sicily in the Western Mediterranean, putting the Pelagie Islands in the Eastern basin, and Malta on the border. Yet, Micheli et al. (2005) working on the genetic features of the seagrass *Posidonia oceanica* in the Gulf of Taranto showed marked similarity with those from the Aegean Sea than those from the Tyrrhenian Sea, supporting the hypothesis that a major biogeographic border separating Western and Eastern Mediterranean crosses the SoS.

According to Spalding et al. (2007), the boundary of the Western Mediterranean ecoregions lies between Cape Bon in Tunisia and the westernmost border of Sicily. Further, the authors distinguished the northern sector of the SoS, as belonging to the Ionian Sea, from the southern one, included into the Tunisia plateau/Gulf of Sidra ecoregion.

Other studies have suggested that the main "physiological" barrier that limits the distribution of species with tropical or boreal affinity in the Mediterranean Sea is represented by the isotherm 15°C in February (Bianchi, 2007; Bianchi et al., 2013). Under this hypothesis, the recognition of a major biogeographic boundary between the Western and Eastern Mediterranean could be identified by the presence of seawater thermal gradient in a south-north direction, where the Non-Indigenous Species (NIS) play an important role in defining the current Mediterranean biogeography (Bianchi et al., 2013).

Because of its recognized role as "crossroad," the SoS represents an important area for the distribution of Non-Indigenous Species (NIS) of distinct biogeographic origins (Atlantic and Indo-Pacific). Therefore, it is crucial to have an updated and detailed knowledge of species occurrence especially in the light of current climate change effects on marine ecosystems (Azzurro, 2008; Geraci et al., 2018; Lejeusne et al., 2010).

About the demersal fauna in the North-Western sector of the SoS, a great part of knowledge comes from scientific bottom trawl surveys, which have been routinely carried out since the mid '80s. These aim to assess the status of fishery resources in the region. Instead, for the megabenthic fauna, species occurrence data are poor and scattered in time and space (Di Lorenzo et al., 2018). Despite caution is needed when quantitatively analysing benthos data collected by trawl surveys (Eleftheriou, 2013), this source of information is extremely useful to investigate the occurrence of epifauna species living on the soft bottoms of the SoS. For example, data collected during trawl surveys allowed the reporting of two rare echinoderms, the starfish *Marginaster capreensis* (Gasco, 1876; Massi et al., 2007) and the brittlestar *Ophiocomina nigra* (Abildgaard in O.F. Müller, 1789; Massi, Sinacori, et al., 2010), and two rare crabs *Heterocrypta maltzami* Miers, 1881 (Massi, Micalizzi, et al., 2010) and *Calappa tuerkayana* Pastore, 1995 (Pipitone et al., 2018). Data from trawl surveys were also used for mapping benthic biocoenoses (Garofalo et al., 2004), and for investigating the spatial distribution of benthic species indicators of Vulnerable Marine Ecosystems, such as the cnidarians *Isidella elongata* (Esper, 1788) and *Funiculina quadrangularis* (Pallas, 1766; Lauria et al., 2017) as well as *Leiopathes glaberrima* (Esper, 1792; Massi et al., 2018). However, to date a detailed list of megazoobenthos inhabiting the trawlable bottoms of the SoS is not available. An old list of the bathyal megabenthic fauna of the trawlable grounds resulting from eight hauls carried out in a restricted area between the Skerki Bank and the westernmost border of Sicily was produced by Arena and Li Greci (1973), who highlighted the nature of transitional area of SoS between Western and Eastern Mediterranean. Other authors produced few comprehensive checklists on Crustacean decapods of the whole SoS, integrating original data with information from literature (Pipitone & Arculeo, 2003) and providing the spatial distribution of 55 species of Crustaceans in different sectors of the SoS (Spanò et al., 2013). Finally, a list of zoo- and phyto-megabenthos found on the trawlable grounds around the Maltese Islands was given by Terribile et al. (2016). Considering the fragmented knowledge on the megabenthos composition and distribution in the Central Mediterranean Sea, here we provide a first detailed checklist of the megabenthic invertebrates identified on the trawlable bottoms in the North-Western SoS during the period 2003–2013. This information represents a baseline to evaluate temporal and spatial trends of the benthic fauna in the area in relation to future climatic variations and anthropogenic perturbations.

Furthermore, because of recognized biogeographic role, species found in the SoS are compared with their occurrence in other biogeographical areas of the Central Mediterranean Sea.

2 | MATERIAL AND METHODS

The study area is located in the North-Western SoS (Figure 1). Samples were derived from two different scientific programmes. The MEDITS (MEDiterranean International Bottom Trawl Surveys) with 7 surveys carried out in the spring/early summer of 2004 and 2008–2013 (Bertrand et al., 2002) and the GRUND (GRUppo Nazionale risorse Demersali) with 3 surveys conducted in the autumn of 2003, 2004 and 2008 (Relini, 2000).

Both surveys followed a stratified random sampling design with allocation of hauls proportional to strata extension (depth strata: 10–50 m, 51–100 m, 101–200 m, 201–500 m, 501–800 m; see Table S1 in Supporting Information). The megazoobenthic fraction of catch, larger than 1 cm according to the MEDITS-Handbook (2017), was sampled and examined in laboratory. As general rule, for each sample the total catch was retained. In the case of very abundant catches, a subsample of 5,000 g maximum was retained for sorting. Specimens were identified at the most detailed taxonomic level possible, and total number and total weight were recorded for each taxon.

Species were assigned by the classical morphological, biometric and meristic analysis of external characters. Scientific names were given according to the "Checklist of Flora and Fauna of the Italian seas" (Relini, 2008, 2010). When the species was not reported in this “Checklist” or for the updating of the scientific name, the World Register of Marine Species (WoRMS Editorial Board, 2020) was followed.

Then, the occurrence of the SoS megazoobenthos species in the other areas of the Central Mediterranean Sea was analysed to investigate species biogeographic affinity. Since our data concerned only the species inhabiting mobile bottom vulnerable to trawling, the affinity was based on comparison of species found in the SoS with the occurrence of the same species in other faunistic lists of megazoobenthos available for the Central Mediterranean Sea.

In this regard, the "Biogeographic Zones" (BZs) proposed by Bianchi (2004) for the seas surrounding Italy and adopted by Relini (2008, 2010) were considered. The BZs are listed as: BZ1 Ligurian Sea,

