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2023 Med QSR Non-indigenous Species (EO2) assessment

UNEP/MAP
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Note by the Secretariat

The 2023 MED QSR Roadmap and Needs Assessment was endorsed by COP 21 (Naples, Italy, December 2019) with Decision IG.24/4. It defines the vision for the successful delivery of the 2023 MED QSR, and outlines key IMAP-related processes, milestones and outputs to be undertaken, with their timelines.

The main assessment chapters of the 2023 MED QSR are based on assessments of Common Indicators (CI) and some Candidate Common Indicators (CCI) within Ecological Objectives (EO) for biodiversity and fisheries, pollution and marine litter and cost and hydrography clusters. Where feasible, and where the data allow, CIs are integrated within and across EOs.

As a contribution to the 2023 MED QSR biodiversity (EO1) and non-indigenous species (EO2) chapters, SPA/RAC has prepared six thematic assessment reports for benthic habitats, cetaceans, Mediterranean monk seal, seabirds, marine turtles and non-indigenous species (NIS).

The present proposal of the 2023 MED QSR chapter related to non-indigenous species was presented and discussed during the CORMON Biodiversity and Fisheries meeting (Athens, 9-10 March 2023). The conclusions and suggestions of the meeting were integrated in the current version that is submitted for discussion by the Meeting of the Integrated Ecosystem Approach Correspondence Groups (CORMONs) with a view of its finalization and consideration by the 10th Meeting of the EcAp Coordination Group to be held in September 2023.

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1. Key messages

~~To be added in the second draft to be presented in the integrated CORMON.~~

1. Ecological Objective 2 (EO2) "Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem" with a single Common Indicator (CI6) assesses "Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas (in relation to the main vectors and pathways of spreading of such species)".
2. Our results indicate that for the past 15-20 years new NIS introduction rates have been relatively stable in the West Mediterranean and the Adriatic, close to levelling off in the East Mediterranean but increasing in the Central Mediterranean. At the same time, there has been a notable increase in research effort and reporting, spurred by both policy requirements but also scientific interest coupled with citizen science initiatives, particularly in the southern Mediterranean.
3. Consequently, clear interpretation of these trends is hampered by the lack of long-term standardised monitoring data, as it is not possible to disentangle the confounding effects of differential recording efforts spatially and temporally from real changes in pathway pressure or vector management.
4. Nevertheless, a number of invasive, high-impact NIS have displayed an increased geographic expansion in the last decade or so, which can be deduced even behind the "noise" of increased detection and reporting. NIS species of warm affinities with long-range pelagic dispersal appear to have been favoured by climate change and increased seawater temperatures to penetrate the cooler regions of the Mediterranean, secondary anthropogenic dispersal however still plays an important role in the spread of the more sedentary species.

2. Background information and methodology

2.1 Introduction

~~1.~~5. Biological invasions are globally identified as one of the main drivers of biodiversity loss, with impacts ranging from loss of genetic diversity to native population losses, species displacements, habitat modifications and even whole ecosystem shifts (IPBES, 2019). Consequently, the role of non-indigenous species (NIS) as a pressure that threatens ecosystems is addressed in the framework of numerous policies and strategies worldwide. In the Mediterranean Sea and in the context of the Barcelona Convention, the Protocol concerning specially protected areas and biological diversity in the Mediterranean (SPA/BD Protocol) invites the Contracting Parties to take "all appropriate measures to regulate the intentional or non-intentional introduction of non-indigenous into the wild and prohibit those that may have harmful impacts on the ecosystems, habitats or species" (UNEP/MAP, 2017a).

~~2.~~6. In the Mediterranean Sea, one of the most invaded ecosystems in the world (Costello et al., 2021), it is currently estimated that the number of NIS is in the range of 1000 with no sign of decline in their introduction rate. Recent work has demonstrated that, besides the unabated rate of new introductions, the rate of alien species spread and establishment is also increasing, with upwards of 70% of the introduced species being considered established (Zenetos & Galanidi, 2020; Zenetos et al., 2022a; b), causing the degradation of distinctive Mediterranean communities and habitats (Katsanevakis et al., 2014). In the western Mediterranean, negative impacts are caused primarily by invasive macrophytes, whereas in the Levantine and the Aegean Sea by fishes, and in the Adriatic Sea by introduced molluscs (Tsirintantis et al., 2022). Competition for resources, habitat creation/modification through ecosystem engineering, and predation are the primary mechanisms of negative effects of Mediterranean NIS. Pathway analysis has revealed that shipping, through ballast water and hull fouling, corridors, recreational boating and aquaculture transfers are primarily responsible for NIS introductions and spread in the region, while the ornamental trade and live food trade, among other activities, also contribute to NIS pressure (Katsanevakis et al., 2013, Tsiamis et al., 2018).

~~3.~~7. The first Mediterranean Quality Status Report (2017 MED QSR), elaborated within the Ecosystem Approach process (UNEP/MAP, 2017b) was built upon existing data from numerous diverse sources and identified a number of needs and gaps to be filled in preparation for the next assessment exercise. The assessment of NIS in particular reflected directional trends and was based on material published until 2016 with data mostly up to 2011, which were also included in the Marine Mediterranean Invasive Alien Species (MAMIAS) database. The most important knowledge gaps with respect to the assessment of NIS were identified as:

- Evidence for most of the reported impacts of alien species is weak, mostly based on expert judgement; a need for stronger inference is needed based on experiments or ecological modelling. The assessment of trends in abundance and spatial distribution is largely lacking.
- Regular dedicated monitoring and long-time series will be needed so that estimation of such trends is possible in the future. NIS identification is of crucial importance, and the lack of taxonomical expertise has already resulted in several NIS having been overlooked for certain time periods. The use of molecular approaches including barcoding are often useful besides traditional species identification.

2.2 Methodology

~~4.~~8. Within the IMAP framework, non-indigenous species are addressed with Ecological Objective EO2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem, Common Indicator 6 (CI6): Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas (in relation to the main vectors and pathways of spreading of such species). Thresholds and quantitative targets for GES have not been determined yet for CI6, but rather GES is based on directional trends, i.e., the reduction or minimisation of the introduction and spread of NIS linked to human activities. Following recommendations in UNEP/MED WG.500/7 (2021) analysis of the temporal trends of new NIS occurrences was conducted at the subregional level for the 1970-2017 period (Note: data until 2022 are available and were used for other aspects of the assessment but not for new NIS trends in order to ameliorate high uncertainties associated with reporting lags).

~~5.~~9. Description of analyses methods:

i) Trends in temporal occurrence: Trends in new NIS introductions were formally tested with regression analyses. Breakpoint analysis was also employed to identify discreet periods of time over which statistical comparisons of the slopes should be carried out.

ii) Trends in spatial distribution: Georeferenced data of selected, high-impact species were mapped at discrete time periods to display the temporal evolution of their spread~~ (Additionally, a case study to be built from Spanish monitoring data submitted to the IMAP Info System at a later draft)~~. Regarding the total xenodiversity, by using first species records in each subregion Venn diagrams were constructed to visualize the overlap in NIS between the four subregions during the 1970-2020 period. This gives an indication of the degree of homogenisation of the NIS biota in the basin in the last 50 years.

~~iv) Impacts of the selected NIS on sensitive habitats were assessed following the Cumulative Impact (CIMPAL) methodology (Katsanevakis et al., 2016), based on species georeferenced presence records on gridded habitat layers (this part will be included in the next draft).~~

~~v~~iii) Finally, interrelated links of status, pressures, and impacts were determined and visualized with the GRID/Table qualitative approach, developed specifically for the needs and objectives of CI6.

2.2.1 Data acquisition

~~6.~~10. Data for trends and impacts were elaborated as follows:

i) Trends in temporal occurrence: Refined and updated national and (sub)regional inventories with data up to December 2020 were produced for the purpose of the elaboration of Mediterranean NIS Baselines (UNEP/MED WG.520/5, 2022). These datasets have been updated since and constitute the data source for the assessment in the trends in the total number of new NIS per assessment spatial unit (Mediterranean subregion). Data consist of first records of NIS per assessment unit, accompanied by year of record, short reference, species status, establishment success, most likely primary introduction pathway(s) and higher-level taxonomic classification for purposes of aggregation. The sources for first NIS records are varied, including monitoring programmes, research projects, atlases and databases but also validated citizen scientist observations in more recent years. Co-ordinates of first species records were partly provided with the national NIS inventories and complemented with data from the HCMR offline database where necessary.

ii) Trends in spatial distribution: Trends in spatial distribution: Invasive, or potentially invasive, species were selected for examination of trends in spatial distribution. Georeferenced data were retrieved from the HCMR offline database, inatularist, published datasets (e.g., Callinectes: Mancinelli et al. 2021, ORMEF: Azzuro et al., 2022, recent extensive update of previously unpublished Mediterranean NIS records: Ragkousis et al., 2023), and from monitoring datasets delivered to SPA/RAC for the purposes of IMAP. Updated maps to be created for the next draft, after the national monitoring data has been incorporated.

~~iii) Impacts of the selected NIS on sensitive habitats were assessed following the CIMPAL methodology (Katsanevakis et al., 2016), based on species georeferenced presence records on gridded habitat layers.~~

2.2.2 Data processing

~~7.~~11. Species inclusion/exclusion criteria: Only validated NIS were considered for the assessment; cryptogenic, debatable and other species of uncertain taxonomic or invasion status were excluded from analyses as were questionable records requiring verification. Furthermore, until more concrete decisions/recommendations are made with regards to quantitative targets in relation to pathway management, data were not disaggregated by pathway.

~~8.~~12. Creation of time series: The first records of each NIS by subregion were binned into 1year intervals to create time series spanning from 1791 to 2020. Guided by previous trends analyses of NIS in the Mediterranean (e.g., Galanidi & Zenetos, 2022; Zenetos et al., 2022c), the period 1970-2017 was selected for analysis, covering 8 MSFD assessment periods. Data after 2017 were not included in order to avoid reporting lag effects and uncertainties (Zenetos et al., 2019), which may skew trends and conclusions about the achievement or not of GES. Thus, the last full reporting period included in our data set was that of 2012-2017, which is considered as the assessment period for this QSR.

13. ~~Selection process~~Species selection for ~~species analysed for trends in~~ spatial distribution ~~and~~maps
~~9.~~ A small number of NIS with high impacts~~:~~
on a variety of habitats were selected for spatial distribution mapping. Starting from the CIMPAL evaluation of the 60 species in Katsanevakis et al. (2016), a shortlist of species was created on the basis of three criteria; habitats they invade, magnitude of impacts and introduction pathway. More specifically, the 13 habitat types examined by Katsanevakis et al. (2016) were merged into six broader habitat types, namely: estuaries & lagoons, Posidonia oceanica and other seagrass and seaweed meadows, coralligenous habitats, soft sediments (0-200 m depth), rocky substrates (0-200 m depth) and pelagic habitats (0-200 m). Subsequently, ~~all~~ NIS species with massive impacts on each of these habitats were marked and a subset was selected~~. Some modifications were made to the scoring and a small number of species was added to the initial list based on new information that has emerged since 2016 and on the study of Tsirintanis et al. (2022).~~ for mapping. Since many of these species have impacts on more than one habitat

types, all 6 broad habitat types were well represented in the final group of 2810 species (Table 1). Finally, primary and secondary pathways of introduction were examined for each species to ensure that all the major pathways are also sufficiently represented.

