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# An Update on Biogeography of Decapod Crustaceans from a Collection of Soft-Bottom Macrofauna of the Central Mediterranean Sea

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# An Update on Biogeography of Decapod Crustaceans from a Collection of Soft-Bottom Macrofauna of the Central Mediterranean Sea

**Tiziano Bacci *, Monica Targusi, Loretta Lattanzi, Veronica Marusso, Benedetta Trabucco and Paolo Tomassetti**

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**Abstract:** Decapod crustaceans are important components of the fauna of soft bottom habitats. In this work, biogeographical updates of decapod crustaceans are provided through the analysis of a large soft bottom benthic macroinvertebrates data set of the central Mediterranean Sea. Decapod crustacean assemblages were collected in the last twenty years by a Van Veen grab on 42 study sites located along the Italian coasts at depths ranging from the surface up to 120 meters. Spatial distribution of the crustaceans examined, which include 123 species belonging to 40 families, has been investigated according to the biogeographical zones identified in the Italian Seas. Spatial distribution of 39 species has been updating, comparing the ISPRA decapod crustacean dataset with the most recent Italian checklists. For the species updated, number of specimens and environmental data, such as bathymetric range and habitat details, are provided for each site investigated. Data are discussed and compared with the existing literature, also referring to what is reported in the World Register of Marine Species (WoRMS), with the aims to contribute to the knowledge of biodiversity of the marine species provide useful data to assist the insiders to update checklists and registers at national and global scale and information on species ecology.

**Keywords:** decapod; crustacean; macrozoobenthos; biogeography; checklist; environmental monitoring; Mediterranean Sea

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## 1. Introduction

Sedimentary habitats cover most of the ocean bottom and constitute the largest single ecosystem on earth in terms of spatial coverage [1]. Benthic infauna provide fundamental data that are relevant to general objectives of most marine monitoring programs: ensuring that human health is not threatened; ensuring that unacceptable harm is not done to the marine ecosystem or marine resources; and supplying managers with information that allows them to make informed decisions concerning continued, reduced, or expanded use of the ocean for waste disposal and other activities [2]. In this regard, environmental monitoring programs related to anthropogenic impact studies on the marine environment often use macrozoobenthos as indicators [3–8], since their dynamics permit an integrated valuation of the space – temporal alteration of the ecosystem [9]. At the same time, environmental monitoring programs can be also a source of valuable scientific data to increase the scientific knowledge of benthic communities and species [10]. Crustacean Decapoda Latreille, 1802 are one of the most important groups in terms of both species richness and ecological roles [11] in the marine environment, which constitute a key taxon linking lower and higher trophic levels [12]. Crustacean decapods total over 14,000 extant species worldwide [13], where they occur from the upper intertidal zone to hadal depths of the seafloor [14]. In the Italian seas there are most of the species typical of the Mediterranean basin [15], 293 of which, reported in the most recent Italian checklists [16]. Although community assemblages, distribution and abundance of decapod crustacean fauna have been described from many Authors in the Western, Central and Eastern Mediterranean basin [17–29] there are still significant gaps in the understanding of their distribution and ecology. In this regard, the resulting faunal picture of decapod crustaceans in the Italian Seas is affected by the intensity of the research activity carried out in the various geographical zones considered and the knowledge on the real distribution of some species is lacking, especially for those difficult to catch [16].

This paper summarizes data from numerous environmental monitoring programs along the Italian continental shelf, with the aims to update biogeographical data on decapods crustaceans, through the analysis of a large soft bottom benthic macroinvertebrates data set of the central Mediterranean Sea. In this regard, spatial distribution of more of one hundred species were examined, according to the records available in the biogeographical zones in the Italian Seas [16]. Data are discussed and compared with the existing literature, also referring to what is reported in the World Register of Marine Species (WoRMS) [30], with the aims to contribute to the knowledge of biodiversity of the marine species, provide useful data to assist the insiders to update checklists and registers at national and global scale and information on species ecology.

## 2. Materials and Methods

### *2.1. Sampling Strategy, Field and Laboratory Procedures*

Data from 42 study sites located along the Italian continental shelf were extracted from ISPRA's data set (Figure 1), gained through numerous environmental monitoring campaigns carried out in Italy from 1999 to 2022 for different purpose, such as sand dredging, offshore installation developments (i.e. gas platform, liquefied natural gas re-gasification structures, cable) aquaculture facilities, beach nourishments. Soft bottom benthic macroinvertebrates were collected by a Van Veen grab (0.1 $m^2$ covering area) at depths ranging from the surface up to 120 meters. For each case studies were reported number of sampling stations, divided into depth ranges (1–10 m; 10.1–20 m; 20.1–30 m; 30.1–50 m; >50 m) (Table 1). Samples had been taken at 845 stations, differently placed and monitored in the time in each study site depending on the sampling strategy and project financing, collecting several thousand of samples overall. Sediments sampled were sieved through a 1-mm mesh and the retained material was preserved in seawater adding 4% CaCO3-buffered formalin. Macrozoobenthic samples were further sorted into major taxonomical groups and the collected decapods crustaceans counted and classified to the lowest possible taxonomic level.

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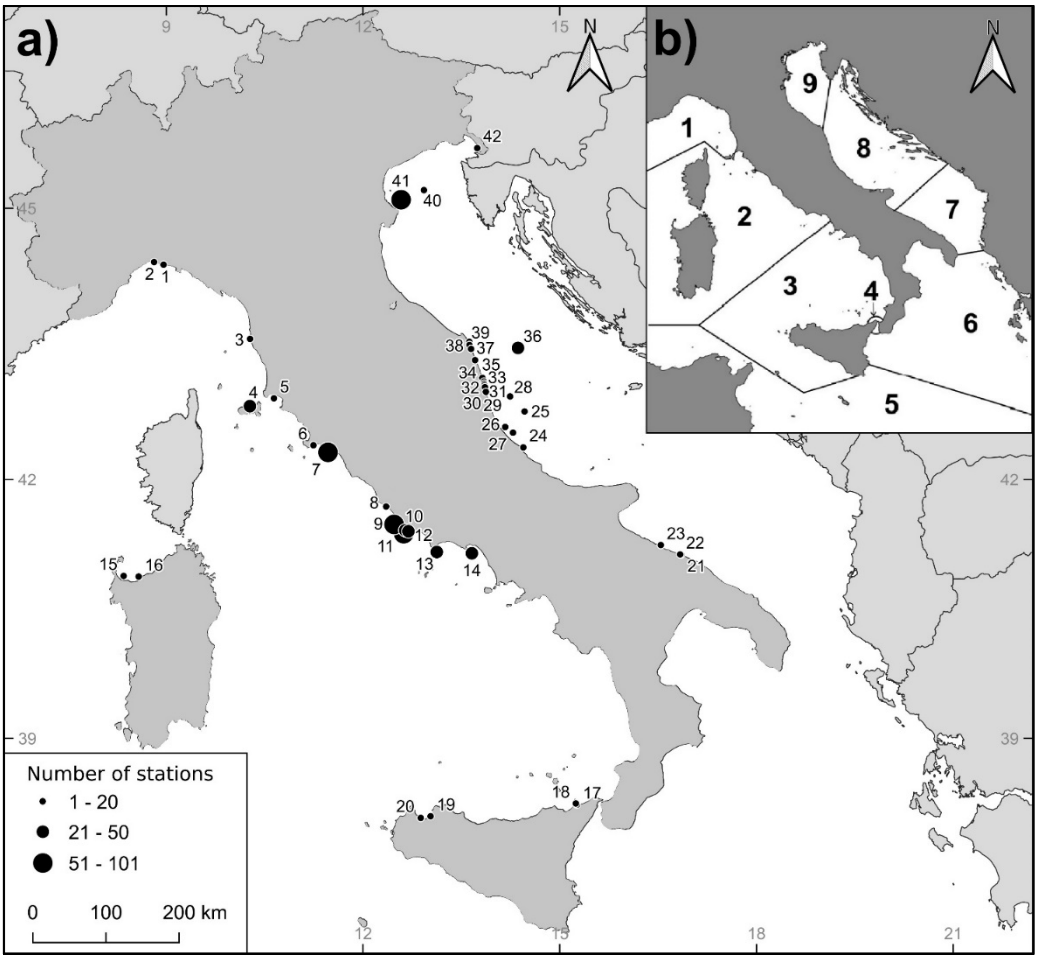