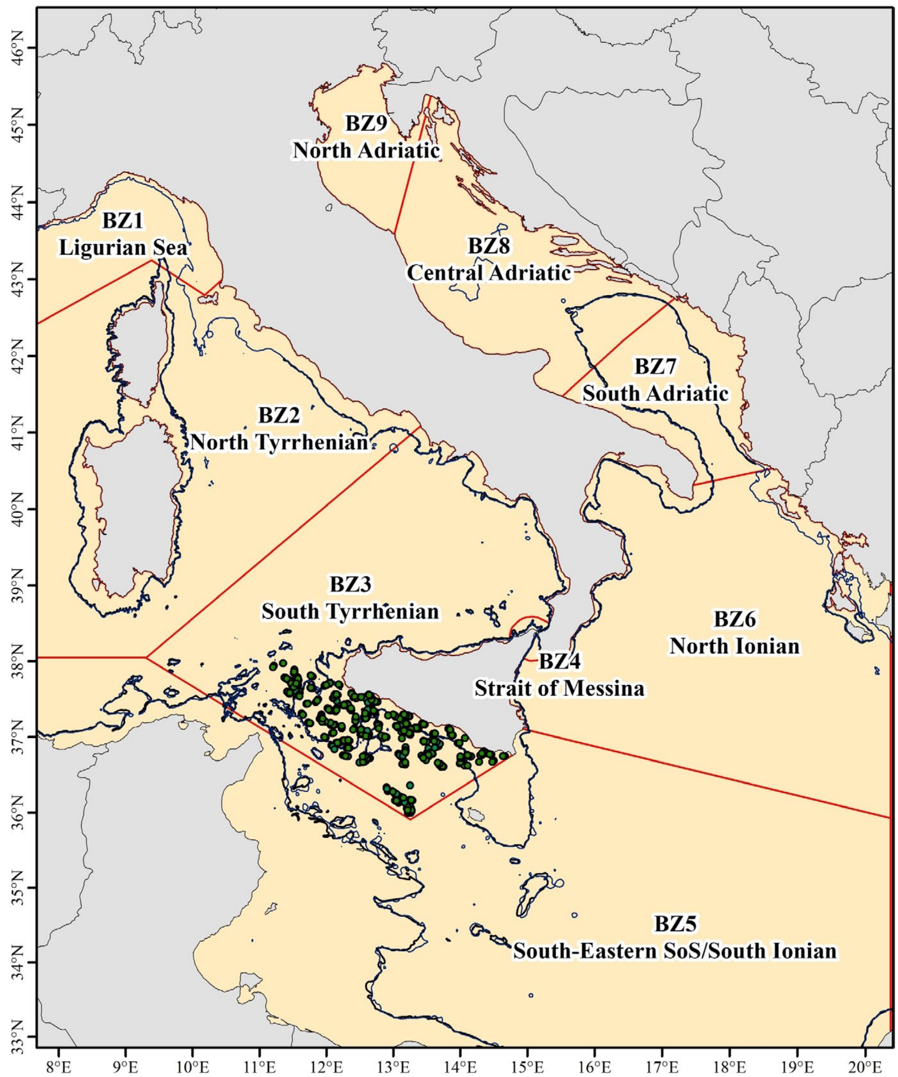

FIGURE 1 Biogeographic zones (BZs) of the Central Mediterranean, according to Bianchi (2004). The distribution of the hauls in which megazoobenthos was caught and the bathymetric of 200 m are also displayed

BZ2 North Tyrrhenian, BZ3 South Tyrrhenian, BZ4 Strait of Messina, BZ5 South-Eastern SoS/South Ionian, BZ6 North Ionian, BZ7 South Adriatic, BZ8 Central Adriatic and BZ9 North Adriatic, and are shown in Figure 1. According to this BZ subdivision, the North-Western SoS falls in the BZ3, while the South-Eastern SoS is included in the BZ5.

Data on megazoobenthos species occurrence in each BZ were obtained from Relini (2008, 2010), and integrated with information from literature (Arena & Li Greci, 1973; Carlier et al., 2009; Chakroun & Zaghbib-Turki, 2017; Chebbi, 2010; Chimienti et al., 2014; Chimienti et al., 2019; El Lakhrach et al., 2012; Koukouras & Matsa, 1998; Massi et al., 2018; Mastrototaro et al., 2013; Mifsud et al., 2009; Pérez-Ruzafa and López-Ibor, 1988; Petović, 2018; Relini, 1979; Weber, 1977; Terribile et al., 2016).

The similarity among species composition of the investigated area and other biogeographic areas of the Central Mediterranean Sea was evaluated by an Affinity Index (AI; Bibiloni et al., 1998), calculated by both overall species and phylum as:

$$AI = \frac{N_c}{N_{SoS}} \times 100.$$

with N_c = number of species in common between SoS and a given BZ.

N_{SoS} = total number of species found in the SoS.

The AI, representing the percentage of common species between SoS and the other areas considered, varied between 0 and 100 (where 0 corresponding to lowest affinity and 100 meaning the highest affinity).

Multivariate statistics were performed to assess the similarity among biogeographic zones using the PRIMER v7 software (Clarke & Warwick, 2001). The dataset contained a total of 358 species in terms of presence/absence and was used to construct a similarity matrix based on the Jaccard similarity index. Successively cluster analysis (visualized using a dendrogram) was applied to verify if different biogeographic zones have similar species composition. Non-metric Multi-Dimensional Scaling (nMDS) was used to graphically represent the ordination in space of the sampled stations based on the Jaccard similarity matrix.

3 | RESULTS

During the surveys in the North-Western SoS, a total of 838 benthos samples were collected (645 and 193 in MEDITS and GRUND programmes respectively).

The identified megazoobenthos species belong to 12 phyla listed in phylogenetic order as: Porifera (class: Demospongiae), Cnidaria (classes: Anthozoa, Hydrozoa), Nemertea (class: Hoplonemertea), Rotifera (class: Eurotatoria), Brachiopoda (class: Rhynchonellata), Bryozoa (classes: Gymnolaemata, Stenolaemata), Sipuncula (classes: Phascolosomatidea, Sipunculidea), Annelida (classes: Clitellata, Polychaeta), Mollusca (classes: Gastropoda, Scaphopoda, Bivalvia), Arthropoda (class: Malacostraca, Thecostraca), Echinodermata (classes: Asteroidea, Crinoidea, Echinoidea, Holothuroidea, Ophiuroidea) and Chordata (class: Ascidiacea). Overall, 374 taxa including 358 species and 16 genera were identified and are listed in Table S2 (see Supporting Information).

The percentage distribution of abundance by taxa in the different classes is shown in Figure 2, and in decreasing order are: Malacostraca (23%), Gastropoda (20%), Bivalvia (16%), Anthozoa (8%), Ascidiacea, Asteroidea, Holothuroidea and Demospongiae (4%), Polychaeta and Echinoidea (3%), Hydrozoa, Ophiuroidea and Gymnolaemata (2%) and Thecostraca (1%).

Overall, the North-Western SoS megabenthos shows the highest affinity with the North Tyrrhenian and the Ligurian Sea, followed by the South-Eastern SoS/South Ionian, the North Ionian and the Central Adriatic. The lowest affinity was found with the North Adriatic and the Strait of Messina (Figure 3).

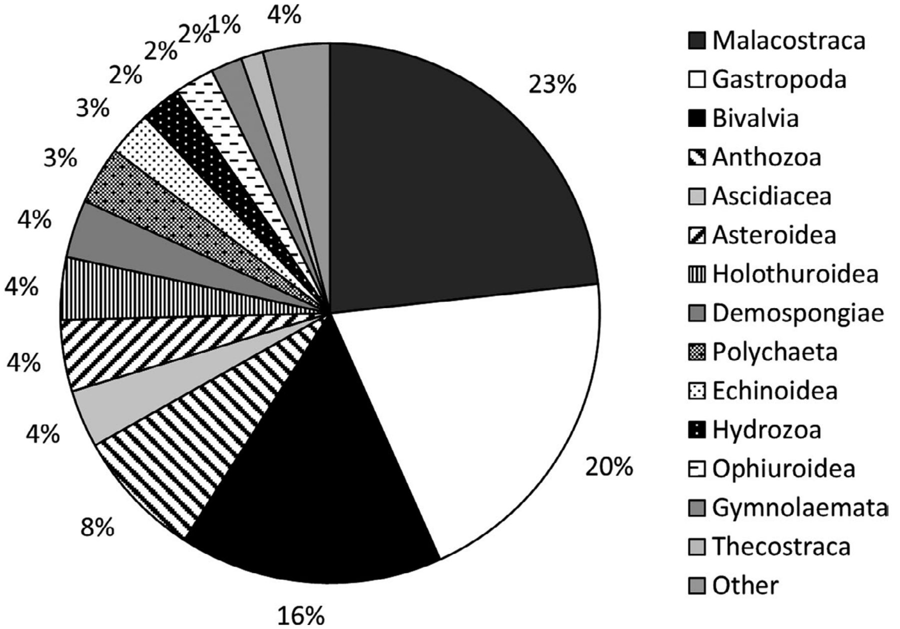

FIGURE 2 Percentage distribution of abundance by taxa in the different classes of the study area

The plot of MDS (based upon a 70% of similarity) confirms the same pattern, with a pooled group of similar BZ, with SoS showing the highest affinity with the Ligurian Sea (BZ1) and the North Tyrrhenian (BZ2; 85% of similarity), and two other separated groups represented by the North Adriatic (BZ9) and the Strait of Messina (BZ4; Figure 4).

3.1 | Results by Phylum

The Affinity Index (AI) of the North-Western SoS with the BZs of the Central Mediterranean Sea is reported in Table 1 and described by main phylum.

3.2 | Porifera

A total of 9 species belonging to the class Demospongiae were identified. The North-Western SoS showed the highest affinity (AI = 100) with both the Ligurian Sea and the Central Adriatic. High affinities were also found with the North Ionian and the North Adriatic, while the lowest value was observed for the Strait of Messina (AI = 11; Table 1).