Table 1. List of species ~~analysed~~selected for ~~trends in~~ spatial distribution ~~and impacts~~mapping. EC-Aqua = Escape from large aquaria (accidental), EC-Mar = Escape from mariculture, REL = Release (intentional), TC = Transport-Contaminant, UNA = Unaided, TS = Transport-Stowaway, TS-Shipping indicates both/either ballast water and/or hull fouling as vectors

Habitats	**Species**	**Pathway**	
~~rocky~~	~~*Brachidontes pharaonis*~~	~~Corridor~~	~~TS-Fouling/Other~~
lagoons/seagrass/soft/rocky	*Lagocephalus sceleratus*	Corridor	Unaided
seagrass/soft/rocky/coral	*Pterois miles*	Corridor	Unaided
~~pelagic~~	~~*Rhopilema nomadica*~~	~~Corridor~~	~~Unaided~~
~~seagrass/rocky~~	~~*Siganus luridus*~~	~~Corridor~~	~~Unaided~~
~~seagrass/rocky~~	~~*Siganus rivulatus*~~	~~Corridor~~	~~Unaided~~
~~rocky~~	~~*Stypopodium schimperi*~~	~~Corridor~~	~~Unaided~~
Seagrass/soft/rocky/pelagic	*Plotosus lineatus*	Corridor	UNA
lagoons/pelagic	*Mnemiopsis leidyi*	TS-Ballast	Unaided
lagoons/soft	*Callinectes sapidus*	TS-Ballast	TS, UNA
Soft	*Anadara transversa*	TS-Fouling	TC
~~soft~~seagrass/rocky/coral	~~*Caulerpa taxifolia*~~*Acrothamnion preissii*	EC~~-Aqua~~ / TS-Angling	TS-~~angling, TS-hull, TC~~Shipping
Rocky	*Codium fragile subsp. fragile*	TC	TS-ball
lagoons/seagrass	*Caulerpa taxifolia var. distichophylla*	EC-Aqua	TS-angling, TS-hull, UNA
~~soft/rocky~~	~~*Magallana gigas*~~	~~EC-Mar~~	
~~soft~~	~~*Ruditapes philippinarum*~~	~~EC-Mar~~	~~REL-Fishery~~
~~seagrass/rocky/coral~~	~~*Acrothamnion preissii*~~	~~EC / TS-Angling~~	~~TS-Shipping~~
~~lagoons/soft/rocky~~	~~*Agarophyton vermiculophyllum*~~	~~TC~~	~~TS-Fouling~~
~~rocky~~	~~*Bonnemaisonia hamifera*~~	~~TC~~	~~TS-Fouling~~
~~soft/rocky/pelagic~~	~~*Crepidula fornicata*~~	~~TC~~	~~TS-Fouling~~
lagoons/rocky	*Rugulopteryx okamurae*	TC	
~~rocky~~	~~*Codium fragile subsp. fragile*~~	~~TC~~	~~TS-ball~~
~~soft/rocky/coral~~	~~*Caulerpa cylindracea*~~	~~TS-Ballast~~	~~EC~~
~~lagoons/pelagic~~	~~*Mnemiopsis leidyi*~~	~~TS-Ballast~~	~~Unaided~~
~~lagoons/soft/rocky~~	~~*Rhithropanopeus harrisii*~~	~~TS-Ballast~~	~~Unaided~~
~~soft~~	~~*Anadara transversa*~~	~~TS-Fouling~~	~~TC~~
~~seagrass/rocky/coral~~	~~*Lophocladia lallemandii*~~	~~TS-Fouling~~	~~Corridor~~
~~seagrass/rocky/coral~~	~~*Womersleyella setacea*~~	~~TS-Fouling~~	~~EC-Aqua~~
~~rocky~~	~~*Spondylus spinosus*~~	~~TS-Fouling~~	~~TS, UNA~~
~~lagoons/soft~~	~~*Arcuatula senhousia*~~	~~TS-Shipping~~	~~TC-Cont~~

~~rocky~~	~~*Asparagopsis taxiformis*~~	~~TS-Shipping~~	~~Corridor~~
~~lagoons/soft~~	~~*Callinectes sapidus*~~	~~TS-ball~~	~~TS, UNA~~

2.2.3 Mapping and visualisation

~~10.~~14. Mapping and visualisation include:

- Map of new NIS records per 6-year reporting period (5 periods as below) at the regional level.
- Distribution maps of selected taxa per discrete time period.
- Venn diagrams illustrating the number of NIS shared between Mediterranean subregions at discreet time intervals.

2.2.4 Data analyses

~~11.~~15. Following the recommendations in the document on Monitoring and Assessment Scales, Assessment Criteria and Thresholds Values for the IMAP Common Indicator 6 Related to Non-Indigenous Species (UNEP/MED WG.500/7, 2021), analysis of the temporal trends of new NIS occurrences was conducted at the subregional level. Thresholds and quantitative targets for GES have not been determined yet for CI6, but rather GES is based on directional trends, i.e., the reduction or minimisation of the introduction and spread of NIS linked to human activities (see BOX 1). Consequently, trends in occurrence were analysed in two different ways. The first method involves breakpoint analysis in order to identify structural changes in the dataset, representing dates (i.e., years) when the mean introduction rate displays significant changes (increases or decreases). Breakpoint analysis was performed on the 1970-2011 time-series, i.e., excluding the 2012-2017 assessment period, with which comparisons are made. Once time periods with stable mean values were detected, 95% Confidence Intervals around the means were calculated as a measure of uncertainty. Subsequently, the mean NIS introduction rate of the 2012-2017 assessment period with its 95%CI was calculated and compared with the respective values of the breakpoint generated segments, providing a qualitative assessment (for details of the approach see Galanidi & Zenetos, 2022; Östman et al., 2020; Zeileis et al., 2003).

~~12.~~16. For the purposes of comparability with earlier assessments, the 6-year reporting periods that span and capture the significant changes in yearly NIS introduction rates identified with breakpoint analysis for further statistical analysis with ANOVA and linear regression were subsequently selected, as per the recommendations of the guidance factsheet for CI6 (UNEP/MED WG.514/12, 2021) – and in line with OSPAR guidelines for the NE Atlantic (OSPAR, 2022).

~~13.~~17. Five 6-year reporting periods (1988-1993, 1994-1999, 2000-2005, 2006-2011, 2012-2017) were analysed for all sub-regions. Linear regression was employed to formally characterise the temporal trend in cumulative NIS records within each period (i.e., regression slope, which equals the mean yearly introduction rate for each period). Slopes were statistically compared with analysis of variance (ANOVA).

2.3 Links with other EOs and CIs

~~14.~~18. EO1 Biodiversity: Strong interrelations in particular with CI1 and CI2 (Benthic habitats). Through their impacts on keystone species, communities and habitat structure, non-indigenous species act as a pressure on the condition and, to a lesser degree the extent, of sensitive benthic habitats (most notably Posidonia and other seagrass and seaweed meadows, coralligenous habitats and shallow rocky substrates). Biodiversity and Fisheries Cluster – ~~Linkage methodology~~Methodological linkages extend to ~~be discussed; potential to~~ the use of the same broad habitat layers ~~from EMODnet~~ in EUSeaMap ~~if suitable; possibly feed the~~2021 with the addition of priority EO1 priority habitat layers from Giakoumi et al.

(2013) and making available the spatially explicit results of the CIMPAL or NIS distribution data to CI2index as a direct pressure layer on EO1 habitats.

15.19. EO3 Harvest of commercially exploited fish and shellfish: Fishing activities can act as vectors of introduction and spread of NIS, such that Fishing effort (CI10) can be considered a pressure on NIS CI6. Furthermore, shellfish culture and related transfers is responsible for one of the five most important pathways of NIS introduction. Biodiversity and Fisheries Cluster - Linkage methodology to be discussed.

16.20. EO 4 Marine food webs: NIS can alter food webs through predation and competition, thereby acting as a source of disturbance and pressure on marine food webs. EO4 Indicators not developed.

17.21. EO 8 Coastal ecosystems and landscapes: Land use change (Candidate Indicator 25) in the form of man-made structures in shallow coastal waters (renewable energy devices, coastal defences, oil and gas extraction?) creates newly available habitats for colonisation of NIS that act as steppingstones for spread and often as NIS hotspots. Aggregate extraction is another source of introduction and spread vectors. Indicator under development

18.22. EO 10 Marine litter: Drifting marine litter has been demonstrated to act as a vector of NIS introduction and spread at both inter-oceanic and regional scales. The amount of litter washed ashore and/or deposited on coastlines (CI22, beach macro-litter) can act as a direct pressure on CI6. Linkage methodology to be discussed.

3. Drivers, Pressures, State, Impact, Response (DPSIR)

3.1 DPSIR Analysis with a focus on NIS and CI6

19.23. For the purposes of the current DPSIR analysis for EO2/CI6 NIS are considered a "State" variable.

20.24. The sectors in the first column of Table 2 are aligned with the DPSIR framework, as applied within the Guidance document provided for mapping interrelations between pressures. impacts and states within the IMAP Biodiversity cluster (UNEP/MED WG.502/Inf.11, 2021) and the MSFD (EC, 2018 - MSFD Guidance Document 14), i.e., Drivers are the human activity Themes or Sectors. The more specific activities outlined in the second column of Table 2 are in direct analogy to the Pathways of introduction as described and categorised in the CBD classification scheme and its extensions/refinements (CBD, 2014; Harrower et al., 2017; Pergl et al., 2020), while the pressures in column 3 describe the mechanisms through which the activities enhance NIS introduction and spread. The unwanted “state” is in all cases the increase in number of species, abundance and distribution of NIS (i.e., not-GES of CI6). NIS impacts were not further elaborated in this exercise (but can be listed/summarised with bullet points or similar).

21.25. The intensity of the pressure-state interactions in Table 2 was based on qualitative assessment/expert judgement, augmented by data on NIS pathways in the Mediterranean presented in the results section and past literature.

22.26. As illustrated in Figure 2 (Section 4.2) and in agreement with previous pathway analyses of Mediterranean NIS (Katsanevakis et al., 2013; Tsiamis et al., 2018), maritime transport is the predominant sector contributing to NIS propagule pressure in the region. This is effected both directly through shipping and the associated ballast water and hull fouling transfers which render harbours NIS hotspots, and indirectly through the opening of corridors between previously unconnected water bodies for navigational purposes. This is especially the case for the eastern Mediterranean. Cultivation of living resources, particularly shellfish culture, is the second most impacting sector, with shellfish transfers being important vectors of NIS introduction and spread, especially in the western Mediterranean and the Adriatic. Tourism and recreation contribute to NIS pressure primarily through recreational boating and associated infrastructure, whereby hull fouling species are introduced and use marinas as "stepping stones" for further spread. Additionally, increased solid waste production, mostly in the form of floating plastic litter, can act as a vector for spread of already established NIS. Extraction of living resources (animals and plant) for the ornamental trade, the live food trade and fisheries also increase NIS propagule pressure through a variety of mechanisms.