**Figure 1. a)** Location of the 42 study areas from which data was extracted. Study areas are numbered (from 1 to 42) from the Ligurian Sea to the northern Adriatic Sea. The circles of the study areas 17 and 18 and 21 and 22 are partially overlapping respectively (for details see table 1). The dimension of the circle is proportional to the number of stations investigated in each area. b) The nine biogeographical zones described in the Italian Seas are as according to [31] and followed in the checklist of flora and fauna of the Italian Seas [32].

**Table 1.** The 42 study areas located in the biogeographical zones identified in the Italian Seas [31] and the related names of Italian Seas (C= central; S= southern; N=northern). Number of sampling stations for each study area divided into depth ranges.

| Study areas | Sea | Biogeographic zone | Geographical coordinates | | Number of stations | Depth ranges (m) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Latitude (N) | Longitude (E) | | 0-10 | 10.1-20 | 20.1-30 | 30.1-50 | >50 |
| 1. Genova #1 | Ligurian Sea | 1 | 44°23'16'' | 08°57'34'' | 3 | 0 | 3 | 0 | 0 | 0 |
| 2. Genova #2 | Ligurian Sea | 1 | 44°24'59'' | 08°48'52'' | 3 | 1 | 2 | 0 | 0 | 0 |
| 3. Livorno | Ligurian Sea | 1 | 43°34'25'' | 10°16'44'' | 3 | 2 | 1 | 0 | 0 | 0 |
| 4. Elba | N Tyrrhenian Sea | 2 | 42°49'36'' | 10°16'31'' | 41 | 1 | 2 | 3 | 16 | 19 |
| 5. Follonica | N Tyrrhenian Sea | 2 | 42°54'51'' | 10°38'32'' | 5 | 0 | 0 | 3 | 2 | 0 |
| 6. Porto Ercole | N Tyrrhenian Sea | 2 | 42°23'17'' | 11°14'39'' | 11 | 0 | 0 | 11 | 0 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7. Montalto | C Tyrrhenian Sea | 2 | 42°18'29" | 11°28'01" | 101 | 0 | 2 | 8 | 67 | 24 |
| 8. Castel Porziano | C Tyrrhenian Sea | 2 | 41°41'21" | 12°21'10" | 12 | 3 | 3 | 3 | 3 | 0 |
| 9. Torvaianica | C Tyrrhenian Sea | 2 | 41°29'07" | 12°28'27" | 82 | 8 | 4 | 4 | 8 | 58 |
| 10. Nettuno | C Tyrrhenian Sea | 2 | 41°25'06" | 12°38'42" | 21 | 5 | 6 | 7 | 3 | 0 |
| 11. Anzio | C Tyrrhenian Sea | 2 | 41°22'45" | 12°37'17" | 87 | 0 | 0 | 0 | 80 | 7 |
| 12. Sabaudia | C Tyrrhenian Sea | 2 | 41°24'24" | 12°41'35" | 40 | 6 | 3 | 5 | 8 | 18 |
| 13. Terracina | C Tyrrhenian Sea | 2 | 41°10'12" | 13°07'32" | 50 | 9 | 3 | 2 | 13 | 23 |
| 14.Gaeta | C Tyrrhenian Sea | 2 | 41°09'18" | 13°39'37" | 33 | 0 | 4 | 2 | 10 | 17 |
| 15. Porto Torres | Sardinian Sea | 2 | 40°53'42" | 08°21'01" | 17 | 0 | 0 | 5 | 12 | 0 |
| 16. Castelsardo | Sardinian Sea | 2 | 40°53'16" | 08°34'45" | 9 | 0 | 0 | 2 | 7 | 0 |
| 17. Milazzo #1 | S Tyrrhenian Sea | 3 | 38°13'29" | 15°14'46" | 5 | 0 | 0 | 0 | 5 | 0 |
| 18. Milazzo #2 | S Tyrrhenian Sea | 3 | 38°12'38" | 15°15'49" | 8 | 4 | 2 | 1 | 1 | 0 |
| 19. Trappeto | S Tyrrhenian Sea | 3 | 38°04'16" | 13°01'54" | 14 | 0 | 0 | 14 | 0 | 0 |
| 20. Castellammare del Golfo | S Tyrrhenian Sea | 3 | 38°03'04" | 12°52'51" | 14 | 0 | 0 | 0 | 14 | 0 |
| 21. Bari #1 | S Adriatic Sea | 7 | 41°08'28" | 16°51'08" | 3 | 1 | 2 | 0 | 0 | 0 |
| 22. Bari #2 | S Adriatic Sea | 7 | 41°08'33" | 16°50'11" | 7 | 2 | 4 | 1 | 0 | 0 |
| 23. Bisceglie | S Adriatic Sea | 7 | 41°14'59" | 16°32'32" | 11 | 0 | 0 | 11 | 0 | 0 |
| 24. Ortona | C Adriatic Sea | 8 | 42°21'49" | 14°26'41" | 5 | 0 | 0 | 0 | 5 | 0 |
| 25. Pescara #1 | C Adriatic Sea | 8 | 42°46'02" | 14°27'50" | 12 | 0 | 0 | 0 | 0 | 12 |
| 26. Pescara #2 | C Adriatic Sea | 8 | 42°35'36" | 14°10'07" | 12 | 0 | 12 | 0 | 0 | 0 |
| 27. Pescara #3 | C Adriatic Sea | 8 | 42°31′46" | 14°17'17" | 15 | 0 | 0 | 6 | 5 | 4 |
| 28. S. Benedetto del Tronto | C Adriatic Sea | 8 | 42°56'05" | 14°14'36" | 10 | 0 | 0 | 0 | 0 | 10 |
| 29. Grottammare | C Adriatic Sea | 8 | 42°59'11" | 13°52'30" | 8 | 8 | 0 | 0 | 0 | 0 |
| 30. Cupramarittima | C Adriatic Sea | 8 | 43°02'16" | 13°51'36" | 8 | 8 | 0 | 0 | 0 | 0 |
| 31. Massignano | C Adriatic Sea | 8 | 43°03'29" | 13°51'13" | 4 | 4 | 0 | 0 | 0 | 0 |
| 32. Campofilone | C Adriatic Sea | 8 | 43°04'40" | 13°50'57" | 4 | 4 | 0 | 0 | 0 | 0 |
| 33. Pedaso | C Adriatic Sea | 8 | 43°06'04" | 13°50'40" | 6 | 6 | 0 | 0 | 0 | 0 |
| 34. Fermo | C Adriatic Sea | 8 | 43°08'30" | 13°49'15" | 8 | 8 | 0 | 0 | 0 | 0 |
| 35. Civitanova Marche #1 | C Adriatic Sea | 8 | 43°20'20" | 13°42'33" | 8 | 8 | 0 | 0 | 0 | 0 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 36. Civitanova Marche #2 | C Adriatic Sea | 8 | 43°28'27" | 14°21'51" | 36 | 0 | 0 | 0 | 0 | 36 |
| 37. Porto Recanati | C Adriatic Sea | 8 | 43°27'47" | 13°38'54" | 14 | 14 | 0 | 0 | 0 | 0 |
| 38. Numana | C Adriatic Sea | 8 | 43°30'23" | 13°37'22" | 10 | 10 | 0 | 0 | 0 | 0 |
| 39. Sirolo | C Adriatic Sea | 8 | 43°32'33" | 13°37'17" | 6 | 6 | 0 | 0 | 0 | 0 |
| 40. Chioggia #1 | N Adriatic Sea | 9 | 45°11'37" | 12°55'48" | 18 | 0 | 0 | 4 | 14 | 0 |
| 41. Chioggia #2 | N Adriatic Sea | 9 | 45°05'28" | 12°34'53" | 71 | 15 | 5 | 51 | 0 | 0 |
| 42. Trieste | N Adriatic Sea | 9 | 45°38'35" | 13°44'33" | 10 | 2 | 8 | 0 | 0 | 0 |