3.3 | Cnidaria

A total of 29 species of the class Anthozoa were recognized, of which only *Caryophyllia (Caryophyllia) smithii* Stokes & Broderip, 1828 can be considered ubiquitous, occurring in all the biogeographic zones.

A total of 7 species of the class Hydrozoa were found, resulting *Aglaophenia pluma* (Linnaeus, 1758), *Kirchenpaueria halecioides* (Alder, 1859) and *Nemertesia ramosa* (Lamarck, 1816) the most diffused in the Central Mediterranean (present in 7 out of 9 BZs, including the SoS).

Overall, 36 species of Cnidaria were identified in the North-Western SoS, showing the highest affinity with the Ligurian Sea (AI = 100) followed by the Central Adriatic and then by the North Tyrrhenian. The affinity index with the other BZs resulted ≤50 (Table 1).

3.4 | Bryozoa

A total of 6 species belonging to the class Gymnolaemata were identified. *Myriapora truncata* (Pallas, 1766) and *Schizobrachiella sanguinea* (Norman, 1868) were widely distributed in the Central Mediterranean (present in 8 out of 9 BZs).

Only 1 species of the class Stenolaemata was identified, *Frondipora verrucosa* (Lamouroux, 1821). The species is reported for the North Tyrrhenian, the Strait of Messina, the South-Eastern SoS/South Ionian, the North Ionian and the North Adriatic.

With regards to Bryozoa, the North-Western SoS presented the highest affinity with the North Tyrrhenian (AI = 100), then with the Ligurian Sea, the South-Eastern SoS/South Ionian and the North Adriatic followed by the North Ionian. The lowest affinity resulted with the Central Adriatic (AI = 14; Table 1).

3.5 | Annelida

Only 1 species of the class Clitellata, *Pontobdella muricata* (Linnaeus, 1758), was identified. This species is reported for the Ligurian Sea, the North Tyrrhenian, the North Ionian and the South Adriatic.

A total of 12 species of the class Polychaeta were identified. Six of these are ubiquitous in the Central Mediterranean Sea (*Hesione splendida* Lamarck, 1818, *Hyalinoecia tubicola* [O.F.Müller, 1776], *Laetmonice hystrix* [Savigny in Lamarck, 1818], *Sabella spallanzanii* [Gmelin, 1791], *Serpula vermicularis* Linnaeus, 1767 and *Spirobranchus triqueter* [Linnaeus, 1758]).

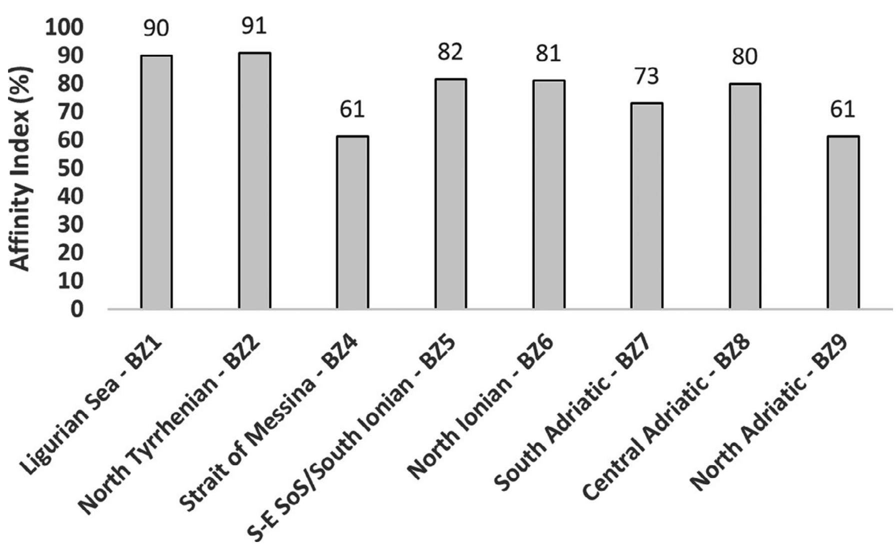

FIGURE 3 Affinity index calculated between SoS (BZ3) and other biogeographic areas of the Central Mediterranean

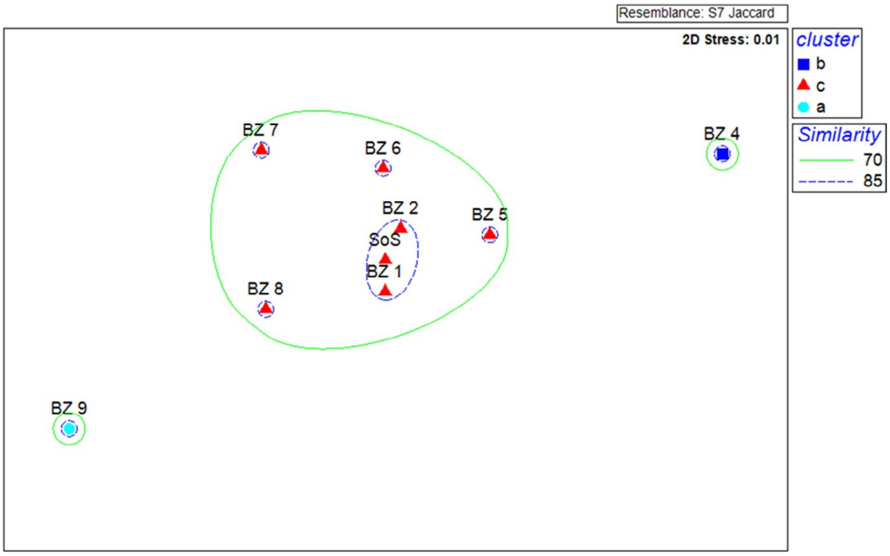

FIGURE 4 MDS ordination for all biogeographic zones considered in this study. The green lines show the results of the cluster analysis overlaid to the MDS ordination at 70% and 85% of Similarity. Presence/absence data were used to calculate Jaccard similarity coefficient based on 358 species

With regards to Annelida, the North-Western SoS showed a very high affinity (92 ≤ AI ≤ 100) with most of the biogeographic zones of the Central Mediterranean. Only the Strait of Messina showed an affinity index lower than 50 (Table 1).

3.6 | Mollusca

A total of 74 species of the class Gastropoda were recognized, being more than half of them (47) ubiquitous. With regards to Gastropoda, the highest affinity of the North-Western SoS was found with the North Tyrrhenian and the South-Eastern SoS/South Ionian with 72 and 70 shared species respectively. The lowest affinity was observed for the Central and North Adriatic with 54 and 47 species in common.

It is worth noting that the gastropod *Armina neapolitana* (Delle Chiaje, 1824) was exclusively shared within the western biogeographic zones of the Central Mediterranean (Ligurian and North Tyrrhenian Seas), while *Xenophora crispa* (König, 1825) resulted common in the eastern biogeographic zones (South-Eastern SoS/South Ionian and North Ionian).

A total of 3 species of the class Scaphopoda were found: *Antalis dentalis* (Linnaeus, 1758), *A. inaequicostata* (Dautzenberg, 1891) and *A. panorma* (Chenu, 1843). All these species are also reported for the North Tyrrhenian and the Central Adriatic.

A total of 55 species of the class Bivalvia were identified, 15 of which resulting diffused all around the Central Mediterranean Sea. Areas showing the greatest number of species in common were the North Tyrrhenian and the South-Eastern SoS/South Ionian (both with 52 species) and the Ligurian Sea (46 species).

A total of 132 species of Mollusca were identified in the North-Western SoS. With regards to Mollusca, the highest affinity of the study area resulted, in order, with the North Tyrrhenian, the South-Eastern SoS/South Ionian, the Ligurian Sea, the North Ionian and the Strait of Messina (Table 1).

3.7 | Arthropoda

A total of 86 species of the class Malacostraca were identified, being about a third of them (30) ubiquitous in the Central Mediterranean. It is important to note that *Palinurus mauritanicus* (Gruvel, 1911) resulted in common only with the western biogeographic zones of the Central Mediterranean (Ligurian and North Tyrrhenian Seas).