~~23.~~27. The effects of climate change are accelerating in the Mediterranean and exacerbating the impact of other drivers and pressures (EEA, 2020). As concerns NIS in particular, aspects of climate change affect their introduction and spread in two ways; i) by increasing the invasibility of the receiving environment, e.g, thermally stressed native species become weaker competitors or retreat to cooler regions, marine heat waves cause mass mortalities of native species (Garrabou et al., 2022), increased water temperatures favour the establishment and population growth of warm water, introduced species, ii) by modifying or exacerbating pressures associated with certain human activities, e.g., increasing the needs for aquaculture transfers due to mortalities or changes in suitable habitats for cultivation, extreme phenomena increase the need for coastal infrastructure, offering more habitats for colonisation, etc.

Table 2. General overview of sectors and associated activities that exert the highest pressures with regards to the introduction, spread and abundance of NIS, within the DPSIR framework.

Sectors – sources of pressures	**Specific sector activities potentially associated with NIS**	**Specific pressures/impacts associated with NIS introduction and spread**	**State (measured with CI6)**
Maritime transport	Shipping Shipping infrastructure (ports/harbours) Navigational dredging Man-made maritime canals (corridors)	Uptake and discharge of NIS propagules with ballast water & sediment Translocation of NIS through hull fouling Entrainment and translocation of NIS in niche areas (e.g., sea chests, bilge water, anchor chains and wells, rudders, propellers, etc.) Ports as gateways and stepping stones for NIS introduction & spread Dredge spoils containing NIS can act as vectors of spread Opening of corridors between previously unconnected water bodies	The unwanted state is the increase in number of species, abundance, distribution of NIS
Extraction of living resources	Fisheries Collection of bait Live food trade Ornamental trade Rearing & display in large aquaria (public or private)	Entanglement of NIS in fishing gear, niche areas, hull fouling Discards of NIS as bycatch Translocation of NIS as live bait Accidental escape or intentional release of specimens during transportation, from live food markets, unsold stock Intentional release of unwanted specimens from house aquaria (including NIS) Accidental escape from large aquaria	The unwanted state is the increase in number of species, abundance, distribution of NIS

Cultivation of living resources	Shellfish (and finsfish) culture Shellfish translocations for seeding, ongrowth, purification, etc.	Intentional introduction and spread of NIS target species for culture / escape from confinement Unintentional introduction and spread of NIS hitchhikers together with target species Infrastructure (cages, ropes, trays, etc.) introduces additional substrate for colonisation / ghost fishing Introduction of NIS contaminants with introduced cultivated fish/shellfish (parasites & pathogens)	The unwanted state is the increase in number of species, abundance, distribution of NIS
Extraction of non-living resources	Oil & gas extraction and associated infrastructure Maintenance and services to oil/gas platforms Aggregate extraction	Hard substrates for colonisation/hotspots/stepping stones Increased shipping	The unwanted state is the increase in number of species, abundance, distribution of NIS Increased spread of NIS
Energy sector (renewable)	Offshore wind farms (and maintenance) Wave energy extraction devices (and maintenance) Tidal energy extraction devices (and maintenance)	Hard substrates for colonisation/hotspots/stepping stones Increased shipping	The unwanted state is the increase in number of species, abundance, distribution of NIS Increased spread of NIS
Tourism & recreation	Recreational boating Associated infrastructure (marinas, piers, pontoons, etc.) Recreational and sport fishing Increased solid waste production and disposal, particularly of plastic	Entrainment of NIS on boats (fouling, niche areas) and trailers Movement of cruise-ships, boats and trailers can translocate NIS Hard substrates for colonisation/ NIS hotspots/stepping stones Marine litter as a vector of NIS introduction and spread	The unwanted state is the increase in number of species, abundance, distribution of NIS Increased spread of NIS
Urbanisation and Industry	Land use change (infrastructure, coastal defences) Industrial units, production of energy/goods Wastewater & desalination plants Solid waste production and disposal	Hard substrates for colonisation/ NIS hotspots/stepping stones Thermal inputs from point discharges (cooling waters) Salinity changes from point discharges Marine litter as a vector of NIS introduction and spread	Increased habitat suitability for NIS (establishment, abundance)

Research & Education	Import and ex-situ breeding for research experiments	Accidental escape from confinement	The unwanted state is the increase in number of species, abundance, distribution of NIS
Additional pressures associated with more than one sectors	Climate change	Changes in seawater temperature Increased marine heat waves Degradation/decline/loss of native species & communities Increased frequency of extreme phenomena (impacts on coastal infrastructure)	Increased invasibility of ecosystems Increased habitat suitability for NIS (establishment, abundance) Increased abundance/distribution of NIS

Table 3. Tabular representation of interactions between anthropogenic pressures and the occurrence, abundance and spread of NIS (CI6).

Sectors – sources of pressures	**Maritime transport**				**Extraction of living resources**					**Cultivation of living resources**		**Extraction of non-living resources**			**Energy sector (renewable)**			**Tourism & recreation**				**Urbanisation and Industry**				**Research & Education**	**Additional**
Specific sector activities potentially associated with NIS	Shipping	Ports/harbours	Navigational dredging	Man-made maritime canals	Fisheries	Collection of bait	Live food trade	Ornamental trade	Rearing & display in large aquaria	Shellfish (and finfish) culture	Shellfish translocations for seeding, ongrowth, purification, etc.	Oil & gas extraction and associated	Maintenance and services to oil/gas	Aggregate extraction	Offshore wind farms (and maintenance)	Wave energy extraction devices (and	Tidal energy extraction devices (and	Recreational boating	Associated infrastructure (marinas,	Recreational and sport fishing	Increased solid waste production and	Land use change (infrastructure, coastal	Industrial units, production of	Wastewater & desalination plants	Solid waste production and disposal	Import and ex-situ breeding for research experiments	Climate change
CI6	Red	Red	Orange	Red	Orange	Orange	Orange	Orange	Orange	Red	Red	Orange	Orange	Orange	Yellow	Orange	Yellow	Red	Red	Orange	Orange	Orange	Orange	Orange	Orange	Yellow	Red

Red	Significant contribution of pressure to CI6
Orange	Minor contribution of the pressure to CI6
Yellow	No pressure, but possible development of pressure to CI6
Green	No contribution to CI6

4. Good environmental status (GES) / alternative assessment

4.1 Theme selected for GES assessment:

Mid-Term Strategy (MTS) Core Theme: Biodiversity and Ecosystems

Ecological Objective EO2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.
IMAP Common Indicator Common Indicator 6 (CI6): Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas (in relation to the main vectors and pathways of spreading of such species)

Good Environmental Status (GES) definitions and targets (Decision IG.21/3)

BOX 1. Thematic Decisions -Taken from UNEP(DEPI)/MED IG.21/9 - Annex II

Operational objective	Indicator	GES	Proposed Targets
2.1 Invasive non-indigenous species introductions are minimized	2.1.1. Spatial distribution, origin and population status (established vs. vagrant) of non-indigenous species	Introduction and spread of NIS linked to human activities are minimised, in particular for potential IAS	**State** The number of species and abundance of IAS introduced as a result of human activities is reduced. **Pressure/Response** - Improved management of the main human related pathways and vectors of NIS introduction (Mediterranean Strategy for the management of ballast waters, Aquaculture early warning systems, etc.) - Action plans developed to address high risk NIS, should they appear in the Mediterranean.
	2.1.2 Trends in the abundance of introduced species, notably in risk areas	Decreasing abundance of introduced NIS in risk areas	**State** Abundance of NIS introduced by human activities reduced to levels giving no detectable impact
2.2. The impact of non-indigenous particularly invasive species on ecosystems is limited	2.2.1 Ecosystem impacts of particularly invasive species	No decrease in native species abundance, no decline of habitats and no change in community structure that have been generated by IAS via competition, predation or any other direct or indirect effect.	**Pressure/Response** Impacts of NIS reduced to the feasible minimum

	2.2.2 Ratio between non indigenous invasive species and native species in some well-studied taxonomic groups	Stable or decreasing proportion of NIS in the different habitats	**State** To be set upon species choice and their related impact degree of the invasive upon the indigenous ones, taking into account the role of Climate Change in accelerating the establishment of NIS populations.

~~24.~~28. Definition of terms and expected outputs for Operational objective 1 (guidance factsheet for CI6 - UNEP/MED WG.514/12, 2021):

- ~~–~~‘Trend in abundance’ is defined as the change between assessment periods in the estimated population density/ranks of a non-indigenous species in a specific marine area.
- ~~–~~‘Trend in temporal occurrence’ is defined as the change between assessment periods in the estimated number of new introductions and the total number of non-indigenous species in a specific country or preferably the national part of each subdivision, preferably disaggregated by pathway of introduction.
- ~~–~~‘Trend in spatial distribution’ is defined as the change of the total marine ‘area’ occupied by non-indigenous species. This area should be defined according to the scale of assessment.

Expected assessments outputs

- ~~–~~Graphs of the time series of the calculated metrics (abundance, occurrence, spatial extent), including confidence intervals; regression analysis is the recommended approach for temporal trends;
- ~~–~~Distribution maps of the selected NIS, highlighting temporal changes in their spatial distribution;
- ~~–~~National annual inventories (and also by the national part of each marine subdivision, if relevant) of non-indigenous species and respective year of introduction if known;
- ~~–~~National inventories clustering NIS according to main pathways of introduction (e.g., seaways, shipping, mariculture, etc.) if known;

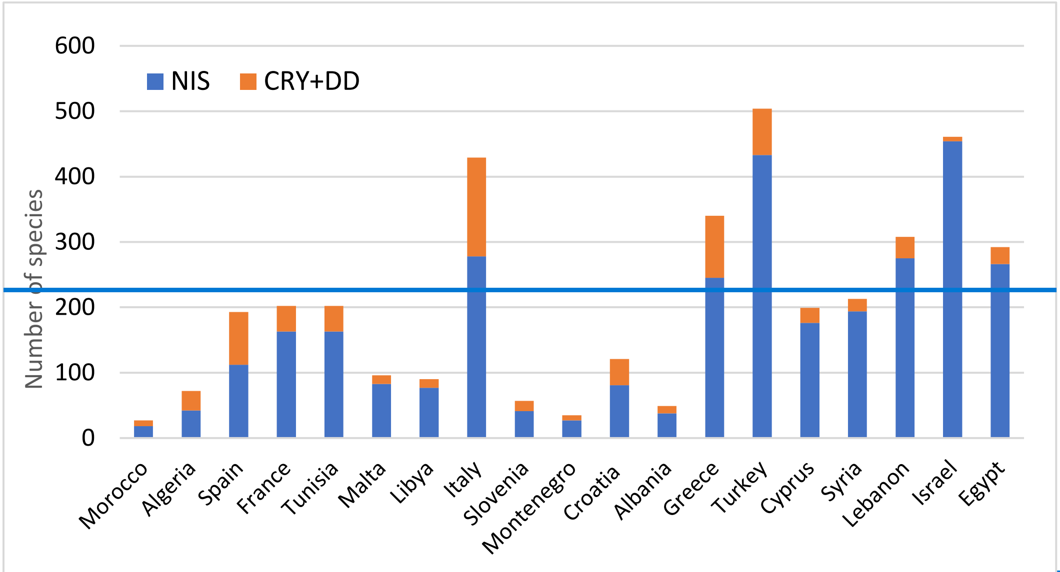
~~Based on data availability and the state of progress in methodology and indicator development, the current assessment will focus on trends in temporal occurrence with some indicative examples of trends in spatial distribution (for selected highly invasive species) and in the upcoming draft (to be presented to Integrated CORMON) assessment of impacts.~~