### 2.2. Data Analyses

The spatial distribution of each species was analysed according to the division of the Italian Seas into nine biogeographical zones, proposed by [31] (Figure 1) and applied in the Italian checklist of marine flora and fauna [32]. No study areas were available for this study from biogeographical zones 4, 5 and 6. Spatial distribution of species has been updating, comparing the ISPRA decapod crustacean dataset with the most recent Italian checklists [32], highlighting: i) species included in Italian check list and in our study as new record in one or more biogeographical zone, ii) species of our study not included in Italian check list. For the species updated, number of specimens and environmental data, such as bathymetric range and habitat details, are provided for each site investigated. In addition, the biogeographical data for each species updated were analysed and compared also referring to geo-units and related sources reported in the World Register of Marine Species (WoRMS) [30] and to Ocean Biodiversity Information System (OBIS) [33] occurrences documented in WoRMS. If available, data was compared also with other existing literature.

For many species, voucher specimens were available in ISPRA's reference collection, which is based on the material collected in numerous monitoring surveys.

## 3. Results

A total of 123 species of decapod crustaceans, belonging to 40 families distributed across the Italian biogeographical zones 1, 2, 3, 7, 8 and 9, were identified. Most of the study sites are in the zone 8 (38.1 %) and in the zone 2 (33.3 %), follow the zone 3 (9.5 %), the zones 9 and 7 (7.1 %) and the zone 1 (4.8 %). The largest number of stations fall between 30.1 and 50 meters (32.3 %) follow the depth range >50 m (27.0 %), the depth range 10.1-20 m (16.9 %), the depth range 0-10 m (16.0 %), the lesser one fall between 10.1 and 20 meters (7.8 %).

The allocation of the 123 species by biogeographical zones, as reported in the checklist of flora and fauna of the Italian Seas [32], is presented in white in Table 2. Results arising from the ISPRA decapod crustacean dataset confirmed the presence of these species in some biogeographical zones (in light grey) and updated the distribution of 32 of these species (in dark grey) if compared with the most recent Italian checklists [32]. In addition, the results shown the existence of 7 species in the Italian seas not yet documented in the Italian checklist (Table 2). Overall, the results if compared with the most recent Italian checklists [32] updated the biogeography of 39 species through 50 new records at biogeographical zone level (85 new records at study area level). The largest number of records have been recorded in zone 2, follow with larger number of records the zones 9, 7, follow with smaller number of records the zones 8, 3 and 1. No species not yet documented in the Italian checklist have been found in zones 8 and 1 (Figure 2).

**Table 2.** Distribution of the 123 species by the nine biogeographical zones of the Italian Seas. In white, the distribution of the selected species as reported in the checklist of flora and fauna of the Italian Seas [32]; in light grey, records confirming the species distribution; in dark grey, species included in Italian checklist and in our study as new record in one or more biogeographical zones; in black, species of our study not included in Italian check list.