A total of 5 species belonging to the class Thecostraca were found, all ubiquitous with the exclusion of *Paralepas minuta* (Philippi, 1836) present only in the Ligurian Sea, the North Tyrrhenian, the South-Eastern SoS/South Ionian and the North Ionian.

Considering the whole phylum, a total of 91 species were identified in the North-Western SoS. Regarding to Arthropoda, the highest affinity of the study area was reported with the North Tyrrhenian and the North Ionian, followed by the Ligurian Sea, the South Adriatic and the Central Adriatic (Table 1).

3.8 | Echinodermata

A total of 16 species of the class Asteroidea were found, being more than half of them (9) ubiquitous. With regards to Asteroidea, the highest affinity of the North-Western SoS was found with the North Tyrrhenian (15 shared species) and the Ligurian Sea (14 species). It is worth noting the occurrence in the North-Western SoS of two rare stars *Odontaster mediterraneus* (von Marenzeller, 1893) and *Ceramaster grenadensis* (Perrier, 1881).

Two species of the class Crinoidea, *Antedon mediterranea* (Lamarck, 1816) and *Leptometra phalangium* (Müller, 1841), were identified. Their presence is reported in all the biogeographic zones except the Strait of Messina where only the first one is present.

A total of 10 species of the class Echinoidea were recognized, being 7 ubiquitous in the Central Mediterranean. As respect to

TABLE 1 Affinity Index (AI) calculated per phylum, among the North-Western SoS and other biogeographic sectors of the Central Mediterranean

Phyla	Number of species	BZ1 Ligurian Sea	BZ2 North Tyrrhenian	BZ4 Strait of Messina	BZ5 S-E SoS/ South Ionian	BZ6 North Ionian	BZ7 South Adriatic	BZ8 Central Adriatic	BZ9 North Adriatic
Porifera	9	100	89	11	44	89	56	100	89
Cnidaria	36	100	67	28	50	33	44	86	44
Bryozoa	7	86	100	29	86	71	43	14	86
Annelida	13	100	92	46	77	92	92	92	92
Mollusca	132	86	96	82	93	85	65	75	60
Arthropoda	91	91	97	66	80	96	91	85	51
Echinodermata	51	88	90	59	88	82	82	80	71
Chordata	11	73	64	0	91	82	64	82	91

Echinoidea, the highest affinity of the study area was found with the Ligurian Sea and the South-Eastern SoS/South Ionian with all the species in common, then with the North Tyrrhenian and the North Ionian with 9 out of 10 species in common.

A total of 14 species of the class Holothuroidea were found, being ubiquitous *Leptopentacta elongata* (Düben & Koren, 1846), *L. tergestina* (M. Sars, 1859) and *Phyllophorus (Phyllophorus) urna* Grube, 1,840. Concerning to Holothuroidea, the highest affinity of the North-Western SoS was found with the South Adriatic (13 shared species) followed by the Ligurian Sea, the North Tyrrhenian and the North Ionian (all with 12 species).

A total of 9 species of the class Ophiuroidea were identified, almost all (7 species) ubiquitous in the Central Mediterranean. All the biogeographic zones showed high affinity with the North-Western SoS, particularly the South-Eastern SoS/South Ionian (all the species in common), then the North Tyrrhenian and the Strait of Messina with 8 out of 9 species in common. It is worth to note that the rare black brittlestar *Ophiocomina nigra* (Abildgaard in O.F. Müller, 1789) shared only with the biogeographic zone South-Eastern SoS/South Ionian confirming the SoS as the eastern border of the species in the Mediterranean (Massi, Sinacori, et al., 2010).

Then, overall 51 species of Echinodermata were identified in the North-Western SoS that showed a highest affinity with the North Tyrrhenian followed by the Ligurian Sea, the South-Eastern SoS/South Ionian, the North Ionian, the South Adriatic and the Central Adriatic (Table 1).

3.9 | Chordata

A total of 11 species of Chordata, belonging to the class Ascidiacea, were recognized of which *Ascidia mentula* Müller, 1776, *Ascidiella aspersa* (Müller, 1776), *Ciona intestinalis* (Linnaeus, 1767), *Halocynthia papillosa* (Linnaeus, 1767) and *Phallusia mamillata* (Cuvier, 1815) are widely diffused in the Central Mediterranean (present in 8 out of 9 BZs).

The overall species of Chordata identified in the North-Western SoS showed a variable level of affinity (64 ≤ AI ≤ 91) with different biogeographic sectors of the Central Mediterranean Sea except the micro-sector of the Strait of Messina where no species were shared. At last, the highest affinity of the North-Western SoS was recorded with the South-Eastern SoS/South Ionian and the North Adriatic (Table 1).

3.10 | Other phyla

Other phyla were present with few identified species. In particular, as follow:

Nemertea: only 1 species of the class Hoplonemertea was found, *Malacobdella grossa* (Müller, 1776). This species was not reported for the Messina Strait, the South-Eastern SoS/South Ionian, the Central and the North Adriatic.

Rotifera: only 1 species belonging to the class Eurotatoria was found, *Zelinkiella synaptae* (Zelinka, 1887). The species was not reported for the Messina Strait and the South-Eastern SoS/South Ionian.

Brachiopoda: only 2 species of the class Rhynchonellata were found: *Gryphus vitreus* (Born, 1778) and *Megerlia truncata* (Linnaeus, 1767), being the last widely diffused along the Central Mediterranean Sea (present in 8 out of 9 BZs).

Sipuncula: three species of the class Sipunculidea were recognized in the North-Western SoS. The most diffused species is *Sipunculus (Sipunculus) nudus* Linnaeus, 1766 (present in 7 out of 9 BZs). Only 1 species of the class Phascolosomatidea was identified, *Phascolosoma (Phascolosoma) granulatum* Leuckart, 1828. It is reported for the Ligurian Sea, the South-Eastern SoS/South Ionian and the whole Adriatic Sea. With regards to Sipuncula, the North-Western SoS presented the highest affinity (AI = 100) with the Ligurian Sea, South, Central and North Adriatic.

4 | DISCUSSION

Here, we produced the first checklist of megabenthos fauna of trawlable bottoms of the North-Western SoS, which allowed to improve greatly the knowledge on the species occurrence in the area. Since the importance attributed by literature to the SoS as main biogeographic boundary between Western and Eastern Mediterranean, this study contributes to some relevant aspects of biogeography in the Central Mediterranean Sea. Considering the entire examined biota, the highest affinity of the North-Western SoS, compared to the other areas of the Central Mediterranean Sea, resulted between the Ligurian and the North Tyrrhenian Seas (Western Mediterranean) with about 90% of shared species, followed by South-Eastern SoS/South Ionian and North Ionian (Eastern Mediterranean), and Central Adriatic with about 80% of species in common. On the other hand, the lowest affinity was recorded for the North Adriatic and the Strait of Messina with about 60% of shared species. This is in agreement with other studies that suggested a high similarity of the North Adriatic and Strait of Messina areas with the Atlantic Ocean, and, consequently, very different from the biogeographic aspect of the other sectors of the Mediterranean Sea. In particular, strong cooling in winter, low salinity due to significant river input and great tidal range make North Adriatic more similar to the Atlantic than to the rest of the Mediterranean (Bianchi et al., 2012). On the other hand, the peculiar hydrodynamic regime of the Strait of Messina, characterized by very strong tidal currents, creates a favourable habitat for species with Atlantic affinity (De Domenico et al., 2009; Fredj & Giaccone, 1995).

The high biogeographical affinity of Porifera, Annelida, Mollusca, Arthropoda and Echinodermata species of SoS with most of the Central Mediterranean Sea reflects their high capability to colonize wide areas. Although the species dispersal patterns are related with their reproductive strategy (direct or larval development), and the length of the free-living larval stage (Jackson, 1986), recent study focused on the existing paradox for which many organisms without pelagic larval phase can have geographic distribution comparable to those with pelagic dispersal.