4.2 GES Assessment for CI/ alternative assessment for CI6

4.2.1. Descriptive characteristics of the entire baseline (1791-2020)

~~25.~~29. At the pan-Mediterranean level, a total of ~~1006~~1008 validated, non-indigenous species have been found throughout the basin until the end of 2020, of which 143 are Macrophytes, ~~222~~223 Mollusca, ~~187~~188 Arthropoda, ~~173~~172 Fishes, 29 Ascidiacea, 83 Annelida, 32 Bryozoa, 42 Cnidaria, ~~46~~47 Foraminifera and 49 taxa belong to other taxonomic groups. Among the ~~1006~~1008 validated marine NIS, ~~735~~742 are currently considered established, which makes the overall establishment rate in the Mediterranean Sea almost ~~73~~74%. This value varies in the different subregions, with the lowest establishment rate in ADRIA (62%) and the highest in EMED (~~71~~73%). When it comes to actual numbers, as expected, the eastern Mediterranean has the highest number of NIS with 788 species, followed by WMED (N=~~332~~338), CMED (N=~~305~~304) and ADRIA (N=~~208~~211).

~~26.~~30. During the validation process of the national baselines, ~~65~~66 species emerged as data deficient: ~~58~~59 characterised by divergence of opinion as to their alien or cryptogenic status and 7 as suspected questionable records. The highest number of species is observed in Israel and Türkiye, followed by Italy, Greece, Lebanon and Egypt, with values generally decreasing towards the Adriatic and western Mediterranean countries (Figure 1).



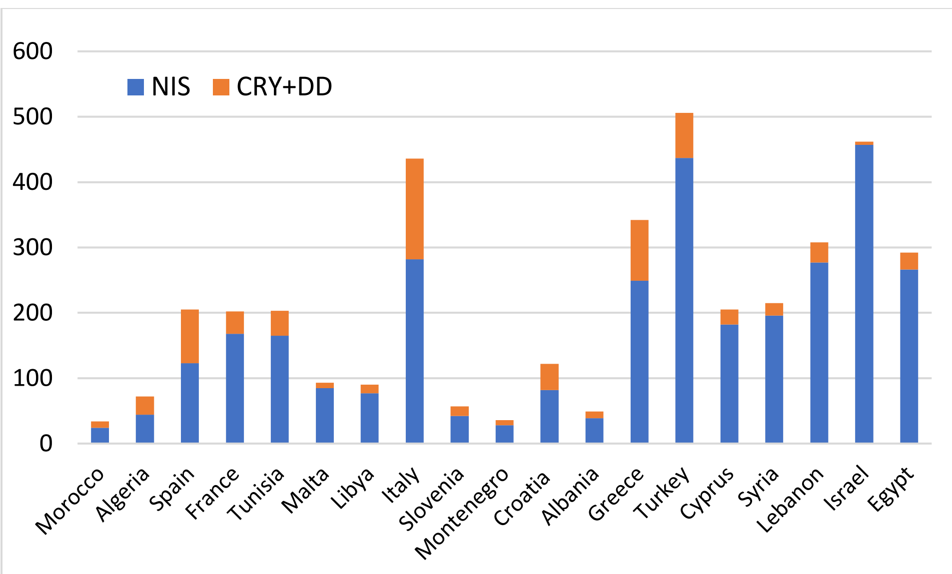


Figure 1. Number of NIS, cryptogenic (CRY) and data deficient (DD) species, detected in each Mediterranean country by December 2020.

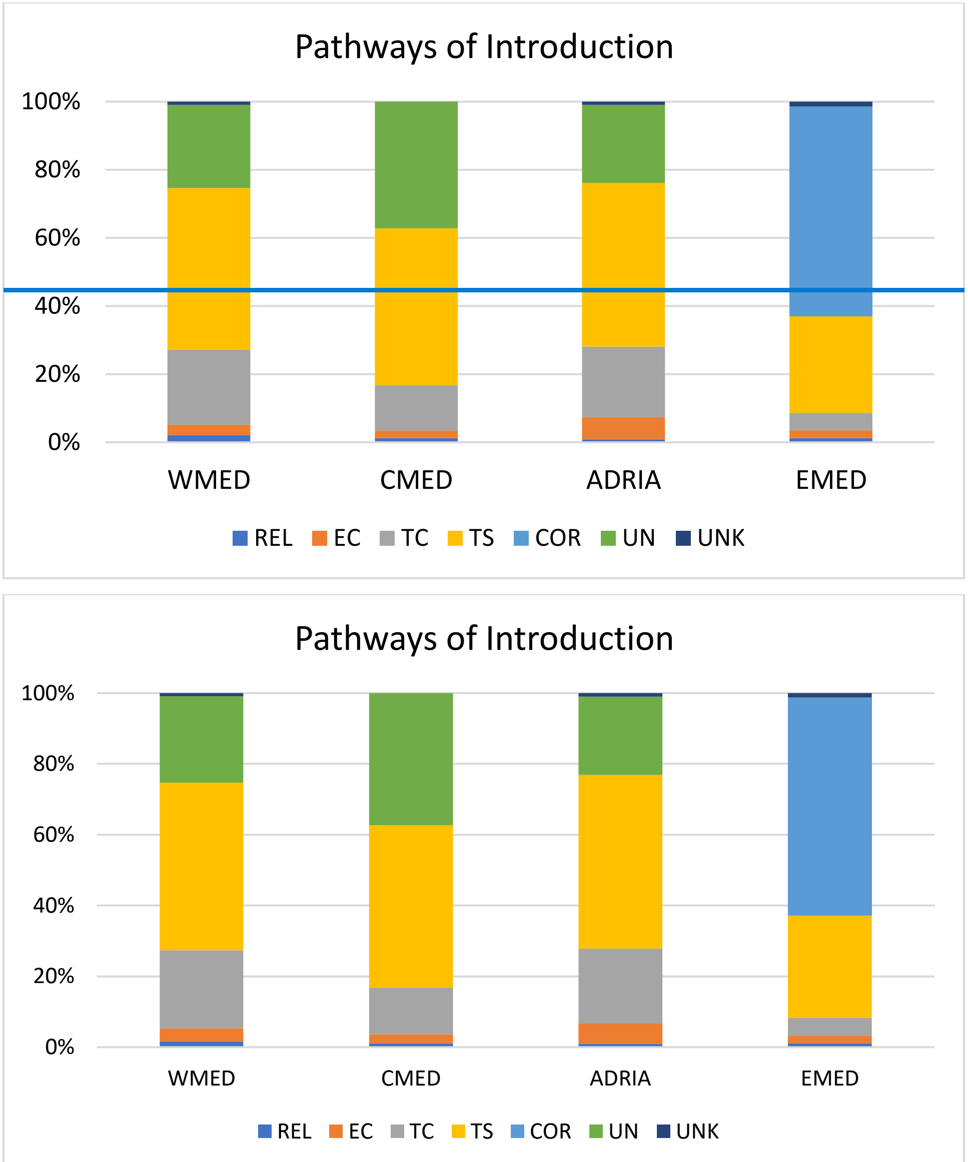


Figure 2. Primary pathways of introduction of marine NIS per Mediterranean subregion. REL = Release in nature, EC = Escape from Confinement, TC = Transport-Contaminant on animals, TS = Transport-Stowaway (including Ship/boat ballast water, Hull fouling and Other means of transport), COR = Corridor, UN = Unaided, UNK = Unknown.

27.31. Roughly half the non-indigenous species present in the Mediterranean have Corridor as their primary pathway of introduction, (Figure 2). This number reaches 6061% in the Eastern Mediterranean, but this pathway is not applicable moving westwards and northwards to the other subregions, where Lessepsian species migrate to a large extent by natural dispersal (pathway Unaided). CMED has the largest proportion of Unaided species, as it accepts naturally dispersing NIS propagules from all other subregions. Noteworthy also is the higher percentage of Contaminant species in ADRIA (1921%) and the WMED (19.422%), which are inadvertently transported with aquaculture activities, while escapees have their largest representation in ADRIA, with 6.5 % of the species assumed to have escaped from mariculture or from non-domestic aquaria. Intentional releases from domestic aquaria represent only 1-2% of all introductions, with the highest number of species appearing in the western and eastern Mediterranean. The two main shipping vectors together (i.e., Ballast water and Hull fouling) constitute the primary pathway for almost one third of the NIS entering the Mediterranean but as high as ~~45~~49% of the NIS present in ADRIA.