| **Species** | **Biogeographical Zones of Italian Seas** | | | | | | | | | **Remarques** |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| *Parapenaeus longirostris* (Lucas, 1846) | + | + | + | + | + | + | + | + | | |
| *Sicyonia carinata* (Brünnich, 1768) | + | + | + | + | + | + | + | + | + | |
| *Solenocera membranacea* (Risso, 1816) | + | + | + | + | + | + | + | + | + | |
| *Richardina fredericii* Lo Bianco, 1903 | + | + | + | | | | | + | | |
| *Balssia gasti* (Balss, 1921) | + | + | + | | + | + | | + | | |
| *Palaemon adspersus* Rathke, 1836 | + | + | + | + | | + | + | + | + | |
| *Alpheus glaber* (Olivi, 1792) | + | + | + | + | + | + | + | + | + | |
| *Alpheus dentipes* Guérin, 1832 | + | + | + | + | + | + | + | + | + | |
| *Athanas nitescens* (Leach, 1814) | + | + | + | + | + | + | + | + | + | |
| *Athanas nitescens var. laevirhincus* (Risso, 1816) | | + | | | | | | | | |
| *Synalpheus gambarelloides* (Nardo, 1847) | + | + | + | + | + | + | | + | + | |
| *Synalpheus africanus* Crosnier & Forest, 1965 | | | + | | | | | | | |
| *Eualus occultus* (Lebour, 1936) | + | + | + | | + | | | + | + | |
| *Eualus pusiolus* (Krøyer, 1841) | | + | | | | | + | | + | |
| *Eualus cranchii* (Leach, 1817) | + | + | + | + | + | + | + | + | + | A1 |
| *Hippolyte leptocerus* (Heller, 1863) | + | + | + | | | + | + | + | + | |
| *Hippolyte inermis* Leach, 1816 | + | + | + | + | + | + | + | + | + | |
| *Chlorotocus crassicornis* (A. Costa, 1871) | + | + | + | + | + | + | + | + | | |
| *Processa acutirostris* Nouvel & Holthuis, 1957 | + | + | + | + | + | + | + | + | + | |
| *Processa canaliculata* Leach, 1815 | + | + | + | | | + | + | + | + | |
| Processa edulis (Risso, 1816) | + | + | + | + | + | + | + | + | + | A2 |
| *Processa elegantula* Nouvel & Holthuis, 1957 | + | + | + | | | + | | + | + | |
| *Processa intermedia* Holthuis, 1951 | | | | | | | | | + | |
| *Processa macrophthalma* Nouvel & Holthuis, 1957 | + | + | + | + | + | + | + | + | + | |
| *Processa modica carolii* Williamson in Williamson & Rochanaburanon, 1979 | + | + | + | | + | + | | + | + | |
| *Processa nouveli nouveli* Al-Adhub & Williamson, 1975 | + | + | + | | | + | + | + | + | |
| *Aegaeon cataphractus* (Olivi, 1792) | + | + | + | | | + | + | + | | |
| *Crangon allmanni* Kinahan, 1860 | | + | | | | | | | + | |
| *Crangon crangon* (Linnaeus, 1758) | | | + | | | | + | + | + | |
| *Philocheras monacanthus* (Holthuis, 1961) | + | + | + | | | | + | + | + | |
| *Philocheras bispinosus* (Hailstone, 1835) | | + | + | | | | + | + | + | |
| *Philocheras sculptus* (Bell, 1847) | + | + | + | | | | | + | + | |
| *Philocheras trispinosus* (Hailstone in Hailstone & Westwood, 1835) | + | + | + | | | | | + | + | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Calocaris macandreae* Bell, 1846 | + | + | + | | + | + | + | + | + | |
| *Callianassa subterranea* (Montagu, 1808) | | + | + | + | | | + | + | + | |
| *Necallianassa acanthura* (Caroli, 1946) | | | + | | | | + | + | + | |
| *Necallianassa truncata* (Giard & Bonnier, 1890) | | + | + | | | | + | + | + | |
| *Gilvossius tyrrhenus* (Petagna, 1792) | | + | + | | | + | | | + | A3 |
| *Gourretia denticulata* (Lutze, 1937) | + | + | + | | + | | + | + | + | |
| *Jaxea nocturna* Nardo, 1847 | | + | + | | + | | + | + | + | |
| *Upogebia deltaura* (Leach, 1816) | | + | + | | + | + | | + | + | |
| *Upogebia mediterranea* Noël, 1992 | + | + | + | | + | + | | + | + | |
| *Upogebia pusilla* (Petagna, 1792) | + | + | + | + | + | + | + | + | + | |
| *Upogebia stellata* (Montagu, 1808) | | | | | + | | | + | + | |
| *Upogebia tipica* (Nardo, 1869) | + | + | + | | | + | + | + | + | |
| *Scyllarides latus* (Latreille, 1803) | + | + | + | + | + | + | + | + | | |
| *Calcinus tubularis* (Linnaeus, 1767) | + | + | + | + | + | + | + | | | |
| *Dardanus arrosor* (Herbst, 1796) | + | + | + | + | + | + | + | + | + | |
| *Dardanus calidus* (Risso, 1827) | + | + | + | + | + | + | | + | | |
| *Diogenes pugilator* (Roux, 1829) | + | + | + | + | + | + | + | + | + | |
| *Paguristes eremita* (Linnaeus, 1767) | + | + | + | + | + | + | + | + | + | |
| *Paguristes syrtensis* de Saint Laurent, 1971 | | + | + | | + | + | | | | |
| *Anapagurus bicorniger* A. Milne-Edwards & Bouvier, 1892 | + | + | + | | | + | + | + | + | |
| *Anapagurus breviaculeatus* Fenizia, 1937 | + | + | + | | + | + | + | + | + | |
| *Anapagurus chiroacanthus* (Liljeborg, 1856) | + | + | + | | + | + | + | | + | |
| *Anapagurus laevis* (Bell, 1845) | + | + | + | + | + | + | + | + | + | |
| *Anapagurus petiti* Dechancé & Forest, 1962 | + | + | + | | + | + | + | + | + | |
| *Anapagurus smythi* Ingle, 1993 | | + | + | | | | | | | |
| *Cestopagurus timidus* (Roux, 1830) | + | + | + | + | + | + | + | + | + | |
| *Pagurus alatus* Fabricius, 1775 | + | + | + | + | + | + | + | + | | |
| *Pagurus anachoretus* Risso, 1827 | + | + | + | + | + | + | + | + | + | |
| *Pagurus chevreuxi* (Bouvier, 1896) | + | + | + | | + | | | | | |
| *Pagurus cuanensis* Bell, 1845 | + | + | + | + | + | + | + | + | + | |
| *Pagurus excavatus* (Herbst, 1791) | + | + | + | + | + | + | + | + | + | |
| *Pagurus forbesii* Bell, 1845 | | + | + | | + | | + | + | + | |
| *Pagurus prideaux* Leach, 1815 | + | + | + | + | + | + | + | + | + | |
| *Galathea bolivari* Zariquiey Álvarez, 1950 | + | + | + | | + | | | + | + | |
| *Galathea cenarroi* Zariquiey Álvarez, 1968 | + | + | + | | + | | | + | + | |
| *Galathea dispersa* Spence Bate, 1859 | + | + | + | | + | + | + | + | + | |
| *Galathea intermedia* Lilljeborg, 1851 | + | + | + | | + | + | + | + | + | |
| *Galathea strigosa* (Linnaeus, 1761) | + | + | + | | | + | + | + | + | |
| *Dactylonida curvimana* (A. Milne Edwards & Bouvier, 1894) | | | | | + | + | | + | | A4 |
| *Munida intermedia* A. Milne-Edwards & Bouvier, 1899 | | + | + | | + | + | + | + | | |
| *Iridonita speciosa* von Martens, 1878 | | | + | | | + | + | + | | A5 |
| *Pisidia longicornis* (Linnaeus, 1767) | | + | | + | | + | + | + | + | |
| *Pisidia bluteli* (Risso, 1816) | + | + | + | + | + | + | + | + | + | |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Ethusa mascarone* (Herbst, 1785) | + | + | + | + | + | + | + | + | + |
| *Medorippe lanata* (Linnaeus, 1767) | + | + | + | + | + | + | + | + | + |
| *Ilia nucleus* (Linnaeus, 1758) | + | + | + | + | + | + | + | + | + |
| *Ebalia cranchii* Leach, 1817 | | + | + | | | | + | + | + |
| *Ebalia deshayesi* Lucas, 1846 | + | + | + | + | + | | | | + |
| *Ebalia tuberosa* (Pennant, 1777) | + | + | + | | + | + | + | + | + |
| *Ebalia edwardsii* O.G. Costa, 1838 | + | + | + | + | + | + | | + | + |
| *Ebalia granulosa* H. Milne Edwards, 1837 | | + | | | + | + | + | + | + |
| *Ebalia tumefacta* (Montagu, 1808) | | + | | | | | | | + |
| *Achaeus cranchii* Leach, 1817 | + | + | + | | + | + | + | + | + |
| *Achaeus gracilis* (O.G. Costa, 1839) | + | + | + | | + | + | + | + | + |
| *Macropodia linaresi* Forest & Zariquiey Álvarez, 1964 | | + | + | | + | | + | + | + |
| *Macropodia rostrata* (Linnaeus, 1761) | + | + | + | + | + | + | + | + | + |
| *Inachus dorsettensis* (Pennant, 1777) | + | + | + | + | + | + | + | + | + |
| *Inachus parvirostris* (Risso, 1816) | + | + | + | + | + | + | | + | |
| *Eurynome aspera* (Pennant, 1777) | + | + | + | + | + | + | + | + | + |
| *Pisa muscosa* (Linnaeus, 1758) | + | + | + | + | + | + | | + | + |
| *Pisa hirticornis* (Herbst, 1804) | + | + | + | + | | + | | + | + |
| *Derilambrus angulifrons* (Latreille, 1825) | + | + | + | + | + | + | + | + | + |
| *Parthenopoides massena* (Roux, 1830) | + | + | + | + | + | + | + | + | + |
| *Spinolambrus macrochelos* (Herbst, 1790) | + | + | + | | + | + | + | + | |
| *Atelecyclus rotundatus* (Olivi, 1792) | + | + | + | + | | + | + | + | + |
| *Atelecyclus undecimdentatus* (Herbst, 1783) | | + | | | | + | | | |
| *Corystes cassivelaunus* (Pennant, 1777) | + | | | | | + | | + | + |
| *Primela denticulata* (Montagu, 1808) | + | + | + | | + | + | + | + | + |
| *Sirpus zariquieyi* Gordon, 1953 | + | + | + | + | + | + | | + | + |
| *Thia scutellata* (Fabricius, 1793) | | + | + | + | | + | | | |
| *Bathynectes longipes* (Risso, 1816) | + | + | + | + | + | + | + | + | |
| *Liocarcinus bolivari* (Zariquiey Álvarez, 1948) | + | + | + | | + | | | | + |
| *Liocarcinus corrugatus* (Pennant, 1777) | + | + | + | + | + | + | + | + | + |
| *Liocarcinus depurator* (Linnaeus, 1758) | + | + | + | + | + | + | + | + | + |
| *Liocarcinus maculatus* (Risso, 1827) | + | + | + | + | + | + | + | + | + |
| *Liocarcinus navigator* (Herbst, 1794) | + | + | + | + | + | + | + | + | + |
| *Liocarcinus vernalis* (Risso, 1827) | + | + | + | + | | + | + | + | + |
| *Liocarcinus zariquieyi* (Gordon, 1968) | + | + | + | + | + | | + | + | |
| *Goneplax rhomboides* (Linnaeus, 1758) | + | + | + | + | + | + | + | + | + |
| *Eriphia verrucosa* (Forskål, 1775) | + | + | + | + | + | + | + | + | + |
| *Monodaeus couchii* (Couch, 1851) | + | + | + | | + | + | + | + | |
| *Xantho pilipes* A. Milne-Edwards, 1867 | + | + | + | + | + | + | + | + | + |
| *Pilumnus hirtellus* (Linnaeus, 1761) | + | + | + | + | + | + | + | + | + |
| *Pilumnus minutus* De Haan, 1835 | | | + | | | | | | |
| *Pilumnus spinifer* H. Milne Edwards, 1834 | + | + | + | | + | + | + | + | + |
| *Brachynotus gemmellari* (Rizza, 1839) | + | + | + | | | + | + | + | + |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Brachynotus sexdentatus* (Risso, 1827) | + | + | + | | | + | + | + | + |
| *Nepinnotheres pinnotheres* (Linnaeus, 1758) | + | + | + | | + | + | + | + | + |
| *Pinnotheres pisum* (Linnaeus, 1767) | + | + | + | | | + | + | + | + |
| *Palicus caronii* (Roux, 1830) | | + | + | | + | + | | + | |