According to Winston (2012), many biological strategies can improve the capability to colonize wide areas for species with absent or reduced larval phase. For example, drifting regards species in which post-settlement juveniles or adults can detach or be detached from their benthic substratum and passively carried to new areas floating at water's surface or below it as in the case of the ubiquitous holothuroids (Hamel et al., 2019). Rafting concerns many encrusting species and mobile species that, by settling on floating substrata propelled by wind and currents, can reach new regions. Hopping is related to species displacement from one patch of hard substratum or favourable sediments microhabitat to another. Creeping regards species that extend their distribution along shores and shelves where habitat remains similar for long distances. Finally, hitchhiking involves species attached to vessel or carried in ballast water of ship to a distant region in which their offspring can survive. Despite all this mechanism could be coexist, available information is not enough to evaluate the contribution of each single pathway in producing the high level of affinity found in the investigated taxa living on the trawlable bottoms in the different areas of the Central Mediterranean Sea.

The number of megazoobenthos species that are in common among the North-Western SoS and the other 8 biogeographic zones of the Central Mediterranean Sea is reported in Figure 5. A total of 358 megazoobenthos species were identified in the North-Western SoS, being 334 species widespread in the entire Central Mediterranean Sea and 36 species shared with both the adjacent western (BZ1 and BZ2) and eastern (BZ5 and BZ 6) areas together. Considering the latter 36 species, only 3 resulted exclusively shared with the adjacent western zones (the cnidarian *Parantipathes larix* (Esper, 1788), the mollusc *Armina neapolitana* (Delle Chiaje, 1824), and the crustacean *Palinurus mauritanicus* Gruvel, 1911), and only 2 with the adjacent eastern sector (the mollusc *Xenophora crispa* [König, 1825], and the brittle star *Ophiocomina nigra* [Abildgaard in O.F. Müller, 1789] only with BZ5). None of megazoobenthos species found in trawlable bottoms resulted endemic of the North-Western SoS.

According to Ferro and Morrone (2014), the biogeographic affinity, expressed in terms of number of taxa which are exclusively in common between adjacent areas, is the main information to identify biogeographic transition zones or attribute a given area to a biogeographic sector.

The emerging pattern of species distribution and biogeographic affinities confirms that the trawlable bottoms of the North-Western SoS represent a transitional zone between Western and Eastern basins of the Mediterranean Sea, although the megazoobenthos species of this area show a marked affinity with the Ligurian Sea and the North Tyrrhenian (Figure 5). In addition, this area is strongly influenced by Sea Surface Temperature (SST) with a gradient decreasing from North-West to South-East (Figure 5).

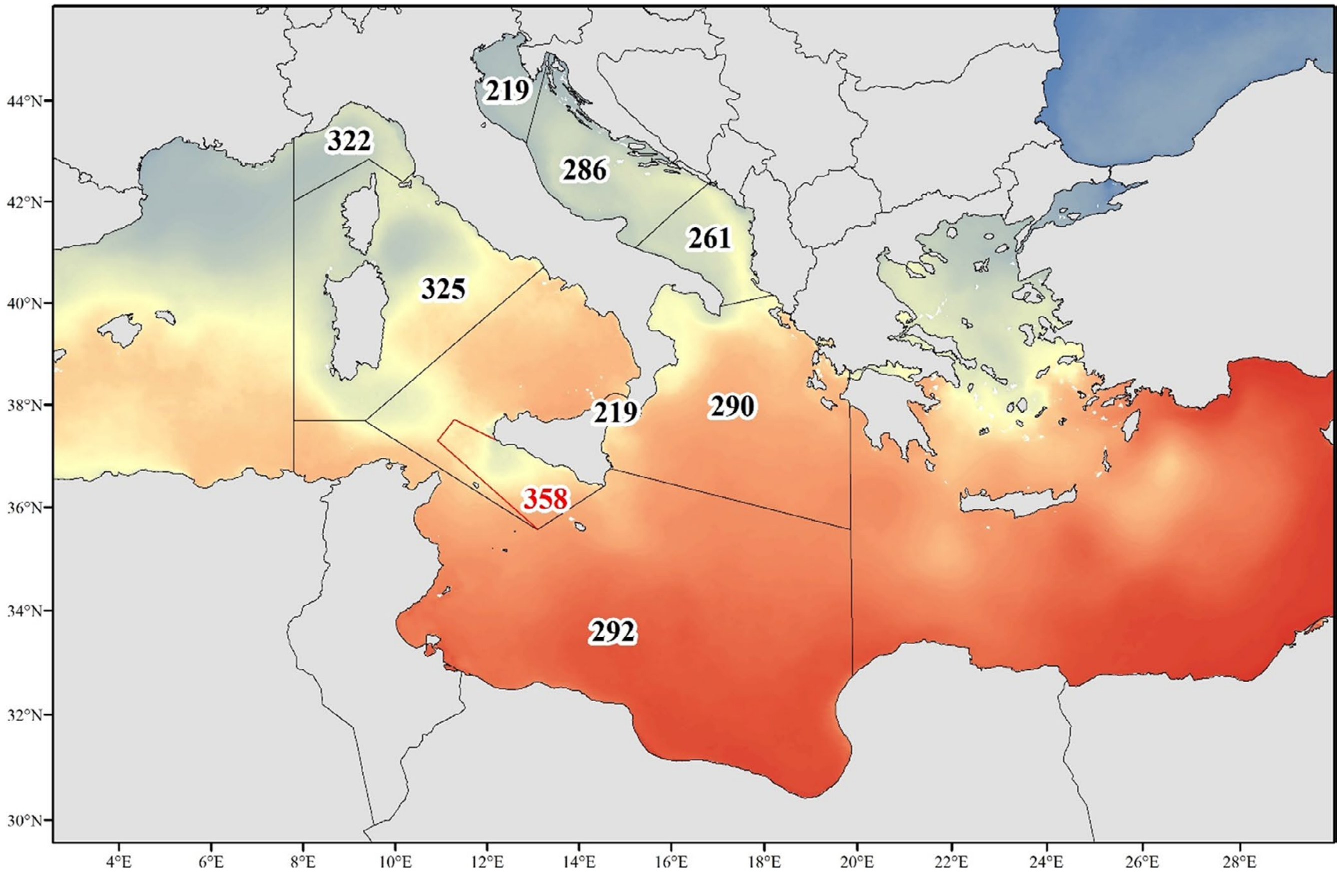

FIGURE 5 Sea Surface Temperature gradient of the Mediterranean Sea and biogeographic zones (BZs) of the Central Mediterranean with the number of the megazoobenthos species in common with the North-Western SoS (358). Climatological mean from the historical data set 1970–2000 of Sea Surface Temperature was obtained from MARSPEC database (Sbrocco & Barber, 2013)

Due to the increasing role of the Non-Indigenous Species (NIS) in defining the biogeography of the Mediterranean, Bianchi (2007) and Bianchi et al. (2013) suggested to revisit the traditional concept of the biogeographic boundary between Western and Eastern Mediterranean (located in the SoS) with a series of sea water gradients in the south-north direction. This is particularly important because the overall richness of native species in the Mediterranean declines from the North-Western to the South-Eastern regions, while the opposite pattern is observed for NIS (Katsanevakis et al., 2014).

Although the high number of samples examined (838 hauls), one of the main results of our study is that NIS of megazoobenthos were not found on the trawlable grounds of the North-Western SoS between 2003 and 2013. Conversely, many Lessepsian NIS, including megabenthic invertebrate, were well established in the South-Eastern SoS. According to Amor et al. (2016), a total of 53 NIS species were reported off the Tunisian coasts (South-Eastern SoS/South Ionian, BZ5), of which 68% were of Indo-Pacific origin (1 Cnidaria, 1 Bryozoa, 5 Annellida, 10 Mollusca gastropoda, 5 Mollusca bivalvia, 12 Crustacea decapoda, 1 Crustacea stomatopoda and 1 Ascidiacea) and 32% of Atlantic origin (3 Cnidaria, 1 Bryozoa, 2 Annellida, 4 Mollusca gastropoda, 2 Mollusca bivalvia and 5 Crustacea decapoda). Furthermore, Sciberras and Schembri (2007) found a total of 20 NIS species (2 Bryozoa, 1 Sipuncula, 11 Mollusca, 4 Crustacea and 2 Echinodermata) around the Maltese Islands (South-Eastern SoS-South Ionian; BZ5), being 66% of Indo-Pacific origin and 34% of Atlantic origin.