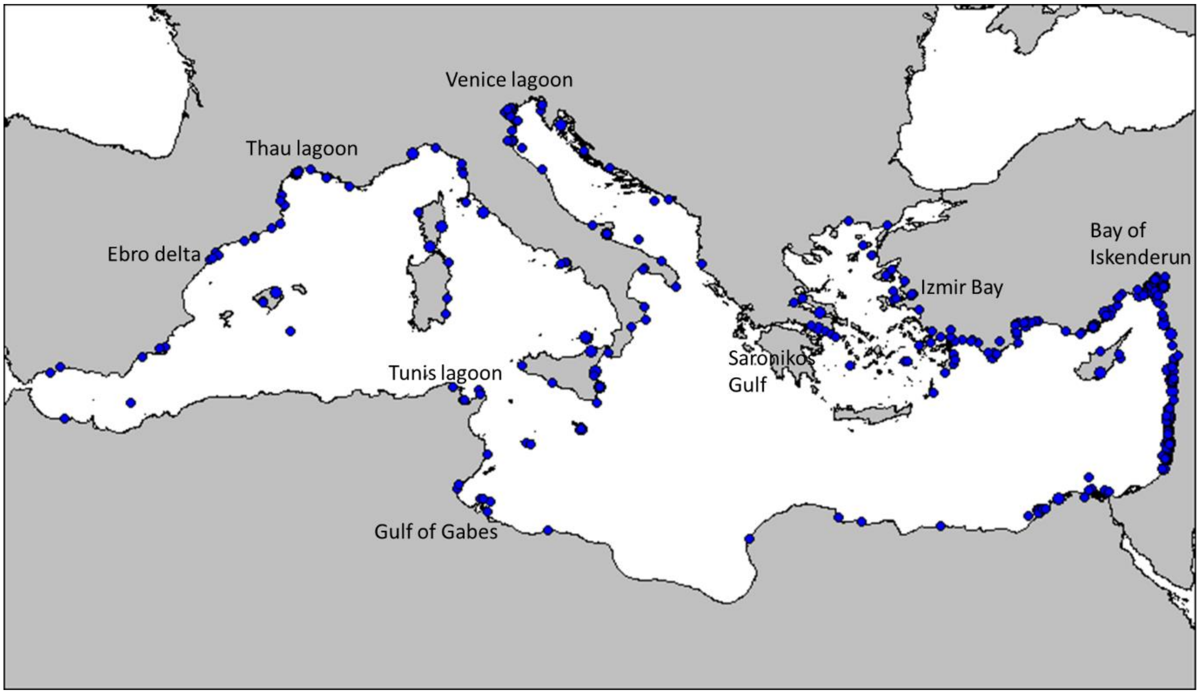
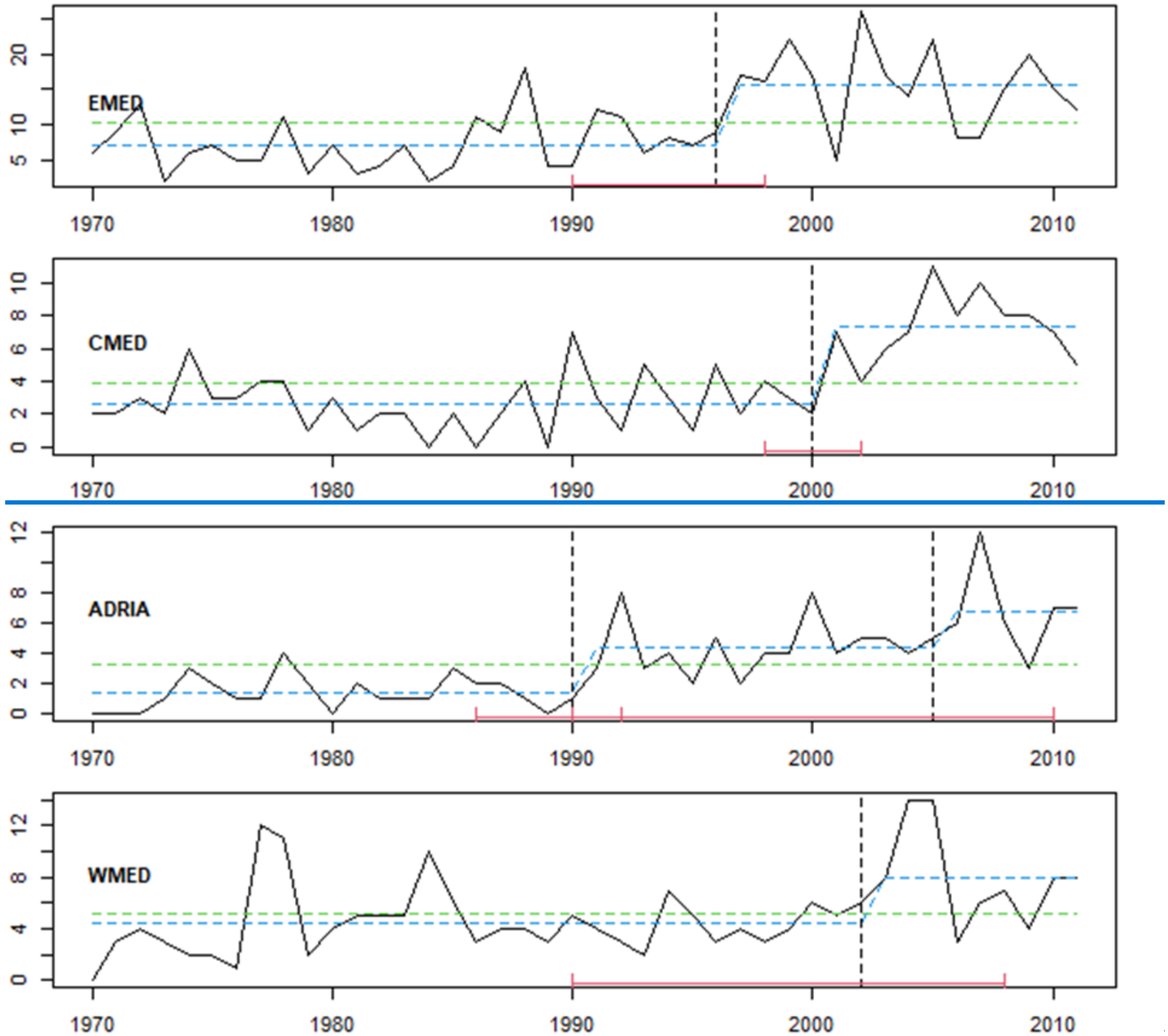


Figure 3. First new NIS records in the Mediterranean, observed between 1988-2017.

~~28.~~32. Figure 3 illustrates the gateways of new NIS records in the Mediterranean since 1988. The above pattern corresponds clearly to the pathways of introduction a) Indo-Pacific species invade [either unaided (Lessepsian NIS) or via shipping] and become visible firstly in the Levantine basin (Egypt, Israel, Lebanon, Syria, south Türkiye); b) accidental introductions with oysters appear in Thau lagoon (France), Venice lagoons (Italy), Ebro delta (Spain), Tunis lagoon (north Tunisia); c) vessel transferred species from the Atlantic are reported mostly from port areas e.g., Bay of Iskenderun, Izmir Bay, Türkiye; Saronikos Gulf (Greece) Gulf of Gabes (Tunis). Research effort and contribution of citizen science has revealed new species across the Mediterranean and has been particularly significant in reporting new records in previously unexplored areas such as Libya.

4.2.2. Temporal trends in occurrence

~~29.~~33. Breakpoint analysis, carried out on the 1970-2011 subset with 2012-2017 as the assessment period, demonstrated that there are indeed different points in time when the NIS introduction rate significantly increased in each Mediterranean subregion, spanning from the mid-1990's to the mid-2000's (Figure 4). During the almost 50 years of the analysed time period NIS introduction rates have more than doubled in EMED, CMED and ADRIA and almost doubled in WMED (Table 4). After the identified breakdates, introduction rates have remained stable in the western Mediterranean and the Adriatic but have markedly increased in the Central Mediterranean (Table 4). In the eastern Mediterranean new NIS records appear slightly elevated for the 2012-2017 period but the value still overlaps with the confidence intervals of the previous time segment (1997-2011).


EMED
20
10
5
1970
1980
1990
2000
2010
CMED
10
8
6
4
2
0
ADRIA
12
8
6
4
2
0
WMED
12
8
4
0

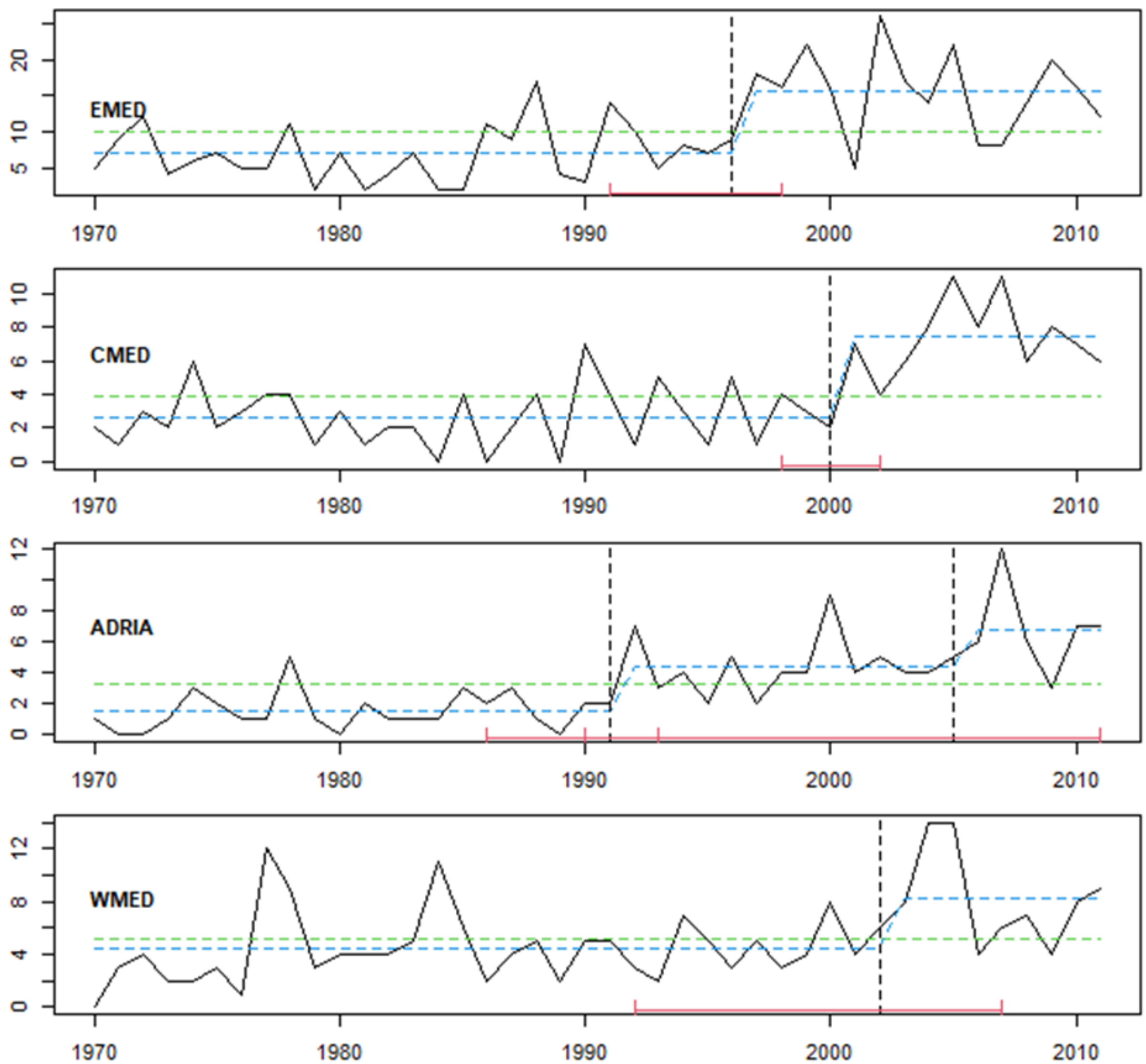
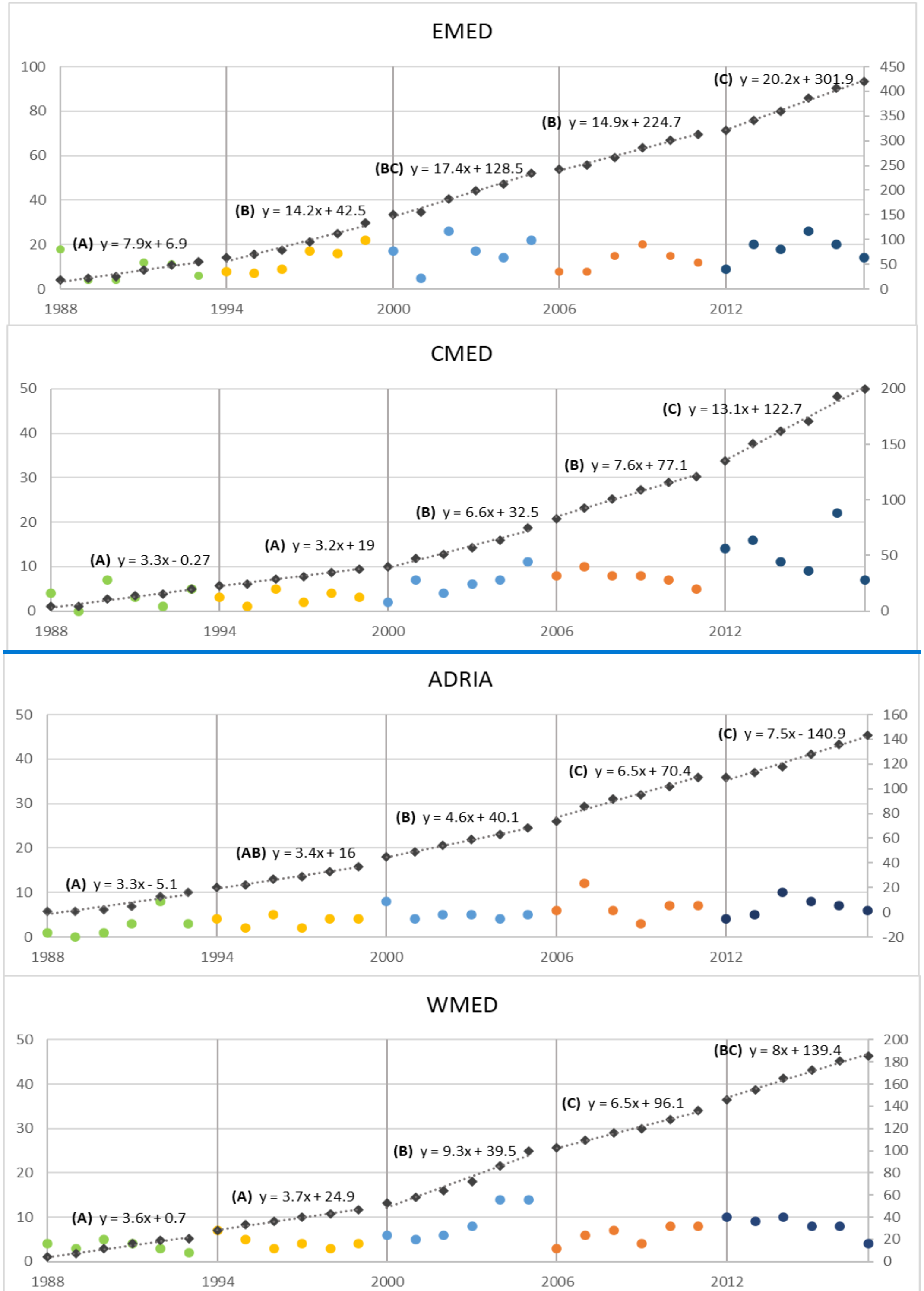