**Remarques:** A1: reported as *Thoralus cranchii* (Leach, 1817) in the Italian checklist [32]. A2: reported as *Processa edulis edulis* (Risso, 1816) in the Italian checklist [32]. A3: reported as *Pestarella thyrrena* (Petagna, 1792) in the Italian checklist [32]. A4: reported as *Munida curvimana* ((A. Milne Edwards & Bouvier, 1894)) in the Italian checklist [32]. A5: reported as *Munida rutllanti* (Zariquiey Alvarez, 1952) in the Italian checklist [32].

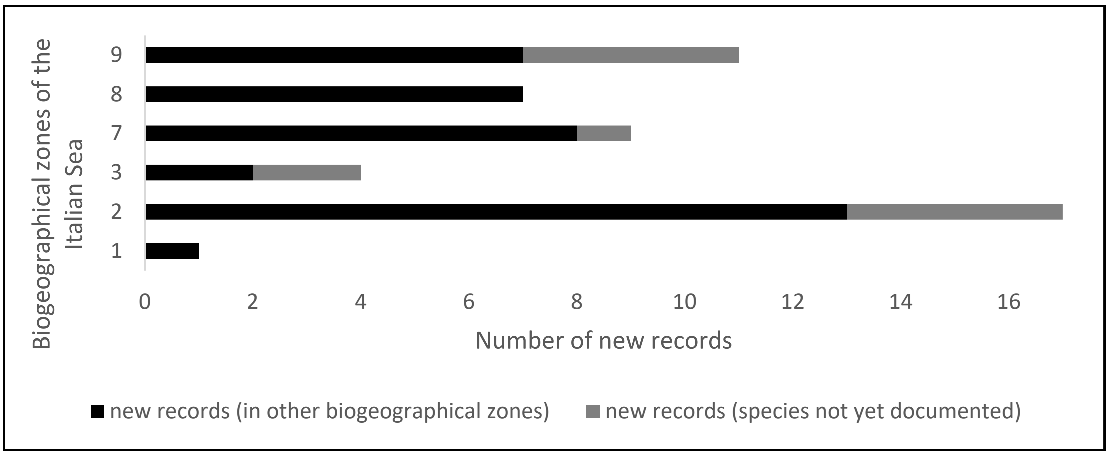


**Figure 2.** Number of new records of our study for each Italian biogeographical zone *sensu* [32]. Number of new records of species not yet documented in the Italian checklist [32] are shown separately. The biogeographical zones 4, 5 and 6 have been omitted since no data were available for these zones in our study.

