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A Systematic Analysis of the Mediterranean Sea (IHO Sea Area) in the WRiMS Database

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Abstract: The invasion of non-native species (NNS) is one of the greatest threats to biodiversity loss and represents a major problem in the Mediterranean Sea. Although many recent EU policies and directives address this problem and numerous scientific papers have been published, the available data remains scattered and incomplete. In 2021, the World Register of Introduced Marine Species (WRiMS), a newly established database, was launched but has not yet undergone systematic analysis. This study performed a thorough examination of the NNS documented in the WRiMS database within the Mediterranean Sea (International Hydrographic Organization Sea Area). Our findings revealed that the majority of species in the WRiMS database for the Mediterranean are classified as "unspecified" or "uncertain", with only 79 species labeled as "invasive" and 13 as "of concern". The number of recorded animal species exceeds that of plants, and most species belong to the phyla Chordata and Mollusca. *Callinectes sapidus* and *Fistularia commersonii* were the most frequently recorded species in the WRiMS for the Mediterranean. Although there exists some data on the impact of NNS and the vectors of their introduction, the information remains incomplete and requires further scientific research. The synthesized and summarized data in the supplement can be valuable input for a range of management decisions and for guiding further scientific research concerning NNS invasions in the Mediterranean Sea.

Keywords: biodiversity; bioinvasion; list of invasive species; NNS; WRiMS

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1. Introduction

Today, the marine environment and its biodiversity are severely affected by anthropogenic activities. The continuous increase in pollution, human exploitation, and climate change in recent decades has further exacerbated the ecological state of the marine environment [1,2]. Pollution, habitat loss, overexploitation, the invasion of non-native species (NNS), and climate change are the main contributors to biodiversity loss [3,4].

The proliferation of non-native species is increasingly recognized as a primary driver of biodiversity loss [5]. As these species continue to establish themselves globally [6,7], and the rate of introductions has risen steadily over the past two centuries [6], their impact on biodiversity has become more pronounced.

EU policies, such as the EU Biodiversity Strategy, the Marine Strategy Framework Directive (MSFD), and the European Strategy for Marine and Maritime Research, address the problem of the introduction of NNS [8,9]. The MSFD defines a good environmental status, i.e., a healthy marine environment by 2020, on the basis of eleven descriptors [10–12]. Descriptor two covers NNS [12], with the frequency and environmental impact of NNS being a key criterion [13]. In addition, the descriptor has been updated and made more detailed by specifying a six-year period during which the minimization and elimination of NNS is required [14]. Furthermore, Regulation (EU) No. 1143/2014 lays down management rules to prevent the introduction of NNS and minimize their impact [15]. The list of invasive alien species of Union concern is established [16], and a risk assessment procedure is required for each species [17]. However, a standardized global risk assessment approach has yet to be established. Implementing robust risk assessment practices is crucial for effective bioinvasion management [18].

The debate is still ongoing about whether all introduced species become invasive and negatively impact the environment [19–21]. Some authors highlight that the positive impacts of NNS can include an increase in species richness, abundance, and diversity [22–24]; contributions to ecosystem services [23]; and benefits to human well-being and conservation management [25–27]. The rate of invasion of species varies according to their biological characteristics and the abiotic and biotic factors of the new environment [28] and is unpredictable with each new introduction [29]. Some authors estimate that 25% of invertebrates and plants are successful at invasion and become established, while the probability of vertebrates becoming established is much higher (50%) [30]. Although the effects increase with colonization and spread, some species may have negative effects at the time of introduction [20,31].

The same species may have been introduced in different places by different pathways. Moreover, understanding and knowing the pathways of introduction is crucial for controlling and minimizing the rate of introduction [32], as once established, removing species from the new environment is often difficult or impossible [33]. While determining the pathway of introduction can be challenging, detailed records of new or introduced NNS can be valuable [34].

Although there are already several databases on NNS, the World Register of Introduced Marine Species (WRiMS) is a newly established database connected to WoRMS and covers all NNS, distinguishing between native and introduced geographic ranges [35]. It provides an overview of species that have been intentionally or accidentally introduced by humans and currently contains 2767 species [36]. The detailed datasets with taxonomic, geographic, impact, and vector information on the species are constantly revised and updated by experts [35].

With around 17,000 species and a high endemism rate [3], the Mediterranean region is a hotspot of biodiversity [3,37,38]. The Mediterranean is also strongly influenced by anthropogenic factors, and the invasion of NNS has a significant impact on biodiversity [3,39]. The impact of NNS in the Mediterranean together with overfishing on biodiversity is greater than the impact of global warming [40]. Some authors refer to the Mediterranean region as a hotspot of bioinvasion [41,42] due to high invasion rate [43]. The literature reports that around 1000 non-native species have been introduced [8,43], half of which are classified as invasive species [43,44] with an increase in introduced and establish NNS [34,45,46] In the period of three years (2017–2019), 23 newly introduced and already established species are recorded [45]. The most common vector for introduction into the Mediterranean are shipping, the aquarium trade, the Suez Canal [8,45], and, as a secondary vector, natural dispersion [34,45]. Although there are many publications on NNS in the Mediterranean, some authors report gaps in knowledge regarding their impact [47] and incomplete data [7,48,49] which may lead to inadequate management [7,47].

The WRiMS database provides comprehensive and up-to-date NNS data [35], but a systematic analysis of data on hotspots, species abundance, impacts and dispersal vectors in Mediterranean Sea has not yet been carried out. The aim of this paper is to: (1) extract, identify and analyze all available publications and NNS records from WRiMS for the Mediterranean Sea from 1990 (2) identify the most affected area of NNS, (3) identify the most studied NNS phylum, (4) identify the most frequently recorded species, (5) analyze NNS invasiveness, (6) crosscheck all NNS records for species of Union concern and member state concern. In addition, the impact and vector data for NNS that pose a high risk of invasiveness will be extracted, analyzed, and assessed. All data will be synthesized and summarized and can serve as useful input for various management decisions.