Figure 4. Number of new NIS introductions per year (y-axis) in different Mediterranean subregions for the period 1970-2011 (continuous black line) with breakpoints and fitted mean values superimposed: vertical dashed line indicates breakpoint or year of significant change in the mean values of new NIS, with 95% confidence intervals around the breakdate (CIs) in red brackets; dashed green line shows the null model of no temporal change in new NIS numbers; and dashed blue line represents fitted mean values before and after the identified breakpoint.

Table 4. Results of the breakpoint structural analysis for each Mediterranean subregion for the period 1970-2011, with 2012-2017 considered as the assessment period. Segment yearly means are the fitted mean values of the yearly number of new NIS before and after the breaks, with 95% Confidence Intervals of the fitted means (95% CI) in parentheses. EMED = eastern Mediterranean (i.e., Aegean and Levantine), CMED = central Mediterranean (i.e., Central and Ionian Sea), ADRIA = Adriatic, WMED = western Mediterranean

	Breakdate	**Segment yearly means (95% CI)**			**2012-2017 mean (95% CI)**
		Segment 1	Segment 2	Segment 3	
EMED	1996	~~7.2~~6.9 (5.~~7, 7.6~~4, 8.5)	15.6 (12.4, 18.8)	na	17.~~8 (12.~~7~~, 22.9~~ (11.1, 24.2)
CMED	2000	2.7 (2, 3.3)	7.~~4~~5 (6, 8.~~7~~9)	na	~~13.2 (10.4, 16)~~12.5 (6.7, 18.3)
ADRIA	~~1990~~1991/2005	1.~~3 (0.8,~~ 5 (1~~.8~~, 2)	4.4 (3.4, 5.~~4~~5)	6.8 (3.8, 9.9)	6.7 (4.9, 8.4)
WMED	2002	4.4 (3.5, 5.4)	8.2 (5.~~1~~4, 11.1)	na	8~~.2 (5.~~ (6.1, 9~~,~~ ~~10.4~~.9)

~~30.~~34. Linear regression was applied to the five 6-year reporting periods that span and capture the significant changes in NIS introduction rates in the 4 Mediterranean subregions (1988-1993, 1994-1999, 2000-2005, 2006-2011, 2012-2017). The introduction rates (i.e., 6-year regression slopes) produced by this analysis are rather similar to the previous approach and reveal the same broad patterns in each subregion (Figure 5), the only difference being that comparisons between introduction rates of the last assessment period (2012-2017) and the rest of the timeline are not as straightforward to interpret with regards to GES targets due to short term fluctuations. Nevertheless, it is still evident that a significant increase in new NIS records occurred in the period between the mid-1990's and the mid-2000's in all Mediterranean subregions, with relatively stable rates from then onwards and no sign of decrease until 2017. On the contrary, there has been a significant increase in NIS introduction rates in the CMED after 2011 and a slight increase, albeit not statistically significant in the EMED.


EMED
(A) y = 7.9x + 6.9
(B) y = 14.2x + 42.5
(BC) y = 17.4x + 128.5
(B) y = 14.9x + 224.7
(C) y = 20.2x + 301.9
CMED
(A) y = 3.3x - 0.27
(A) y = 3.2x + 19
(B) y = 6.6x + 32.5
(B) y = 7.6x + 77.1
(C) y = 13.1x + 122.7
ADRIA
(A) y = 3.3x - 5.1
(AB) y = 3.4x + 16
(B) y = 4.6x + 40.1
(C) y = 6.5x + 70.4
(C) y = 7.5x - 140.9
WMED
(A) y = 3.6x + 0.7
(A) y = 3.7x + 24.9
(B) y = 9.3x + 39.5
(C) y = 6.5x + 96.1
(BC) y = 8x + 139.4
1988
1994
2000
2006
2012

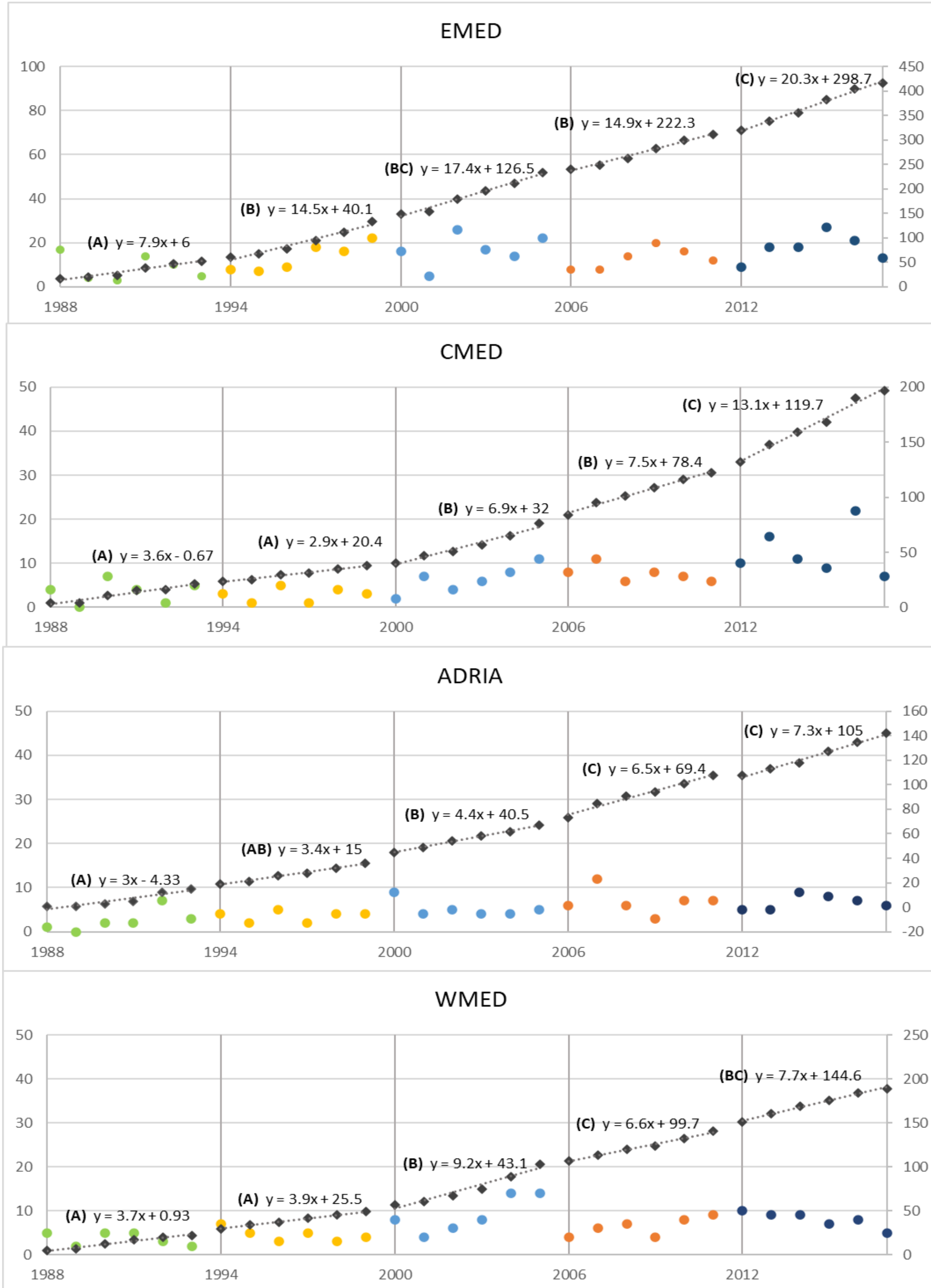
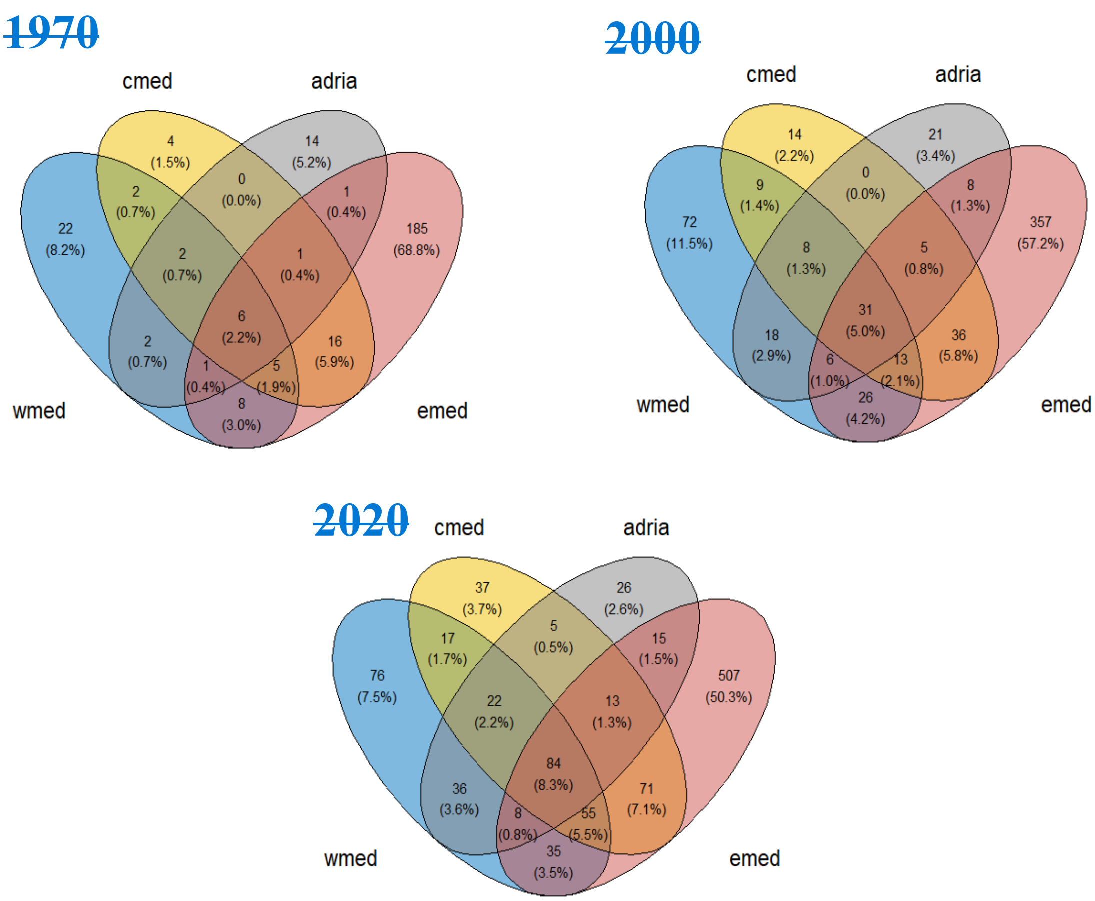