About the 50 new records at biogeographical zone level, for each species updated, are shown below the study areas investigated, number of specimens, bathymetric range and habitat details found in our work. In addition, are shown biogeographical data as reported in the World Register of Marine Species (WoRMS) [30] and other remarques from scientific literature if available. About the 49 new records information related to biogeographical zones, study areas investigated and geographical coordinates are also available in Table S1.

***Richardina fredericii* Lo Bianco, 1903**

Italian biogeographical zone: 8; study area: Pescara #1; n. specimens: 1; depth: 116 m, habitat: bottoms of sandy mud; WoRMS: no documented distribution in Adriatic Sea.

***Balssia gasti* (Balss, 1921)**

Italian biogeographical zone: 8; study area: San Benedetto del Tronto; n. specimens: 1; depth: 85 m, habitat: bottoms of mud; WoRMS: documented distribution in Adriatic Sea in [34].

***Athanas nitescens var. laevirhincus* (Risso, 1816)**

Italian biogeographical zone: 2; study area: Castelsardo; n. specimens: 1; depth: 26 m; habitat: bottoms of sand; WoRMS: *Athanas nitescens var. laevirhincus* is not reported in the data base; other remarques: *Athanas nitescens var. laevirhincus* is described by different Authors [35–37,15]

***Synalpheus africanus* Crosnier & Forest, 1965**

Italian biogeographical zone: 3; study area: Milazzo #2; n. specimens: 9; depth: 3 m; habitat: bottoms of rocky; WoRMS: no documented distribution in Tyrrhenian Sea; other remarques: the species is reported in southern Tyrrhenian Sea in [38], where it was sampled as part of a macrofauna monitoring campaign where scratching was also carried out on rocky bottoms.

***Eualus occultus* (Lebour, 1936)**

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Italian biogeographical zone: 2; study area: Porto Torres; n. specimens: 7; depth: 35 m; habitat: bottoms of sand; WoRMS: documented distribution in Tyrrhenian Sea in [34] and in Western Mediterranean [39,15].

***Eualus pusiolus (Krøyer, 1841)***

Italian biogeographical zone: 2; study area: Porto Torres; n. specimens: 5; depth: 34 m; habitat: bottoms of sand and muddy sand; WoRMS: no documented distribution in Mediterranean Sea, except in Malaga (Spain) [39].

Italian biogeographical zone: 7; study area: Bisceglie: n. specimens: 1; depth: 32 m; habitat: bottoms of muddy sand; WoRMS: no documented distribution in Mediterranean Sea, except in Malaga (Spain) [39].

Italian biogeographical zone: 9; study area: Chioggia #2; n. specimens: 3; depth: 28 m; habitat: bottoms of sand; WoRMS: no documented distribution in Mediterranean Sea, except in Malaga (Spain) [39].

***Hippolyte leptocerus (Heller, 1863)***

Italian biogeographical zone: 8; study area: San Benedetto del Tronto; n. specimens: 3; depth: 85 m; habitat: bottoms of mud; WoRMS: documented distribution in Adriatic Sea in [15,34].

***Processa acutirostris Nouvel & Holthuis, 1957***

Italian biogeographical zone: 2; study area: Castel Porziano, Porto Torres, Castelsardo, Porto Ercole, Follonica; n. specimens: 21; depth: from 22 to 25 m; habitat: bottoms of sand, muddy sand, sandy mud, mud; WoRMS: documented distribution in Tyrrhenian Sea [34] and in Western Mediterranean [15].

Italian biogeographical zone: 7; study area: Bisceglie, Bari #2: n. specimens: 30; depth: from 16 to 32 m; habitat: bottoms of muddy sand; WoRMS: documented distribution in Adriatic Sea in [15,34].

***Processa canaliculata Leach, 1815***

Italian biogeographical zone: 9; study area: Chioggia #2; n. specimens: 17; depth: from 18 to 28 m; habitat: bottoms of sand, muddy sand and sandy mud; WoRMS: documented distribution in Adriatic Sea in [15,34].

***Processa elegantula Nouvel & Holthuis, 1957***

Italian biogeographical zone: 8; study area: S. Benedetto del Tronto; n. specimens: 9; depth: 85 m; habitat: bottoms of mud; WoRMS: no documented distribution in Adriatic Sea, except some OBIS occurrences in the northern.

Italian biogeographical zone: 9; study area: Chioggia #2: n. specimens: 88; depth: from 20 to 28 m; habitat: bottoms of sand, muddy sand and sandy mud; WoRMS: documented distribution in northern Adriatic Sea by OBIS occurrences.

***Processa intermedia Holthuis, 1951***

Italian biogeographical zone: 9; study area: Chioggia #2: n. specimens: 1; depth: 28 m; habitat: bottoms of sand; WoRMS: no documented distribution in Mediterranean Sea, except for some occurrences in Spain [15].

***Crangon allmanni Kinahan, 1860***

Italian biogeographical zone: 2; study area: Nettuno; n. specimens: 2; depth: 6 m; habitat: bottoms of muddy sand; WoRMS: no documented distribution in Mediterranean Sea.

Italian biogeographical zone: 9; study area: Chioggia #2: n. specimens: 2; depth: 28 m; habitat: bottoms of sand; WoRMS: no documented distribution in Mediterranean Sea.

***Philocheras monacanthus (Holthuis, 1961)***

Italian biogeographical zone: 7; study area: Bisceglie; n. specimens: 1; depth: 32 m; habitat: bottoms of muddy sand; WoRMS: documented distribution in Adriatic Sea in [15,34].

***Philocheras sculptus (Bell, 1847)***

Italian biogeographical zone: 2; study area: Porto Torres, Castelsardo; n. specimens: 20; depth: from 23 to 35 m; habitat: bottoms of sand and muddy sand; WoRMS: documented distribution in Tyrrhenian Sea in [34] and in Western Mediterranean [15].