2. Material and Methods

2.1. Study Area

The Mediterranean Sea covers an area of 2,510,000 km^2, and the line between the island of Sicily and the African coast divides the Mediterranean into a western and an eastern part [50]. As a sea between continents and the fact that around 160 million people live on its shores [51], the Mediterranean Sea is heavily influenced by anthropogenic activities. Due to its geographic location, it is a very important shipping route and a popular tourist destination [52]. The study area in this paper is the Mediterranean Sea (IHO Sea Area) (Figure 1) [53].

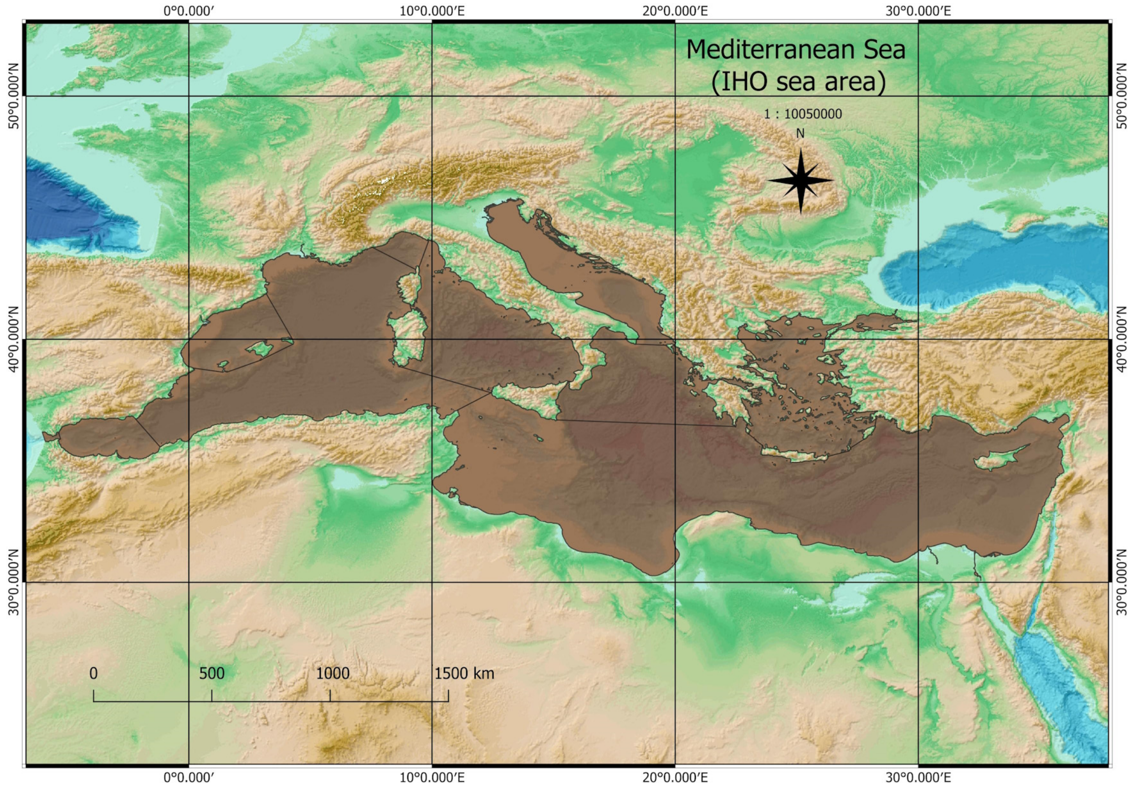

Figure 1. Mediterranean Sea (International Hydrographic Organization Sea Area) [54,55].

2.2. Terminology Description

We used the same terminology that is described in WRiMS [36] as follows:

1. Invasive: Spreading geographically, or where scientific evidence of negative impacts on native biodiversity have been recorded.
2. Invasiveness Not specified: Invasiveness has not been specified or evidence of impact is not clear.
3. Invasiveness Uncertain: Species whose invasiveness is uncertain.
4. Management recorded: Species is being managed to prevent introduction and/or spread.
5. Not invasive: Which have not naturalized, not spread, or not shown to have impacts on native biodiversity.
6. Of concern: Species that have not displayed any invasiveness in the country or sea area where they have been introduced but are known to be invasive in their introduced range elsewhere; and whose life stage forms can be dispersed through ballast water and or hull fouling.

For the impacts classification, we used the following terms: (1) adverse habitat modification, (2) alerts trophic interaction, (3) consume native species (predator or herbivore), (4) impact on human health, (5) loss of aquaculture/commercial/recreational harvest or gain, (6) loss of public/tourist amenity, (7) outcompetes native species for resources and/or space, (8) other impact–undefined or uncertain, and (9) water abstraction or nuisance fouling [35].

For identification of the pathways and vectors, we used the terminology as follows: (1) aquaculture: accidental; (2) canals: natural range expansion through man-made canals and dispersal via the Suez Canal; (3) fisheries: accidental as bait or deliberate translocation of fish or shellfish; (4) individual release: accidental release by individuals (aquarium release); (5) natural dispersion; (6) ships: general, accidental with ballast water; free-living fouling organisms [35].

2.3. Data Collection and Extraction

The WRiMS database was searched using combinations of geounit "Mediterranean Sea (IHO Sea Area)"; introduction "origin = alien", "occurrence = any", "invasiveness = any", distribution status "valid", and synonym "only accepted names" (Figure 2). Each extracted record contained, in addition to data on the species recorded, the cited publication that conducted a study on that species, the marine location where the research was conducted, and the latitude and longitude of the research site.

2.4. Data Analysis

The analysis was carried out in several steps:

1. The number of publications by year from 1990 was analyzed;
2. The most affected areas of the Mediterranean by NNS were analyzed,
3. Bias toward research on specific phyla was searched;
4. The frequency of NNS was analyzed;
5. The NNS were analyzed according to their invasive characterization;
6. All retrieved NNS were analyzed for species of Union concern, member states concern, and high impact categorization;
7. The NNS groups of concern and invasive NNS groups were analyzed in more detail regarding location, impact, vector of dispersal, and sources.