Figure 5: Annual new NIS records (coloured symbols) for each Mediterranean subregion and the trends in cumulative NIS records (dark grey symbols and fitted lines) for the five assessment periods between 1988 and 2017. The equations from the linear regression models are displayed above the fitted curves; letters in parentheses indicate statistically different regression slopes (yearly introduction rates) i.e., slopes that belong to different letter groups are different at the 0.05 level of significance.

4.2.3. Trends in spatial distribution

Total xenodiversity

~~31.~~35. An informative way to summarise the changes in the distribution of NIS at the total xenodiversity level is by employing Venn diagrams to visualise the overlap between NIS species in each subregion and how this has changed over time (Figure 6). The eastern Mediterranean contains the highest number of unique species, even though the percentage has declined from 69% to 50% since 1970. An overall decline in the proportion of unique species is also evident in the Western Mediterranean and the Adriatic but an increase is observed in the Central Mediterranean. Meanwhile, the total number of species shared among all subregions has risen from 6 in 1970 to 84 in 2020 (2.2% to 8.3% respectively), signalling the increasing homogenisation of NIS species in the basin.



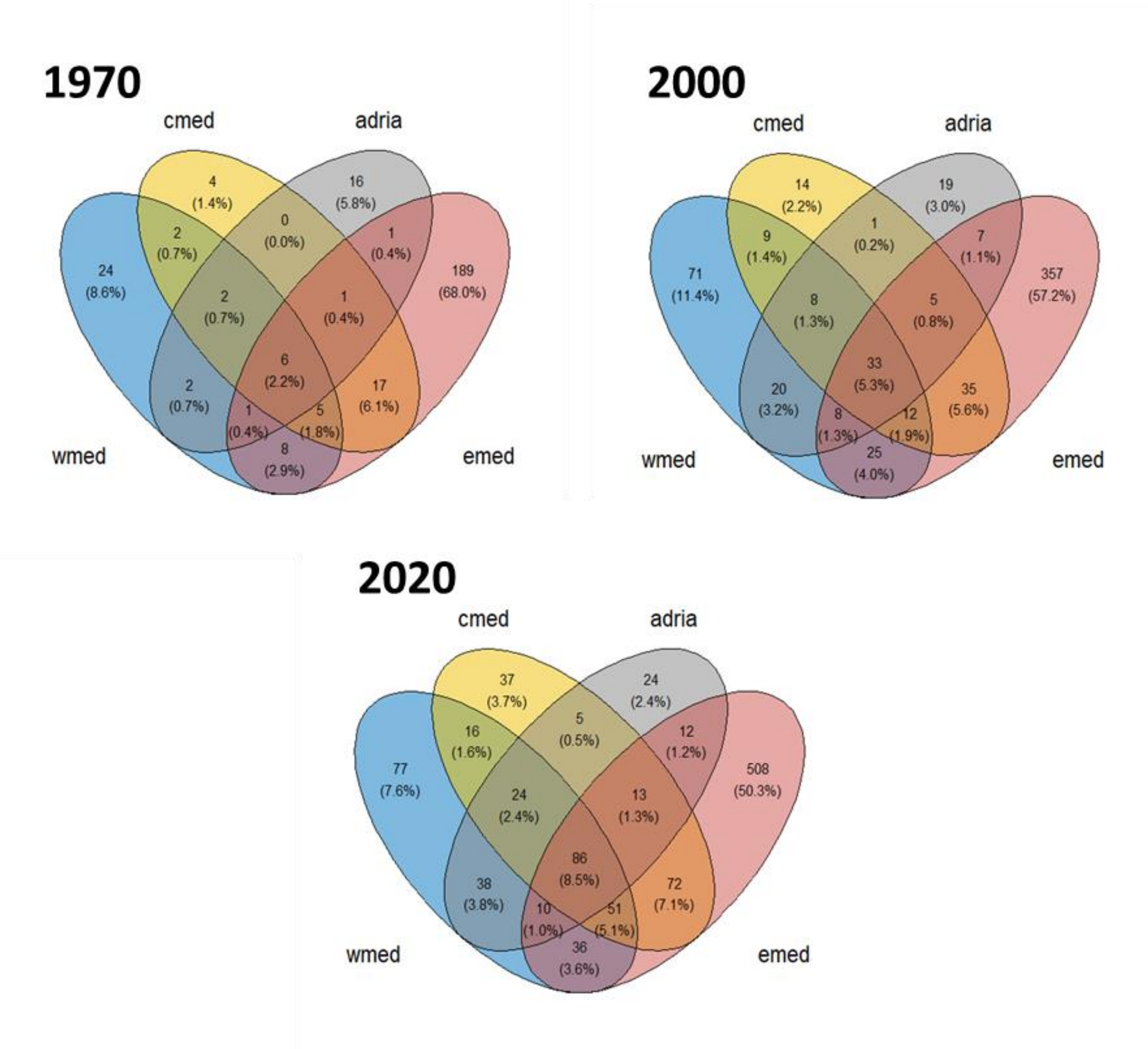


Figure 6. Cumulative number of species that are unique to or shared between the 4 Mediterranean subregions in 1970, 2000 and 2020.

Individual species

~~32.~~36. Distribution maps of selected species are displayed to give a general overview of their spread patterns over time. The associated frequency histograms (number of observations in each time bin) certainly highlight an increase in recording effort over the last 10-15 years but at the same time serve as an indication of the rate and intensity of dispersal. Lessepsian fish species (Figures 7-9), first appearing in the Mediterranean after 1990, are characterised by a typical progression from the southern Levantine northwards but then these patterns vary, depending on life cycle characteristics and environmental tolerances. ***Lagocephalus sceleratus***, with adult active migration as well as pelagic larval dispersal, proliferated rapidly throughout the Levantine and the southern Central Mediterranean but also penetrated the Central Aegean during the warm summer of 2007 and reached the northern Aegean already in the 2006-2011 period. In 2012-2017 it expanded its distribution and has been slowly advancing in the

Adriatic and the southern Western Mediterranean. ***Pterois miles*** was first recorded in Israel in 1991 (Golani & Sonin, 1992) but, with the exception of a single record in Greece in 2008, only started its invasion process after 2012. Until 2017 it had rapidly expanded throughout the Levantine and the southern Aegean, with sporadic records in the Central Mediterranean (Ionian coast of Greece, Sicily and Tunisia). In the last few years, being in the radar of Citizen Science initiatives as an emblematic and highly impactful invasive species (Galanidi et al., 2018), *P. miles* is characterised by a dramatic explosion of observations but more importantly it has penetrated into the Adriatic and is spreading north, an indication that its lower thermal tolerance limit is a critical factor for future spread (Dimitriadis et al., 2020). ***Plotosus lineatus***, a venomous, swarming catfish, is a typical example of the boom-and-bust dynamics often characterising invasive species. After the first report in 2001 (Golani, 2002), it underwent a population explosion and rapidly expanded along the Israeli coast already by 2008-2011 (Edelist et al., 2012). [Note: the distribution records in the current map reflect geo-referenced data availability]. While the species remains widespread in the eastern Levant, its spread northwards has advanced at a slower pace, presumably due to the demersal nature and short duration of its larval phase (Galanidi et al., 2019). *Plotosus lineatus* is the first fully marine species to be included in the list of species of Union concern of Council Regulation 1143/2014 on IAS (EU, 2014).