***Calocaris macandreae Bell, 1846***

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Italian biogeographical zone: 9; study area: Chioggia #2; n. specimens: 1; depth: 28 m; habitat: bottoms of sand; WoRMS: documented distribution in Adriatic Sea in [34].

***Necallianassa acanthura (Caroli, 1946)***

Italian biogeographical zone: 7; study area: Bisceglie; n. specimens: 2; depth: 32 m; habitat: bottoms of muddy sand; WoRMS: documented distribution in Adriatic Sea in [34].

***Necallianassa truncata (Giard & Bonnier, 1890)***

Italian biogeographical zone: 7; study area: Bisceglie; n. specimens: 4; depth: 32 m; habitat: bottoms of muddy sand; WoRMS: documented distribution in Adriatic Sea [34].

Italian biogeographical zone: 8; study area: S. Benedetto del Tronto: n. specimens: 5; depth: 85 m; habitat: bottoms of mud; WoRMS: documented distribution in Adriatic Sea in [34].

***Gilvossius tyrrhenus (Petagna, 1792)***

Italian biogeographical zone: 2; study area: Porto Ercole, Follonica; n. specimens: 8; depth: from 22 to 32 m; habitat: bottoms of mud and muddy sand; WoRMS: documented distribution in Tyrrhenian Sea in [34].

***Gourretia denticulata (Lutze, 1937)***

Italian biogeographical zone: 1; study area: Genova #1, Livorno; n. specimens: 4; depth: from 11 to 16 m; habitat: bottoms of debris; WoRMS: documented distribution in Ligurian Sea by OBIS occurrences.

Italian biogeographical zone: 2; study area: Elba, Follonica, Montalto, Porto Torres, Castelsardo, Gaeta: n. specimens: 204; depth: from 5 to 64 m; habitat: bottoms of mud, sandy mud, muddy sand, sand and debris; WoRMS: no documented distribution in Tyrrhenian Sea.

***Jaxea nocturna Nardo, 1847***

Italian biogeographical zone: 2; study area: Montalto, Torvaianica, Anzio, Nettuno, Sabaudia, Terracina, Gaeta; n. specimens: 79; depth: from 5 to 101 m; habitat: bottoms of mud and sandy mud; WoRMS: documented distribution in Tyrrhenian Sea in [34].

***Upogebia deltaura (Leach, 1816)***

Italian biogeographical zone: 3; study area: Castellamare del Golfo; n. specimens: 5; depth: 42 m; habitat: bottoms of mud; WoRMS: documented distribution in southern Tyrrhenian Sea by OBIS occurrences.

***Upogebia mediterranea Noël, 1992***

Italian biogeographical zone: 2; study area: Castelsardo; n. specimens: 1; depth: 26 m; habitat: bottoms of sand; WoRMS: documented distribution in Tyrrhenian Sea and in Western Mediterranean Sea in [34].

***Upogebia stellata (Montagu, 1808)***

Italian biogeographical zone: 9; study area: Trieste; n. specimens: 1; depth: 16 m; habitat: bottoms of sandy mud; WoRMS: no documented distribution in Mediterranean Sea except some OBIS occurrences in the southern Tyrrhenian Sea and Western Mediterranean Sea.

***Upogebia tipica (Nardo, 1869)***

Italian biogeographical zone: 1; study area: Livorno; n. specimens: 1; depth: 11 m; habitat: bottoms of debris; WoRMS: documented distribution in Ligurian Sea by OBIS occurrences.

Italian biogeographical zone: 2; study area: Elba, Montalto, Porto Ercole, Castel Porziano, Torvaianica, Anzio, Nettuno, Sabaudia, Gaeta, Castelsardo, Porto Torres; n. specimens: 116; depth: from 2 to 90 m; habitat: bottoms of mud, sandy mud, muddy sand, sand and debris; WoRMS: no documented distribution in Tyrrhenian Sea.

***Calcinus tubularis (Linnaeus, 1767)***

Italian biogeographical zone: 7; study area: Bisceglie; n. specimens: 1; depth: 32 m; habitat: bottoms of muddy sand; WoRMS: documented distribution in Adriatic Sea in [34].

***Dardanus arrosor (Herbst, 1796)***

Italian biogeographical zone: 9; study area: Chioggia #2; n. specimens: 2; depth: 28 m; habitat: bottoms of sand; WoRMS: documented distribution in Adriatic Sea in [34].

***Dardanus calidus (Risso, 1827)***

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Italian biogeographical zone: 2; study area: Porto Ercole; n. specimens: 1; depth: 32 m; habitat: bottoms of mud; WoRMS: documented distribution in Tyrrhenian Sea in [34].

***Paguristes syrtensis de Saint Laurent, 1971***

Italian biogeographical zone: 2; study area: Elba; n. specimens: 5; depth: from 32 to 39 m; habitat: bottoms of sand, debris; WoRMS: documented distribution in central Tyrrhenian Sea by OBIS occurrences.

***Anapagurus laevis (Bell, 1845)***

Italian biogeographical zone: 7; study area: Bisceglie, Bari #2; n. specimens: 6; depth: from 16 to 18 m; habitat: bottoms of mud; WoRMS: documented distribution in Adriatic Sea in [34].

Italian biogeographical zone: 8; study area: S. Benedetto del Tronto, Civitanova Marche #1: n. specimens: 2; depth: from 85 to 87 m; habitat: bottoms of mud and sand; WoRMS: documented distribution in Adriatic Sea in [34].

Italian biogeographical zone: 9; study area: Chioggia #1, Chioggia #2: n. specimens: 13; depth: from 5 to 30 m; habitat: bottoms of sand and debris; WoRMS: documented distribution in Adriatic Sea in [34].

***Anapagurus petiti Dechancé & Forest, 1962***

Italian biogeographical zone: 7; study area: Bisceglie; n. specimens: 4; depth: 32 m; habitat: bottoms of muddy sand; WoRMS: no documented distribution in Adriatic Sea.

***Anapagurus smythi Ingle, 1993***

Italian biogeographical zone: 2; study area: Porto Ercole; n. specimens: 2; depth: 32 m; habitat: bottoms of mud; WoRMS: documented distribution in Mediterranean Sea except some occurrences in the Ionian Sea [34].

***Dactylonida curvimana (A. Milne Edwards & Bouvier, 1894)***

Italian biogeographical zone: 8; study area: S. Benedetto del Tronto; n. specimens: 2; depth: 85 m; habitat: bottoms of mud; WoRMS: no documented distribution in Adriatic Sea.

***Pisidia bluteli (Risso, 1816)***

Italian biogeographical zone: 3; study area: Milazzo #1, Castellamare del Golfo; n. specimens: 5; depth: from 35 to 43 m; habitat: bottoms of mud and sandy mud; WoRMS: documented distribution in Tyrrhenian Sea in [34].