Data preprocessing was conducted to transform raw data in usable format for modelling and visualization. The fundamental step of data preprocessing was data cleaning that involved tackling duplicates and missing data. For the performance analysis of our systematic review, the annual number of publications, the locations of observed species, and the regression line between observed and recorded species were revealed and visualized using RStudio 2023.12.0 (R environment version 4.3.2, R Foundation for Statistical Computing Platform). The images were produced using ggplot2 and wordcloud2 packages in R.

The oldest records in WRiMS come from papers dating back to 1792, but only the records from 1990 to October 2023 were analyzed. Earlier years were omitted due to the small number of annual publications and the excessively large time span.

In order to detect if there is a bias toward research on specific phyla, we analyzed and visualized the number of publications found in WRiMS on each phylum in relation to the number of observed species publications reported in WRiMS by linear regression.

Finally, we analyzed the frequency of exact scientific names that appeared in the different records. A word cloud map was generated from these results. The size of the words in the cloud depends on their frequency.

The Lists of invasive alien species of Union concern [16,56,57] was crosschecked for species of Union concern, and the European Alien Species Information Network (EASIN) [58] database was crosschecked for species of Member State concern and species of high impact.

The NNS "of concern" (Table S2) and "invasive" NNS (Table S3) records in WRiMS were analyzed by location, dispersal vector, species impact, and publication, i.e., sources. Although for some species the impact and dispersal vector for a different site are given, these data were only analyzed if they were available for the same site as the species' location.

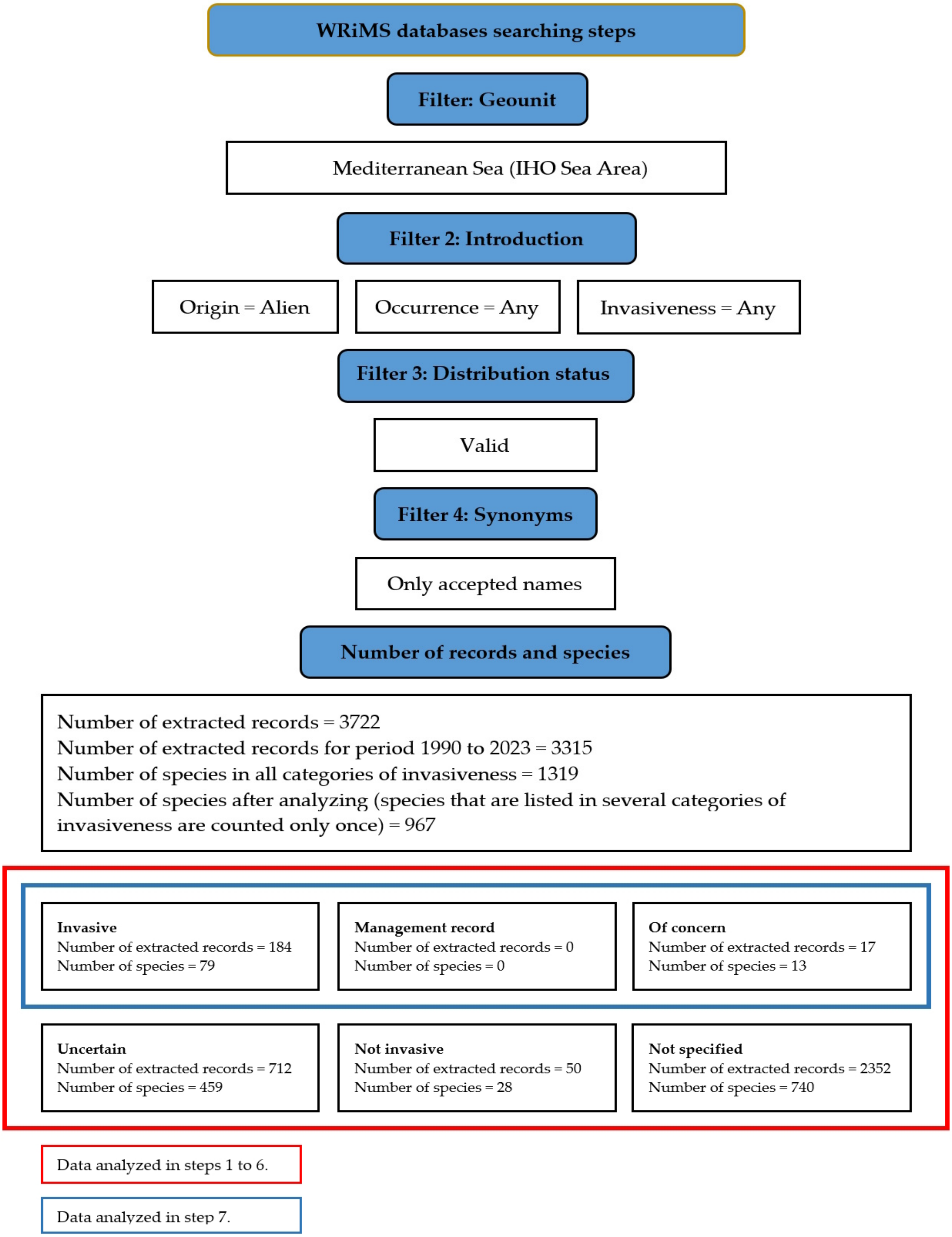

Figure 2. Data collecting steps and number of extracted records and species classified in different categories in WRiMS.

3. Results

Our searches resulted in 3315 records between 1990 and 2023, in which 1319 introduced species were described. The species of "uncertain" and "non-specified" invasiveness categorization was found in the greatest number (Figure 2). A considerable number of "invasive" species were found, yet there is no species in categories "management record" (Figure 2). After preprocessing data, 967 NNS species were analyzed (Table S1).