Therefore, the highest affinity of native megazoobenthos for the Ligurian and Tyrrhenian fauna and the absence of NIS species up to the early 2010s in the North-Western SoS found in our study support the idea of a “semipermeable” biogeographic barrier located between the North-Western and the South-Eastern side of the SoS. This is supposed to regulate, together with the continental mass of Italy and Sicily, the exchange of biota between Western and Eastern Mediterranean basins including the westward expansion of Lessepsian species from the Eastern Mediterranean. The ecological process at the basis of this biogeographic barrier could be find in the cold waters off the southern coast of Sicily due to the well-known persistent up-welling all year around (Béranger et al., 2004). Although some seasonal and interannual variability is known, the upwelling is normally stronger in the Western and Central part of the southern coast of Sicily, including most of the North-Western SoS (Basilone et al., 2013; Jouini et al., 2016).

However, some concerns about the effectiveness of the upwelling system along the south-western coast of Sicily as a barrier to the exchange of thermophilic species between the main Mediterranean basins can be expressed. Bonanno et al. (2014) have shown a progressive increase in salinity and temperature of up-welling waters. In particular, between 1998 and 2013 the temperature of surface water in the up-welling area increased from about 14.0 to 14.5°C, a temperature considered limiting to the distribution of thermophilic fauna in the Mediterranean (Bianchi, 2007). A weaker thermal barrier to movements of tropical NIS from the eastern to the western Mediterranean in the North-Western SoS could favour the processes of tropicalization and homogenization of the entire basin (Bianchi, 2007; Templado, 2014).

According to the weakening of the cold water up-welling, after 2013 two thermophilic Decapods crustacean of Atlantic origin resulted established in the North-Western SoS: *Penaeus atzecus* Ives, 1891 in Scannella et al., (2017), and *Pachygrapsus maurus* (Lucas, 1846) in Tiralongo and Lombardo (2017). Moreover, very recently records of two Lessepsian species, the shrimp *Trachysalambria palaestinensis* (Steinitz, 1932; Insacco et al., 2017) and the stomatopod *Erugosquilla massavensis* (Kossmann, 1,880; Gianguzza et al., 2019) have been reported.

Due to differences of SST pattern among the South Tyrrhenian and the adjacent areas of the Sardinian Channel and the North-Western SoS, it appears to be necessary a deep comparison of the megazoobenthos living on the trawlable bottoms of the North-Western SoS with that inhabiting the South Tyrrhenian. This type of data could be useful for the identification of boundaries of the biogeographic zones within the Central Mediterranean Sea. However, the lack of data collected in a similar way in the South Tyrrhenian does not allow now the issue to be adequately addressed. Since the Mediterranean Sea is expected to become warmer and salter during the 21st century (Adloff et al., 2015), investigating the megazoobenthos community in the biogeographic transitional zone, such as the SoS, coupled with monitoring of main ecological factor, such as the sea water temperature, could be a hint for understanding the effects of the climate change on the marine biota of the Mediterranean Sea.

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CONFLICTS OF INTEREST

The authors declare that there is not conflict of interests.

AUTHOR CONTRIBUTIONS

DM, FF and MG conceived the work. DM, AT, GS and RM analysed the samples. DM, MG, GG and VL analysed the data. DM, FF, MG, GG, VL, RM, AT and GS wrote the manuscript.

DATA AVAILABILITY STATEMENT

Any data are available under request.

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REFERENCES

Adloff, F., Somot, S., Sevault, F., Jordà, G., Aznar, R., Déqué, M., Herrmann, M., Marcos, M., Dubois, C., Padorno, E., Alvarez-Fanjul, E., & Gomis, D. (2015). Mediterranean Sea response to climate change in an ensemble of twenty first century scenarios. *Climate Dynamics*, *45*, 2775–2802. https://doi.org/10.1007/s00382-015-2507-3

Altobelli, C., Perzia, P., Falautano, M., Consoli, P., Canese, S., Romeo, T., & Andaloro, F. (2017). Mediterranean banks in EBSA area: Hotspots of biodiversity under threat. *Marine Environmental Research*, *131*, 57e68. https://doi.org/10.1016/j.marenvres.2017.09.005

Amor, K. O. B., Rifi, M., Ghanem, R., Draeif, I., Zaouali, J., & Souissi, J. B. (2016). Update of alien fauna and new records from Tunisian marine waters. *Mediterranean Marine Science*, *17*, 124–143.10.12681/mms.1371

Arena, P., & Li Greci, F. (1973). Indagine sulle condizioni faunistiche e sui rendimenti di pesca dei fondi batiali della Sicilia Occidentale e della bordura settentrionale dei banchi della soglia siculo-tunisina. *Quaderni Del Laboratorio Di Tecnologia Della Pesca*, *1*, 157–201.

Azzurro, E. (2008). The advance of thermophilic fishes in the Mediterranean sea: Overview and methodological questions. In F. Briand (Ed.), *CIESM Workshop monographs* (Vol. *35*, pp. 39–45). CIESM.

Basilone, G., Bonanno, A., Patti, D., Mazzola, S., Barra, M., Cuttitta, A., & Mcbride, R. (2013). Spawning site selection by European anchovy (*Engraulis encrasicolus*) in relation to oceanographic conditions in the Strait of Sicily. *Fisheries Oceanography*, *22*, 309–323.

Béranger, K., Mortier, L., Gasparini, G. P., Gervasio, L., Astraldi, M., & Crépon, M. (2004). The dynamics of the Sicily Strait: A comprehensive study from observations and models. *Deep Sea Research Part II: Topical Studies in Oceanography*, *51*, 411–440. https://doi.org/10.1016/j.dsr2.2003.08.004

Bertrand, J. A., Gil De Sola, L., Papaconstantinou, C., Relini, G., & Souplet, A. (2002). The general specifications of the MEDITS surveys. *Scientia Marina*, *66*(2), 9–17. https://doi.org/10.3989/scimar.2002.66s29

Bianchi, C. N. (2004). Proposta di suddivisione dei mari italiani in settori biogeografici. *Notiziario Società Italiana Biologia Marina*, *46*, 57–59.

Bianchi, C. N. (2007). Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia*, *580*, 7–21. https://doi.org/10.1007/s10750-006-0469-5

Bianchi, C. N., & Morri, C. (2000). Marine biodiversity of the Mediterranean Sea: Situation, problems and prospects for future research. *Marine Pollution Bulletin*, *40*, 367–376. https://doi.org/10.1016/S0025-326X(00)00027-8

Bianchi, C. N., Morri, C., Chiantore, M., Montefalcone, M., Parravicini, V., & Rovere, A. (2012). Mediterranean Sea biodiversity between the legacy from the past and a future of change. In N. Stambler (Ed.), *Life in the Mediterranean Sea: A Look at Habitat Changes* (Vol. *1*, pp. 55). Nova Science Publishers Inc.

Bianchi, C. N., Boudouresque, C. F., Francour, F., Morri, C., Parravicini, V., Templado, J., & Zenetos, A. (2013). The changing biogeography of the Mediterranean Sea: From the old frontiers to the new gradients. *Bollettino Dei Musei E Degli Istituti Biologici Dell'università Di Genova*, *75*, 81–84.

Bibiloni, M. A., Uriz, M. J., & Ros, J. (1998). Faunal affinities of the Sponges (Porifera) of the Balearic Islands with those of other biogeographical areas. *Oecologia Aquatica*, *11*, 123–133.

Bonanno, A., Placenti, F., Basilone, G., Mifsud, R., Genovese, S., Patti, B., Di Bitetto, M., Aronica, S., Barra, M., Giacalone, G., Ferreri, R., Fontana, I., Buscaino, G., Tranchida, G., Quinci, E., & Mazzola, S.