***Ebalia granulosa H. Milne Edwards, 1837***

Italian biogeographical zone: 9; study area: Chioggia #2; n. specimens: 1; depth: 28 m; habitat: bottoms of sand; WoRMS: documented distribution in Adriatic Sea in [34].

***Ebalia tumefacta (Montagu, 1808)***

Italian biogeographical zone: 2; study area: Montalto, Porto Torres; n. specimens: 5; depth: from 34 to 50 m; habitat: bottoms of mud, sandy mud and muddy sand; WoRMS: no documented distribution in Tyrrhenian Sea.

Italian biogeographical zone: 9; study area: Chioggia #2; n. specimens: 1; depth: 28 m; habitat: bottoms of sand; WoRMS: documented distribution by OBIS occurrences in northern Adriatic Sea.

***Atelecyclus undecimdentatus (Herbst, 1783)***

Italian biogeographical zone: 2; study area: Follonica, Porto Torres; n. specimens: 2; depth: from 22 to 40 m; habitat: bottoms of sand and muddy sand; WoRMS: documented distribution in Tyrrhenian Sea in [34].

***Pilumnus minutus De Haan, 1835***

Italian biogeographical zone: 3; study area: Milazzo #2; n. specimens: 1; depth: 7 m; habitat: bottoms of rock; WoRMS: documented distribution in Mediterranean Sea as alien species in [20,40], where it was sampled as part of a macrofauna monitoring campaign where scratching was also carried out on rocky bottoms.

***Brachynotus gemmellari (Rizza, 1839)***

Italian biogeographical zone: 7; study area: Bisceglie; n. specimens: 1; depth: 32 m; habitat: bottoms of muddy sand; WoRMS: documented distribution in Adriatic Sea in [34].

***Palicus caronii (Roux, 1830)***

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Italian biogeographical zone: 2; study area: Elba; n. specimens: 1; depth: 51 m; habitat: bottoms of debris; WoRMS: documented distribution in Tyrrhenian Sea in [34].

## 4. Discussion

New relevant evidence emerged from the comparison of the results of this study with pre-existing knowledge, analyzing the distribution of 123 species of crustacean decapods in the Italian Sea. The present study contributes to the knowledge of soft-bottom marine invertebrate's biodiversity of the Central Mediterranean Sea by through 49 new records.

With the idea of providing useful data to assist the insiders to update checklists and registers at national and global scale, two reference data set were taken into account by a double-step analysis. Firstly, the Italian checklists [32] were compared with data of our study since it represents the most recent data set at national level officially accepted, hoping to facilitate the next updates of these checklists. In this regard, we updated the biogeography of 39 species, some of which have never been reported in the Italian seas from this national checklist. Secondly, the World Register of Marine Species (WoRMS) [30] was selected since it proves a worldwide register, it contains a huge amount of information constantly updated also related to other data information system, and it is now usually taken as a reference at international level. In this regard, direct comparisons among information contained in the Italian checklists [32], the World Register of Marine Species [30] and our data of this research highlighted several mismatches, which could be of great use to all insiders.

In addition, bathymetry and habitat data reported for each recorded species represent important information on the species ecology. In fact, although the ecological issue is not the main objective of this work, this information integrates the previous knowledge on the ecology of the species and can be a starting point for further studies and investigations.

Since knowledge on distribution of decapod crustaceans in the Italian seas is connected to intensity of the research activity performed in the various geographical zones [16], there are still significant gaps today on this issue. A higher sampling effort increases the chances of rare species being found as also shown for example by our data in the geographical zone 2, characterized by the second larger number of ISPRA's study areas and with the highest number of sampling stations investigated. This relationship between number of sampling stations investigated and number of new records is confirmed by our data in most of cases examined with some exceptions, since other factors evidently come into play. Sampling frequency can obviously further affect the possibilities of catching new species, as showed for example in the geographical sector 9, where a large study area was investigated by ISPRA for many years. Differently, despite in the geographical sector 7 have been carried out a few samplings by ISPRA, it showed a significant number of new records, probably suggesting a no high current knowledge of the area. These evidences of our research and other proves arising from similar investigations could direct specific studies aimed at filling current information gaps.

In addition, this study outlines the importance of environmental monitoring programs related to anthropogenic impact studies as a source of important scientific data on marine invertebrate biogeography and ecology. Frequent monitoring surveys and common sampling methodologies, like those of our research, allow the collection of numerous and comparable data from different study areas, allowing the integration of multidisciplinary information, also opening the way to more specific research and experiments [10]. In this regard, in fact, in addition to public environmental data, there is a large amount of environmental data collected by a variety of subjects, public and private, such as data derived from environmental characterizations and monitoring required for environmental assessment (e.g., EIA) procedures. These data, although collected frequently and often collected with high detail on a local scale in area of particular interest, often remain available only as grey literature and are rarely valued and made accessible to the scientific community. It is fragmented and not available due to the absence of specific and adequate centralized systems that help to organize and collect this type of detailed data in a homogeneous and functional way [41].

The importance of accessibility of environmental data is even more evident when the information refers to biodiversity, as in the case of macrozoobenthic assemblages, issue of this research. An accurate identification of macrozoobenthos requires the intervention of specialist taxonomists, an excellent conservation of the organisms and the presence of a reliable fauna description. Some diagnostic characters are sometimes of doubtful detection and the specimen cannot always be rechecked over time, since the reference collections do not necessarily remain always available, and the specimens can be partially or totally lost for various reasons [42–45]. For all these reasons, it is very important to have redundancy of information from different sources, to mutually confirm the reports and information acquired and to be able to have increasingly robust official reference data sets, increasingly up-to-date and free of potential misunderstandings, often existing on these issues. In this regard, Carriker [46] stressed the importance of accurate identification to unlock the storage and retrieval system of scientific information, given that a species name is the doorway to its literary pedigree.

We hope our research can contribute to the knowledge of biodiversity of the marine species and it can stimulate the return of large existing databases but not yet available both through manuscripts like this, and through the development of further and specific web platforms, able to enhance the large amount of existing environmental data also relating to anthropic impact studies within the environmental assessment. We hope the increasing awareness of importance of environmental monitoring data to increase the state of knowledge of biodiversity of our seas, will promote the centralization and availability of such information for the benefit of the entire scientific community.

**Supplementary Materials:** The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Table S1: records_decapod crustaceans.

**Author Contributions:** Conceptualization, T.B.; investigation, T.B., M.T., L.L., V.M., B.T. and P.T.; data curation, T.B.; validation, T.B., M.T., L.L., V.M., B.T. and P.T; writing—original draft preparation, T.B.; writing—review and editing, T.B., M.T., L.L., V.M., B.T. and P.T. All authors have read and agreed to the published version of the manuscript.

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