A comprehensive analysis was conducted on a total of 815 publications from 1990 to 2023. The trend in publications indicates a notable increase in the number of published papers over the last decade (Figure 3).

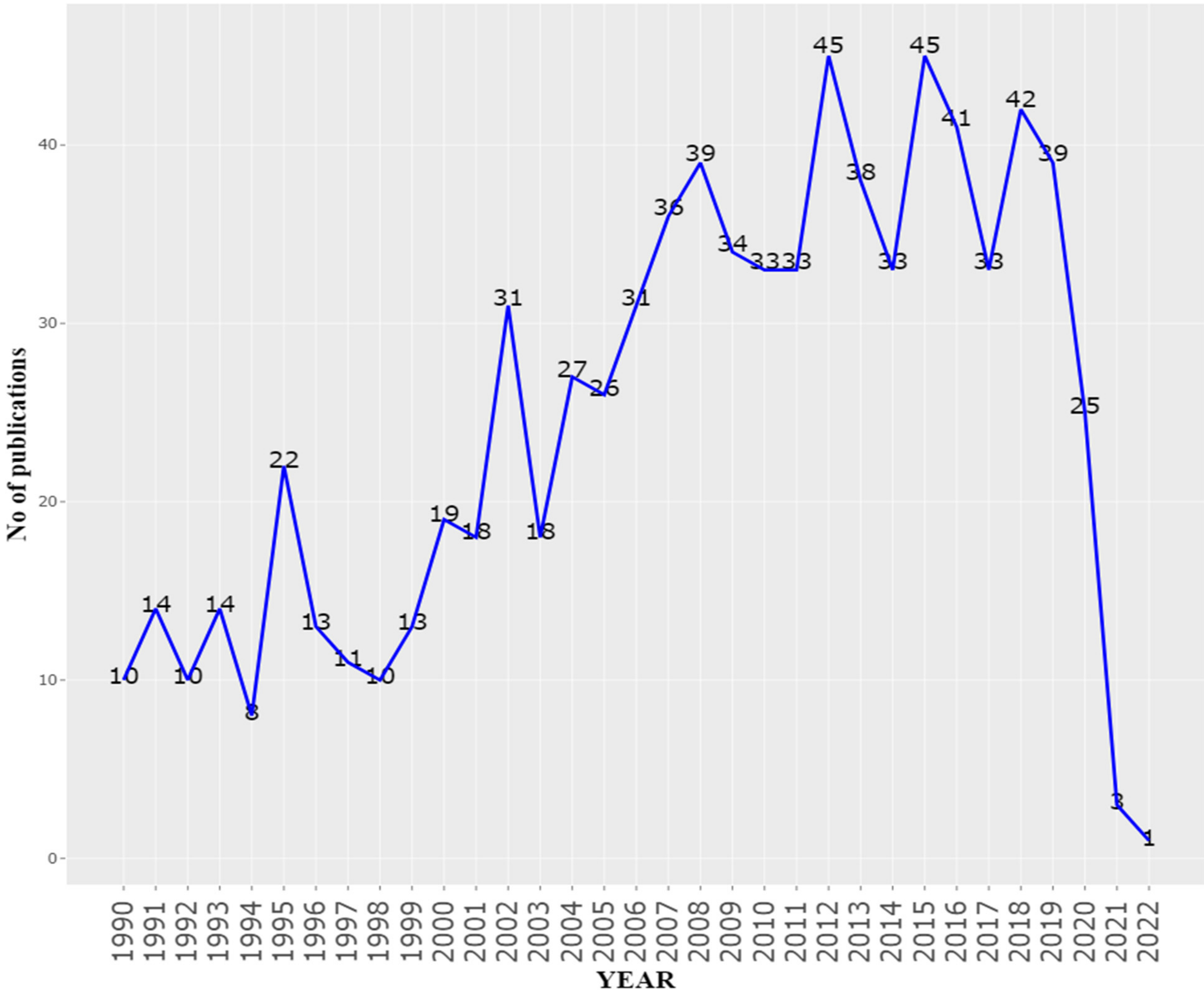

Figure 3. Annual number of publications from the WRiMS Geounit data for 1990 to 2023.

The geographical distribution analysis of NNS as documented in WRiMS reveals the presence of some areas with considerably large numbers of recorded species. Large numbers of species were recorded in the eastern basin of the Mediterranean Sea in the Greek part of the Aegean Sea; the Israeli, Turkish, and Lebanese part of the Mediterranean Sea; and in the western basins, the Tunisian part of the Mediterranean Sea and the Italian part of the Adriatic Sea (Figure 4).