(2014). Variability of water mass properties in the Strait of Sicily in summer period of 1998–2013. *Ocean Science*, *10*, 759. https://doi.org/10.5194/os-10-759-2014

Carlier, A., Le Guilloux, E., Olu, K., Sarrazin, J., Mastrototaro, F., Taviani, M., & Clavier, J. (2009). Trophic relationships in a deep Mediterranean cold-water coral bank (Santa Maria di Leuca, Ionian Sea). *Marine Ecology Progress Series*, *397*, 125–137. https://doi.org/10.3354/meps08361

Chakroun, A., & Zaghbib-Turki, D. (2017). Facies and fauna proxies to reconstruct the MIS 5 and MIS 7 coastal environments in Eastern Tunisia. *Geological Quarterly*, *61*, 186–204.

Chebbi, N. (2010). Etude systématique, bio-écologique et chimique des ascidies de Tunisie (Doctoral dissertation). Sciences de l'environnement. Université du 7 Novembre à Carthage; Institut National Agronomique de Tunisie. https://tel.archives-ouvertes.fr/file/index/docid/814819/filename/Copie_thA_se_nadia_chebbi.pdf

Chimienti, G., Panetta, P., Lionetti, A., Ricci, P., Carlucci, R., & Mastrototaro, F. (2014). Aggiornamenti della malacofauna costiera del medio e basso adriatico. *Biologia Marina Mediterranea*, *21*(1), 232.

Chimienti, G., Bo, M., Taviani, M., & Mastrototaro, F. (2019). Occurrence and Biogeography of Mediterranean Cold-Water Corals. In C. Orejas, & C. Jiménez (Eds.), *Mediterranean Cold-Water Corals: Past, Present and Future. Coral Reefs of the World* (Vol. *9*, pp. 213–243). Springer.

Clarke, K. R., & Warwick, R. M. (2001). An approach to statistical analysis and interpretation. *Natural Environment Research Council*, 1–172.

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram, F., Aguzzi, J., Ballesteros, E., Bianchi, C. N., Corbera, J., Dailianis, T., Danovaro, R., Estrada, M., Froglia, C., Galil, B. S., Gasol, J. M., Gertwagen, R., Gil, J., Guilhaumon, F., Kesner-Reyes, K., … Voultsiadou, E. (2010). The biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. *PLoS ONE*, *5*(8), e11842. https://doi.org/10.1371/journal.pone.0011842

De Domenico, F., Giacobbe, S., & Rinelli, P. (2009). The genus *Antedon* (Crinoidea, Echinodermata) in the Strait of Messina and the nearby Tyrrhenian Sea (Central Mediterranean). *Italian Journal of Zoology*, *76*, 70–75.

de Juan, S., Moranta, J., Hinz, H., Barberá, C., Ojeda-Martinez, C., Oro, D., Ordines, F., Ólafsson, E., Demestre, M., Massutí, E., & Lleonart, J. (2012). A regional network of sustainable managed areas as the way forward for the implementation of an Ecosystem-Based Fisheries Management in the Mediterranean. *Ocean & Coastal Management*, *65*, 51–58. https://doi.org/10.1016/j.ocecoaman.2012.04.024

Di Lorenzo, M., Sinerchia, M., & Colloca, F. (2018). The North sector of the Strait of Sicily: A priority area for conservation in the Mediterranean Sea. *Hydrobiologia*, *821*, 235–253. https://doi.org/10.1007/s10750-017-3389-7

Eleftheriou, A. (Ed.) (2013). *Methods for the study of marine benthos*. (pp. 1-494). Wiley Blackwell.

El Lakhrach, H., Hattour, A., Jarboui, O., Elhasni, K., & Ramos-Esplá, A. A. (2012). Spatial distribution and abundance of the megabenthic fauna community in Gabes gulf (Tunisia, eastern Mediterranean Sea). *Mediterranean Marine Science*, *13*, 12–29. https://doi.org/10.12681/mms.19

Ferro, I., & Morrone, J. J. (2014). Biogeographical transition zones: A search for conceptual synthesis. *Biological Journal of the Linnean Society*, *113*, 1–12. https://doi.org/10.1111/bij.12333

Fredj, G., & Giaccone, G. (1995). Particularités des peuplements benthiques du détroit de Messine. In: L. Guglielmo, A. Manganaro, & E. De Domenico (Eds.), *The Strait of Messina ecosystem* (pp. 119–128). : Dipartimento di Biologia animale ed Ecologia marina, University of Messina.

Garofalo, G., Gristina, M., Toccaceli, M., Giusto, G. B., Rizzo, P., & Sinacori, G. (2004) Geostatistical modelling of biocenosis distribution in the Strait of Sicily. In: T. Nishida, P. J. Kailola, & C. E. Hollingworth (Eds.) *Proceeding of the Second International Symposium on GIS/Spatial Analyses in Fishery and Aquatic Sciences* (Vol. *2*, pp. 241–250).

Garofalo, G., Fiorentino, F., Gristina, M., Cusumano, S., & Sinacori, G. (2007). Stability of spatial pattern of fish species diversity in the Strait of Sicily (central Mediterranean). *Hydrobiologia*, *580*, 117–124.

Geraci, M. L., Scannella, D., Falsone, F., Colloca, F., Vitale, S., Rizzo, P., Di Maio, F., Milisenda, G., & Fiorentino, F. (2018). Preliminary study on the biological traits of the Por's goatfish *Upeneus pori* (Chordata: Actinopterygii) off the southern coast of Lampedusa Island (Central Mediterranean). *The European Zoological Journal*, *85*, 232–242. https://doi.org/10.1080/24750263.2018.1464218

Giaccone, G., & Sortino, M. (1974). Significato biogeografico della vegetazione marina della Sicilia e delle isole minori nell'area del Mare Mediterraneo. *Bollettino Di Studi Ed Informazioni Del Giardino Coloniale Di Palermo*, *26*, 130–146.

Gianguzza, P., Insacco, G., Zava, B., Deidun, A., & Galil, B. S. (2019). Much can change in a year: The Massawan mantis shrimp, *Erugosquilla massavensis* (Kossmann, 1880) in Sicily, Italy. *BioInvasions Records*, *8*, 108–112. https://doi.org/10.3391/bir.2019.8.1.11

Gristina, M., Bahri, T., Fiorentino, F., & Garofalo, G. (2006). Comparison of demersal fish assemblages in three areas of the Strait of Sicily under different trawling pressure. *Fisheries Research*, *81*, 60–71. https://doi.org/10.1016/j.fishres.2006.05.010

Hamel, J.-F., Sun, J., Gianasi, B. L., Montgomery, E. M., Kenchington, E. L., Burel, B., Rowe, S., Winger, P. D., & Mercier, A. (2019). Active buoyancy adjustment increases dispersal potential in benthic marine animals. *Journal of Animal Ecology*, *88*(6), 820–832. https://doi.org/10.1111/1365-2656.12943

Insacco, G., Zava, B., & Corsini-Foka, M. (2017). *Trachysalambria palaestinensis* (Steinitz, 1932) (Decapoda, Penaeidae), a new alien prawn for the Italian water. *Cahiers De Biologie Marine*, *58*, 497–500.

Jackson, J. B. C. (1986). Modes of dispersal of clonal benthic invertebrates: Consequences for species' distributions and genetic structure of local populations. *Bulletin of Marine Science*, *39*(2), 588–606.