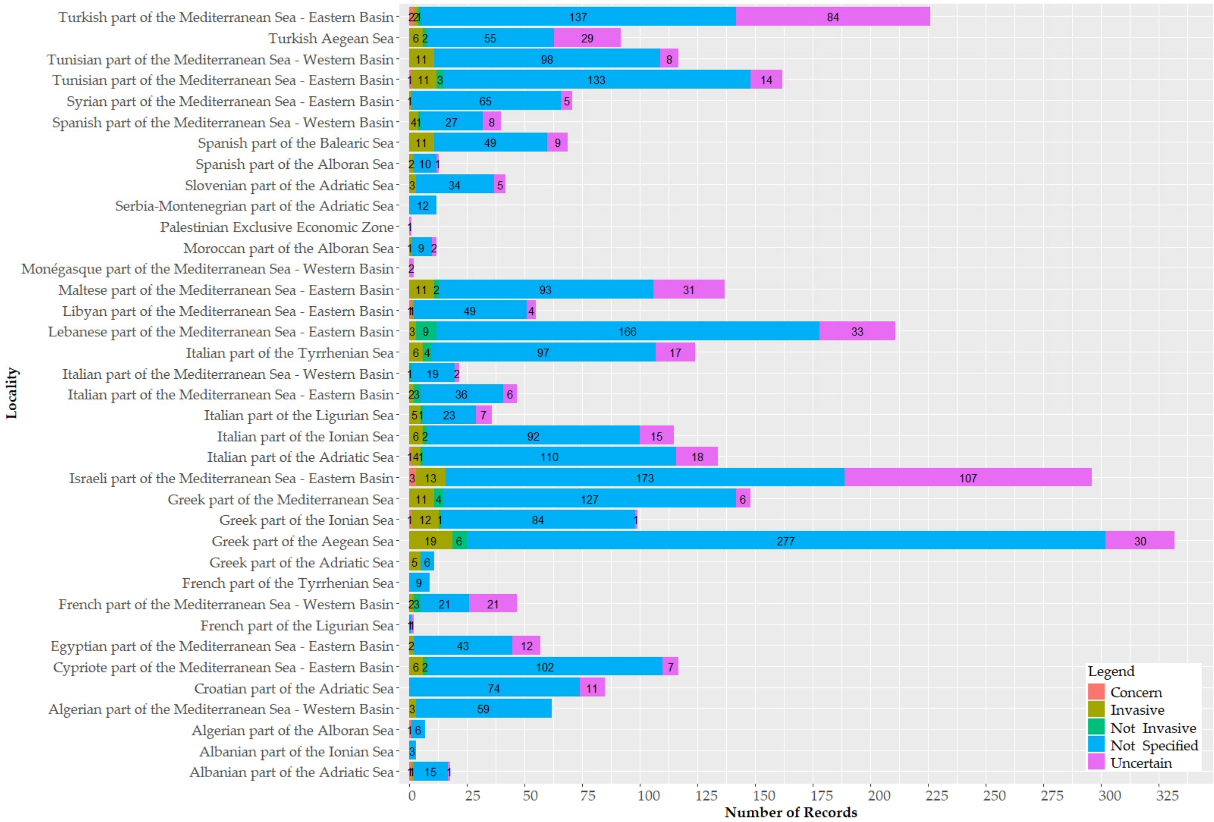

Figure 4. Geographical distribution analysis of all records in WRiMS for the Mediterranean Sea from 1990 to 2023.

The strong correlation between the number of observed species and the number of records for various phyla in the WRiMS database for the Mediterranean Sea, as demonstrated by the high R^2 value (0.9222) and low *p*-value ($p < 0.001$), indicates a robust relationship (Figure 5).

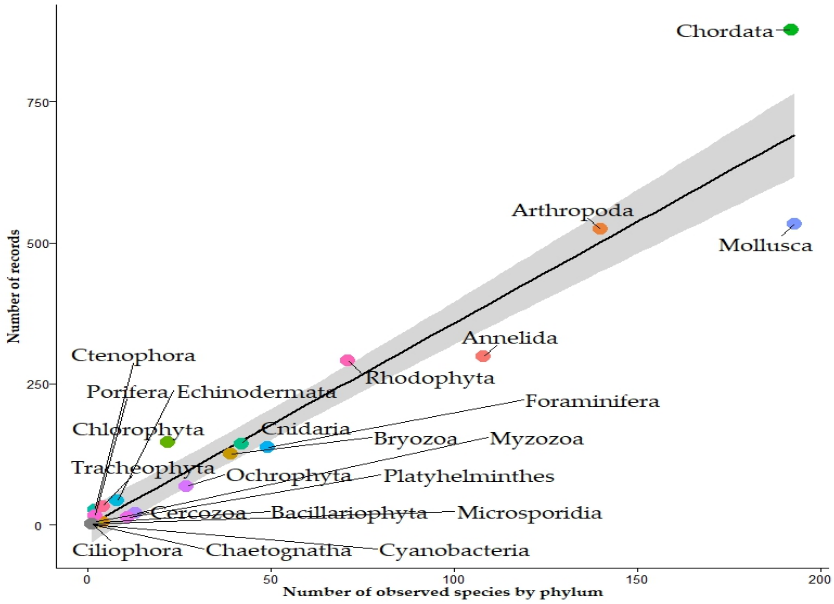

Figure 5. Number of records and number of species for all categories by phylum in WRiMS for Mediterranean Sea ($R^2 = 0.9222$, $p = 1.49 \times 10^{-12} < 0.0001$).

In addition, species abundance was calculated for all categories, disclosing that *Callinectes sapidus* and *Fistularia commersonii* are the most frequently recorded species (Figure 6).

Figure 6. Word cloud map of frequency for all categories and 10 most frequently recorded species in the WRiMS for Mediterranean Sea.

Although species in different locations may have different invasiveness, WRiMS classifies some species into different invasive categories within the same location and by the same author (Table 1).

Table 1. Species with different invasiveness category in WRiMS from the same author and for the same location.

Species Name	Source	Locality	Invasivness
Charybdis (Charybdis) hellerii	[59]	Mediterranean Sea—Eastern Basin	invasive
			uncertain
Elamena mathoei	[60]	Tunisian part of the Mediterranean Sea—Western Basin	not specified
			uncertain
Siganus luridus	[61]	Greek part of the Aegean Sea	invasive
			not specified

3.1. Species on the List of Invasive Alien Species of Union Concern

Of all the species examined (Table S1), only one species from freshwater and oligohaline environments, *Eriocheir sinensis*, is classified as a species of Union concern and one of the 100 worst invaders in the world (Table 2).

Table 2. *Union concern* species present in WRiMS records for Mediterranean Sea.

Scientific Name	Author	Location	WRiMS Invasiveness
Eriocheir sinensis H. Milne Edwards, 1853	[62]	Italian part of the Adriatic Sea	not specified
Eriocheir sinensis H. Milne Edwards, 1853	[59]	French part of the Mediterranean Sea—Western Basin	uncertain
Eriocheir sinensis H. Milne Edwards, 1853	[59]	Mediterranean Sea—Western Basin	uncertain

Table 2. *Cont.*

Scientific Name	Author	Location	WRiMS Invasiveness
Eriocheir sinensis H. Milne Edwards, 1853	[63]	Adriatic Sea	uncertain
Plotosus lineatus (Thunberg, 1787)	[63]	Mediterranean Sea–Eastern Basin	uncertain
Plotosus lineatus (Thunberg, 1787)	[64]	Israeli part of the Mediterranean Sea–Eastern Basin	not specified
Plotosus lineatus (Thunberg, 1787)	[64]	Lebanese part of the Mediterranean Sea–Eastern Basin	not specified
Plotosus lineatus (Thunberg, 1787)	[65]	Lebanese part of the Mediterranean Sea–Eastern Basin	not specified
Plotosus lineatus (Thunberg, 1787)	[66]	Syrian part of the Mediterranean Sea–Eastern Basin	not specified
Plotosus lineatus (Thunberg, 1787)	[67]	Israeli part of the Mediterranean Sea–Eastern Basin	uncertain
Procambarus clarkii (Girard, 1852)	[68]	Italian part of the Adriatic Sea	not specified
Procambarus clarkii (Girard, 1852)	[69]	Italian part of the Adriatic Sea	not specified
Pseudorasbora parva (Temminck and Schlegel, 1846)	[70]	Italian part of the Tyrrhenian Sea	not specified
Rugulopteryx okamurae (E.Y. Dawson) I.K. Hwang, W.J. Lee and H.S. Kim, 2009	[64]	Moroccan part of the Alboran Sea	not specified
Rugulopteryx okamurae (E.Y. Dawson) I.K. Hwang, W.J. Lee and H.S. Kim, 2009	[64]	Moroccan part of the Strait of Gibraltar	not specified
Rugulopteryx okamurae (E.Y. Dawson) I.K. Hwang, W.J. Lee and H.S. Kim, 2009	[71]	Spanish part of the Strait of Gibraltar	not specified

Some of the analyzed species are of Member States concern, and the majority of them are of Spain's concern (Table 3).

Additionally, within the total number of analyzed species from WRiMS for the Mediterranean Sea, 118 (12%) species are categorized in the EASIN database as species of high impact (Table S1).

Table 3. Species of Member States concern (EASIN).

Scientific Name	Member States Concern	High Impact
Acrothamnion preissii (Sonder) E.M.Wollaston, 1968	Spain	yes
Amphibalanus improvisus (Darwin, 1854)	Ireland	yes
Asparagopsis armata Harvey, 1855	Spain	yes
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon, 1845	Spain	yes
Caulerpa cylindracea Sonder, 1845	Spain	yes
Caulerpa taxifolia (M.Vahl) C.Agardh, 1817	Spain	yes
Codium fragile (Suringar) Hariot, 1889	Spain	yes
Cordylophora caspia (Pallas, 1771)	Spain	yes
Crepidula fornicata (Linnaeus, 1758)	Spain, Ireland	yes
Dyspanopeus sayi (Smith, 1869)	Spain	yes
Eriocheir sinensis H. Milne Edwards, 1853	Spain, Ireland	yes
Ficopomatus enigmaticus (Fauvel, 1923)	Spain	yes
Grateloupia turuturu Yamada, 1941	Spain	yes
Lophocladia lallemandii (Montagne) F.Schmitz, 1893	Spain	yes
Mnemiopsis leidyi A. Agassiz, 1865	Spain	yes
Percnon gibbesi (H. Milne Edwards, 1853)	Spain	yes
Procambarus clarkii (Girard, 1852)	Spain, Ireland	yes
Pseudorasbora parva (Temminck and Schlegel, 1846)	Estonia, Spain	yes
Rapana venosa (Valenciennes, 1846)	Ireland	yes
Rhithropanopeus harrisii (Gould, 1841)	Spain	yes
Rhopilema nomadica Galil, Spanier and Ferguson, 1990	Spain	yes
Sargassum muticum (Yendo) Fensholt, 1955	Spain, Ireland	yes
Styela clava Herdman, 1881	Ireland	yes
Stypopodium schimperi (Kützing) Verlaque and Boudouresque, 1991	Spain	yes
Undaria pinnatifida (Harvey) Suringar, 1873	Spain, Ireland	yes
Womersleyella setacea (Hollenberg) R.E.Norris, 1992	Spain	yes
Xenostrobus securis (Lamarck, 1819)	Spain	yes

3.2. Analysis of Species: Different Categories of NNS in WRiMS "of Concern" and "Invasive"

The majority of NNS "of concern" were found in the eastern part of the Mediterranean (Figure 4 and Table S2). Even though most of the dispersal vectors are missing, it should be noted that NNS in the eastern part of the Mediterranean are mostly introduced via canals or are considered as lessepsian migrants, while in the western part they are associated with shipping (Table S2). Only *Cheilodipterus novemstriatus* (Rueppell, 1838) have designated impact for the site: *Other impact–undefined or uncertain; Outcompetes native species for resources and/or space* [72].

NNS "of concern" were analyzed by phylum; only plantae Rhodophyta was presented, while the majority are animal species (88%) with Chordata and Arthropoda being the most presented phylum (Figure 7a).

In the category "invasive", NNS animal species dominate (71%), with Chordata and Mollusca being the most presented phyla. In plantae, Chlorophyta are the most presented phylum (Figure 7b).

The analysis of the recorded locations revealed that majority of "invasive" NNS are found in the eastern part of the Mediterranean (Figure 4 and Table S3), with most "invasive"

NNS detected in Greek part of the Aegean Sea and Israeli part of the Mediterranean–the Eastern basin.

The majority of “invasive” NNS do not have a defined impact, while other impacts are rare. Impacts such as “Other impact–undefined” or “uncertain”, “Outcompetes native species for resources and/or space”, and “Loss of aquaculture/commercial/recreational harvest or gain” are identified more than others (Figure 8a and Table S3).