Jouini, M., Beranger, K., Arsouze, T., Beuvier, J., Thiria, S., Crepon, M., & Taupier-Letage, I. (2016). The Sicily Channel surface circulation revisited using a neural clustering analysis of a high-resolution simulation. *Journal of Geophysical Research: Oceans*, *121*, 4545–4567. https://doi.org/10.1002/2015JC011472

Katsanevakis, S., Coll, M., Piroddi, C., Steenbeek, J., Ben Rais Lasram, F., Zenetos, A., & Cardoso, A. C. (2014). Invading the Mediterranean Sea: Biodiversity patterns shaped by human activities. *Frontiers in Marine Science*, *1*, 32. https://doi.org/10.3389/fmars.2014.00032

Koukouras, A., & Matsa, A. (1998). The thoracican cirriped fauna of the Aegean Sea: New information, check list of the Mediterranean species, faunal comparisons. *Senckenbergiana Maritima*, *28*, 133–142. https://doi.org/10.1007/BF03043144

Lauria, V., Garofalo, G., Fiorentino, F., Massi, D., Milisenda, G., Piraino, S., Russo, T., & Gristina, M. (2017). Species distribution models of two critically endangered deep-sea octocorals reveal fishing impacts on vulnerable marine ecosystems in central Mediterranean Sea. *Scientific Reports*, *7*(1), 1–14. https://doi.org/10.1038/s41598-017-08386-z

Lejeusne, C., Chevaldonné, P., Pergent-Martini, C., Boudouresque, C. F., & Perez, T. (2010). Climate change effects on a miniature ocean: The highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology & Evolution*, *25*, 250–260. https://doi.org/10.1016/j.tree.2009.10.009

Massi, D., Rinelli, P., & Mastrototaro, F. (2007). First records of the rare starfish *Marginaster capreensis* (Gasco, 1876) (Echinodermata, Asteroidea, Poraniidae) in the Strait of Sicily and further information on its recent finding in the Ionian Sea. *Rapports Et procés-verbaux Des Réunions Commission Internationale Pour L'exploration Scientifique De La Mer Méditerranée*, *38*, 537.

Massi, D., Micalizzi, R., Giusto, G. B., & Pipitone, C. (2010). First record of *Heterocrypta maltzami* Miers, 1881 (Decapoda, Brachyura, Parthenopidae) in the Strait of Sicily. *Crustaceana*, *83*, 1141–1145. https://doi.org/10.1163/001121610X520966

Massi, D., Sinacori, G., Titone, A., Micalizzi, R., & Rinelli, P. (2010). New findings of the rare black brittlestar Ophiocomina nigra (Abildgaard, in O.F. Muller, 1789) (Echinodermata, Ophiacantidae) in the Sicilian Channel. *Rapports et procés-verbaux des réunions Commission internationale pour l'exploration scientifique de la Mer Méditerranée*, *39*, 582.

Massi, D., Vitale, S., Titone, A., Milisenda, G., Gristina, M., & Fiorentino, F. (2018). Spatial distribution of the black coral *Leiopathes glaberrima* (Esper, 1788) (Antipatharia: Leiopathidae) in the Mediterranean: A prerequisite for protection of Vulnerable Marine Ecosystems (VMEs). *The European Zoological Journal*, *85*, 169–178.

Mastrototaro, F., Maiorano, P., Vertino, A., Battista, D., Indennidate, A., Savini, A., & D'Onghia, G. (2013). A facies of *Kophobelemnon* (Cnidaria, Octocorallia) from Santa Maria di Leuca coral province (Mediterranean Sea). *Marine Ecology*, *34*, 313–320.

MEDITS-Handbook. (2017). Version n. 9, MEDITS Working Group: pp. 106.

Micheli, C., Paganin, P., Peirano, A., Caye, G., Meinesz, A., & Bianchi, C. N. (2005). Genetic variability of *Posidonia oceanica* (L.) Delile in relation to local factors and biogeographic patterns. *Aquatic Botany*, *82*, 210–221. https://doi.org/10.1016/j.aquabot.2005.03.002

Mifsud, C., Taviani, M., & Stohr, S. (2009). Remarks on Echinodermata from the South Central Mediterranean Sea based upon collections made during the MARCOS cruise (10 to 20th April, 2007). *Mediterranean Marine Science*, *10*, 63–72. https://doi.org/10.12681/mms.109

Oceana. (2011). Oceana MedNet: MPA network proposal for the Mediterranean Sea. In: Madina M. (Ed) http://oceana.org/sites/default/files/reports/OCEANA_MEDNet_ING_16012012_0.pdf

Péres, J. M., & Picard, J. (1964). Nouveau manuel de bionomie benthique de la Mer Méditerranée. *Recueils Des Travaux De La Station Maritime D'endoume*, *31*(47), 137.

Pérez-Ruzafa, A., López-Ibor, A. et al (1988). Echinoderm fauna from the south-western Mediterranean. Biogeographic relationships. In R. D. Burke (Ed.), *Echinoderm biology* (pp. 355–362). A.A. Balkema.

Petović, S. (2018). Additions to the checklist of the malacofauna of the Boka Kotorska Bay (south-east Adriatic Sea). *Studia Marina*, *31*, 23–36.

Pipitone, C., & Arculeo, M. (2003). The marine Crustacea Decapoda of Sicily (central Mediterranean Sea): A checklist with remarks on their distribution. *Italian Journal of Zoology*, *70*, 69–78. https://doi.org/10.1080/11250000309356498

Pipitone, C., Insacco, G., Massi, D., & Zava, B. (2018). New records of *Calappa tuerkayana* Pastore, 1995 (Brachyura, Calappidae) from the central Mediterranean. *Acta Adriatica: International Journal of Marine Sciences*, *59*, 213–217.

Relini, G. (1979). Remarks on Cirripedes of the Ligurian sea. *Rapports Et procés-verbaux Des Réunions Commission Internationale Pour L'exploration Scientifique De La Mer Méditerranée*, *25*(26), 4.

Relini, G. (2000). Demersal trawl surveys in Italian Seas: A short review. *Actes de Colloques. Institut Francais De Recherche Pour L'exploitation De La Mer*, *26*, 76–93.

G. Relini (Ed.) (2008). Checklist della Flora e della Fauna dei Mari Italiani: Parte I. *Biologia Marina Mediterranea*, *15*(1), 1–386.

G. Relini (Ed.) (2010). Checklist della Flora e della Fauna dei Mari Italiani: Parte II. *Biologia Marina Mediterranea*, *17*(2), 387–828.

Sbrocco, E. J., & Barber, P. H. (2013). MARSPEC: Ocean climate layers for marine spatial ecology. *Ecology*, *94*, 979. https://doi.org/10.1890/12-1358.1

Scannella, D., Falsone, F., Geraci, M., Froglia, C., Fiorentino, F., Giusto, G., Zava, B., Insacco, G., & Colloca, F. (2017). First report of Northern brown shrimp *Penaeus aztecus* Ives, 1891 in Strait of Sicily. *BioInvasions Record*, *6*, 67–72. https://doi.org/10.3391/bir.2017.6.1.11

Sciberras, M., & Schembri, P. (2007). A critical review of records of alien marine species from the Maltese Islands and surrounding waters (Central Mediterranean). *Mediterranean Marine Science*, *8*, 41–66. https://doi.org/10.12681/mms.162

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., & Robertson, J. (2007). Marine Ecoregions of the World: A bioregionalization of coast and shelf areas. *BioScience*, *57*, 573–583.

Spanò, N., Porporato, E. M., & Ragonese, S. (2013). Spatial distribution of decapoda in the Strait of Sicily (central Mediterranean sea) based on a trawl survey. *Crustaceana*, *86*, 139–157. https://doi.org/10.1163/15685403-00003143

Templado, J. (2014). Future trends of Mediterranean biodiversity. In S. Goffredo, & Z. Dubinsky (Eds.), *The Mediterranean Sea* (pp. 479–498). Springer.

Terribile, K., Evans, J., Knittweis, L., & Schembri, P. J. (2016). Maximising MEDITS: Using data collected from trawl surveys to characterise the benthic and demersal assemblages of the circalittoral and deeper waters around the Maltese Islands (Central Mediterranean). *Regional Studies in Marine Science*, *3*, 163–175. https://doi.org/10.1016/j.rsma.2015.07.006

Tiralongo, F., & Lombardo, B. M. (2017). New Mediterranean records of Pachygrapsus maurus. In: Lipej, L., et al. (Collective Article) ""New Mediterranean Biodiversity Records" (March 2017)." *Mediterranean Marine Science*, 18, 186–187.

Weber, M. (1977). Prosobranchier (Vorderkiemer) aus dem Litoral der Insel Lastovo, Adriaküste, *Jugoslawien*. *Philippia*, *111*, 314–327.

Winston, J. E. (2012). Dispersal in marine organisms without a pelagic larval phase. *Integrative and Comparative Biology*, *52*(4), 447–457. https://doi.org/10.1093/icb/ics040

WoRMS Editorial Board. (2020). World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ. Accessed 2020-03-09. https://doi.org/10.14284/170

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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