Similar to impacts, the vector of dispersal is not determined for most “invasive” NNS. The most common vector of dispersal is “Canals: *natural range expansion through man-made canals*” and “*dispersal* via *the Suez Canal*”, followed by “*Ships: general*”; “*accidental with ballast water*”; and “*free-living fouling organisms*” (Figure 8b and Table S3).

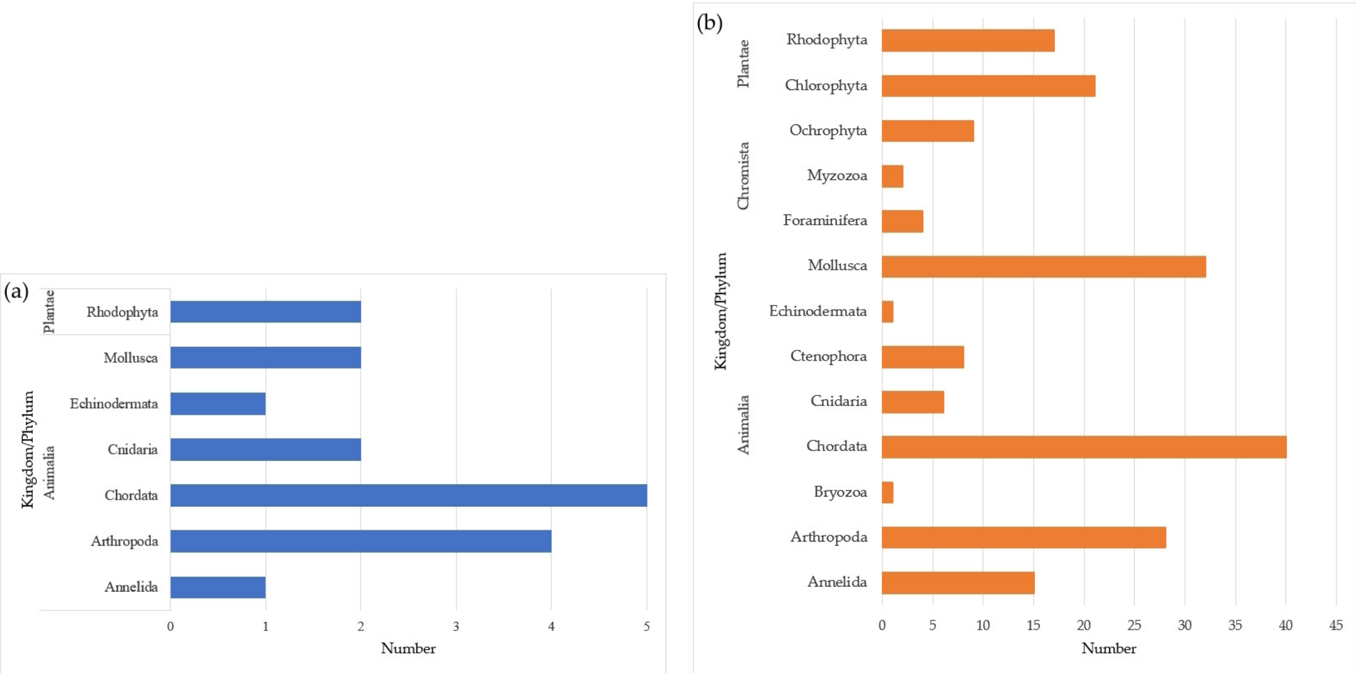

Figure 7. The number of the analyzed phyla of NNS recorded as (**a**) “of concern” or (**b**) “invasive” NNS in WRiMS.

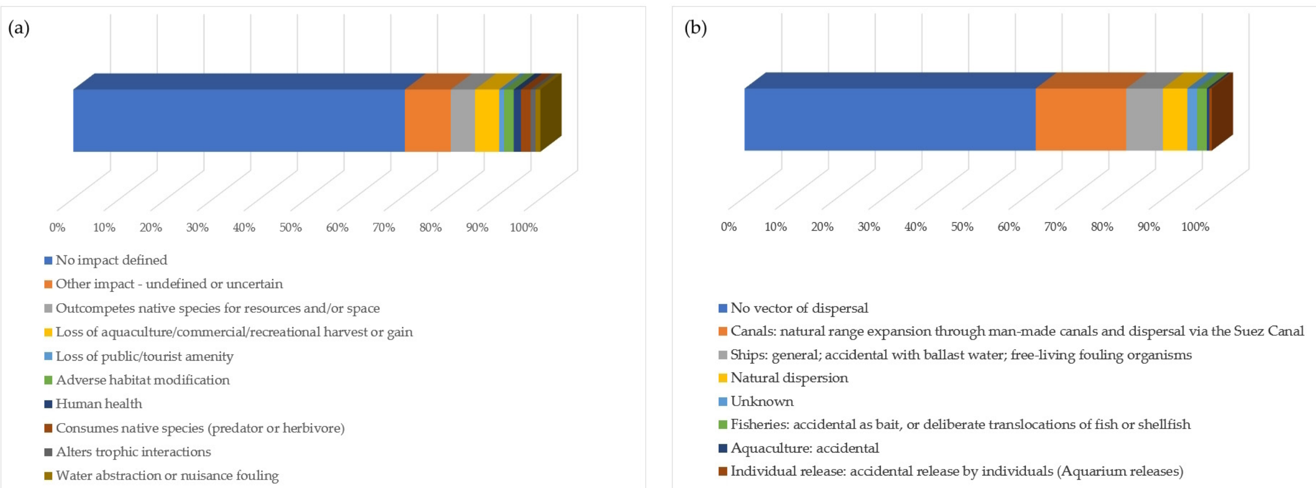

Figure 8. (**a**) Impact and (**b**) Vector of dispersal of NNS recorded as “invasive” NNS in WRiMS.

4. Discussion

The oldest entries in WRiMS are from papers dating back to 1792, and in the last ten years, the number of published papers has increased. It should be noted that the number of publications has dropped dramatically in the last two years, which may be due to the fact that the WRiMS is probably not updated regularly or because the updating process is complicated. Additionally, some data from early 2023 [34] were not yet included at the time of our data extraction (October 2023).

Regarding the location of all recorded species from WRiMS in the Mediterranean Sea, the most affected areas were identified. In the categories of species "of concern" and "invasive", most are found in the eastern Mediterranean region, which is consistent with other relevant lists of NNS [8,43]. Most "invasive" species were found in the Greek part of the Aegean Sea and Israeli part of the Mediterranean—the eastern basin. In a period of 3 years (2017 to 2019), Israel, Turkey, and Egypt have the highest number of new NNS records [45]. In the eastern Mediterranean, especially in the Levant, the Suez Canal is the main vector of the invasion [73–75]. This study focused solely on the Mediterranean Sea, with the limitation that Black Sea records were not included in the analysis. The Black Sea is subject to numerous introductions, contributing to the spread of many invaders to the wider Mediterranean region. One notable example is the spread of *Mnemiopsis leidyi* from the Black Sea to the rest of the Mediterranean [76].

Animal species outnumber plants, and the majority of the species recorded belong to the phyla Chordata and Mollusca, and some phyla were studied less often than expected in WRiMS. The regression model (Figure 5) illustrates a very strong and statistically significant relationship between the number of observed species by phylum and the number of records for each phylum. The high R^2 value indicates that the number of observed species is a good predictor of the number of records, while the very low p-value confirms the statistical significance of this relationship. This model can be useful for understanding biodiversity patterns and prioritizing data collection efforts in different phyla. Despite the strong and significant correlation, this relationship also highlights potential bias in data collection and reporting. Phyla with higher observed species receive more research attention, leading to more records. This results in an imbalanced dataset where some phyla are extensively documented while others are neglected.

The most frequently recorded species in WRiMS are *Callinectes sapidus* and *Fistularia commersonii*, both categorized as one of the 100 worst invaders [77]. *Callinectes sapidus* has a substantial impact on biodiversity and fisheries [77,78]. Today, in the Levantine area, *Callinectes sapidus* is used as a fishery resource due to its high abundance [77,79]. *Fistularia commersonii* species from the Pacific and Indian Oceans' trough Suez Canal expanded into the Mediterranean Sea [80]. It exerts a negative impact on biodiversity [77] and on fisheries, as it preys on commercially important species [80].

Although species invasiveness can vary between locations and over the time [35], analysis of invasiveness categories revealed inconsistencies, with the same publication and species classified into different invasiveness categories for the same area in WRiMS. In this manner, the number of records in WRiMS is higher, necessitating refinement and revisions. Furthermore, in WRiMS, most species fall into the categories "uncertain" or "not specified". To obtain dynamic information on NNS, i.e., abundance, invasiveness, and impact over time, they should be constantly monitored, which requires financial and research resources as well as the involvement of citizen science [81].

The "List of invasive alien species of concern for the European Union" includes 88 species, with only one species, *Eriocheir sinensis*, listed for the Mediterranean and classified as one of the 100 worst invaders in the world. This species has been included from the outset in the initial list of invasive alien species of Union concern [56]. *Eriocheir sinensis*, native to East Asia, was first introduced to Europe in Germany in 1912, accidentally with ballast water [82,83]. In its new environment, *Eriocheir sinensis* exhibits competition and predations, digs riverbanks, and blocks water supply [82] and causes *temporary local extinction of native invertebrates, consumption of bait and captured fish, and damage to fishing gear* [77,84].

The Invasive Species Specialist Group has included *Eriocheir sinensis* as one of the 100 worst invaders in the world [82,85]. Due to its impact on biodiversity and socio-economic activities such as fisheries and aquaculture, health and sanitation, infrastructure and building, it was also ranked among the 100 worst invasive species in the Mediterranean [77]. In WRiMS, its invasiveness is defined as "not specified" or "uncertain" (Table 2). In addition, some of the species analyzed are of concern for Spain, and 12% of all species are classified as high impact species in EASIN. Marine species are rare in the "List of invasive alien species of Union concern," and some authors have proposed the inclusion of new species classified as high to very high risk [42].

Impacts are missing for the majority of "invasive" species, and some non-specific impacts such as "other impacts—undefined" or "uncertain" are recorded. It is important to know the impact of every NNS in order to make a proper management decision.

Similar to impacts, the vector of dispersal is not determined for most "invasive" species. It is often very difficult to link species to the introduction vector, additional data such as habitat and dispersal patterns are used [86]. Recent studies on NNS in the Mediterranean have shown that introductions via the Suez Canal and by shipping were almost equal between 2017 and 2019 and that a significant number are imported via the aquarium trade [45].

5. Conclusions

Each new database represents progress in the management of NNS, and further analysis of such databases can provide valuable information and identify potential issues.

The analysis of the WRiMS database revealed that the number of publications has increased over the last ten years, but there has been a significant decrease in the last two years. This decline may be due to irregular updates or complex updating processes within WRiMS. Due to some inconsistencies in the classification, the number of entries is higher than expected, and it is recommended to review the invasiveness classification. Effective management and mitigation strategies may be overlooked, as most species are currently classified as "uncertain" or "not specified." While some phyla are extensively documented, it is advisable to increase research and documentation of less represented phyla to achieve a more even distribution of records and observed species. The lack of data on the impact and spread of "invasive" NNS, which could influence management efforts, highlights the need for more comprehensive monitoring and assessment.

The management of NNS in the Mediterranean requires available, accurate, and timely data, which can be obtained through the continuous updating and review of databases such as WRiMS. Data on species abundance, invasiveness, impacts, and dispersal vectors should be obtained through funded continuous-monitoring programs supported by research initiatives and citizen science. All these efforts can contribute to the protection of biodiversity and the well-being of the Mediterranean ecosystem by mitigating the negative impacts of NNS.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/d16070358/s1, List of all NNS Table S1, List of NNS "of concern" with impact and vector, Table S2 and List of NNS "invasive" with impact and vectors Table S3.

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