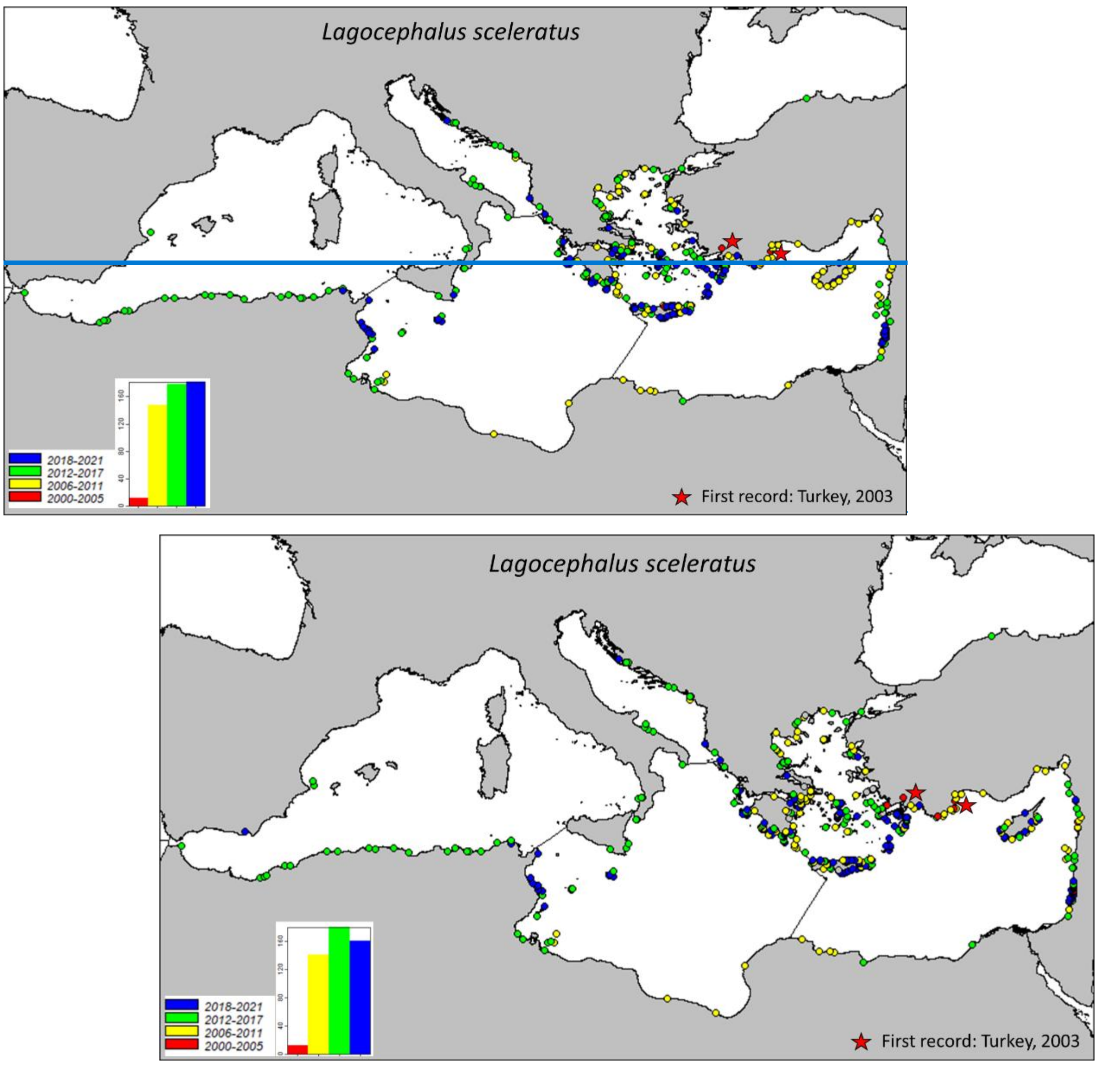


Figure 7. Distribution of *Lagocephalus sceleratus* in the Mediterranean Sea. First record(s) annotated with an asterisk, different colour symbols correspond to different 6-year reporting periods, corresponding frequency histograms depict number of records in each time bin.

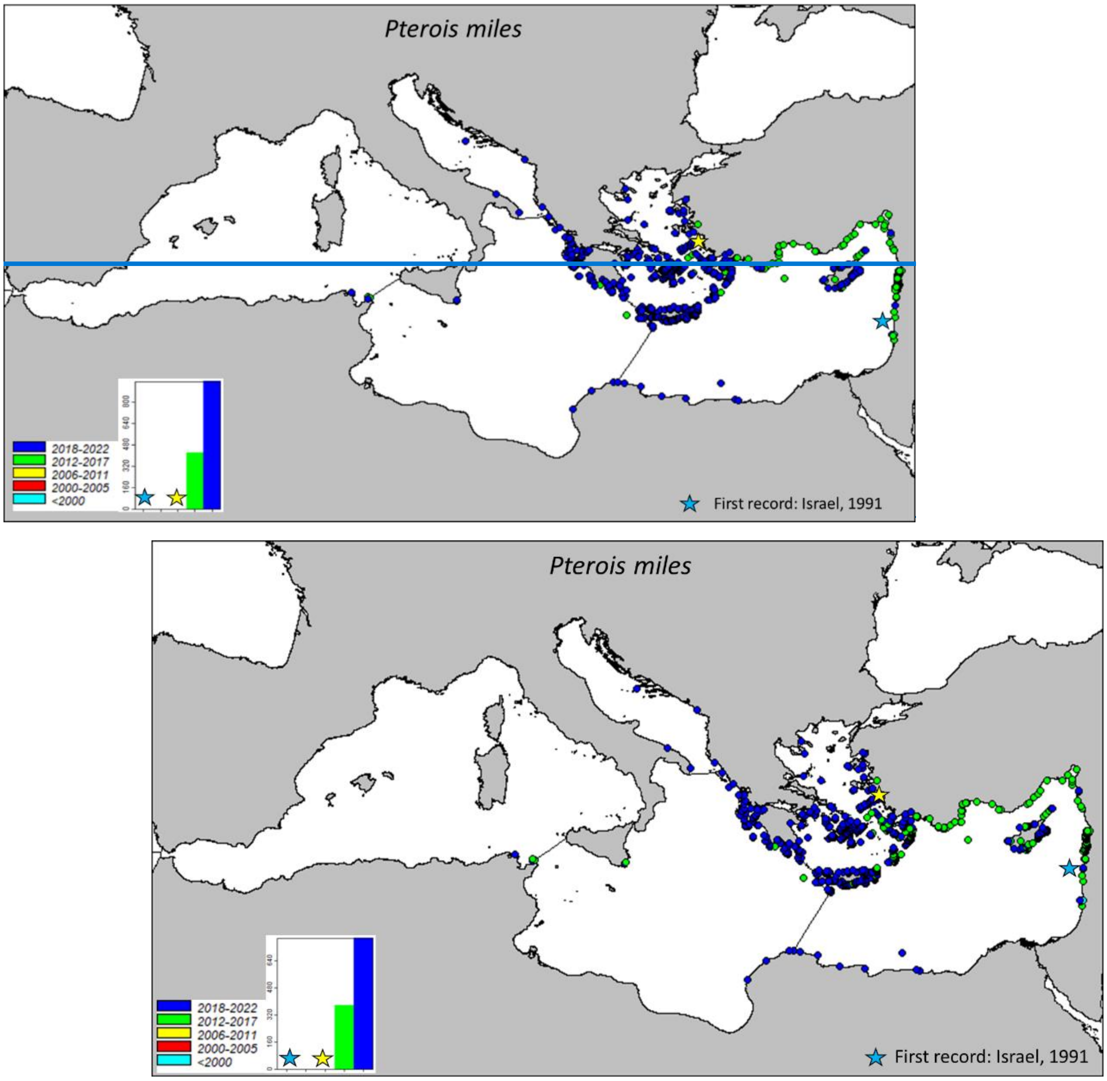
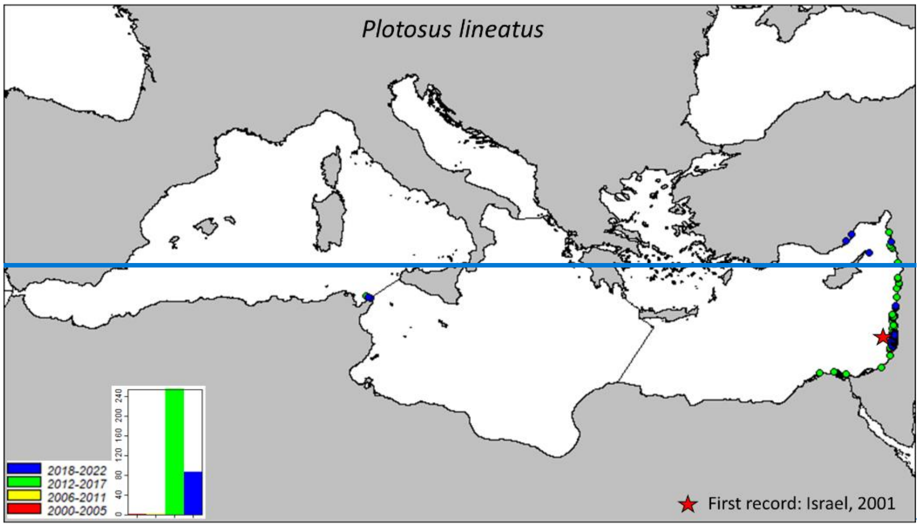


Figure 8. Distribution of *Pterois miles* in the Mediterranean Sea. Details as in Figure 7.



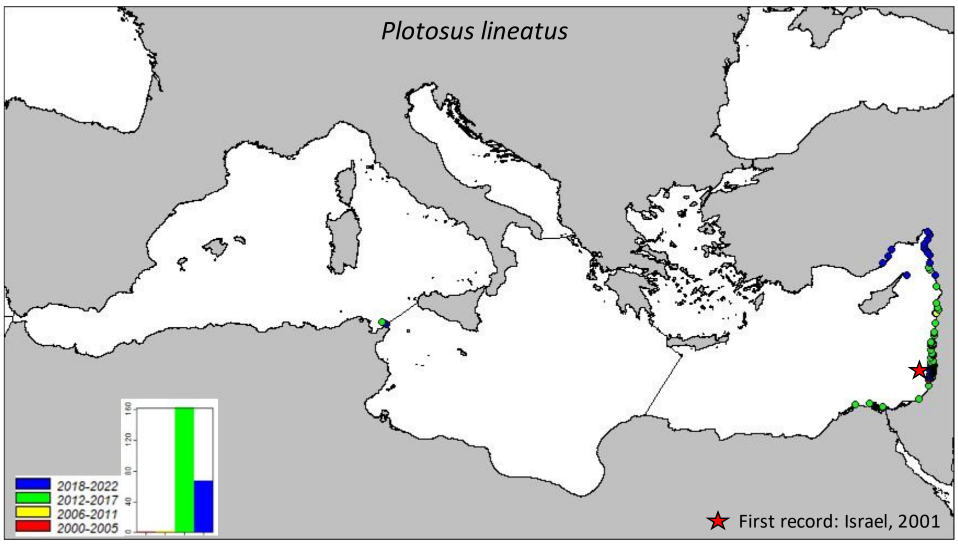


Figure 9. Distribution of *Plotosus lineatus* in the Mediterranean Sea. Details as in Figure 7.

~~33.~~37. The distribution pattern of ***Mnemiopsis leydyi*** in the current map (Figure 10) is largely a result of the spatial and temporal distribution of recording effort, following distinct bloom events (e.g., ~~70~~more than 60% of all mapped observations stem from ~~five publications, 102 of which~~two data series, one from large scale surveys in the Northern Aegean between 2004-2010 – Siapatis pers.comm. to ELNAIS - and the other from sampling in the Northern Adriatic in 2016 – Malej et al., 2017). The species is clearly present throughout the basin, having arrived in the early 1990's as a range expansion of a Black Sea population or with ballast water following its introduction into the Black Sea (Shiganova et al., 2001, Bolte et al., 2013) and subsequently spread in all subregions, aided by ballast water transport or unaided with water currents. Despite a considerable lag time from first introduction to population growth in the Mediterranean (Bolte et al., 2013), *M. leydyi* is undoubtedly established in most subregions.

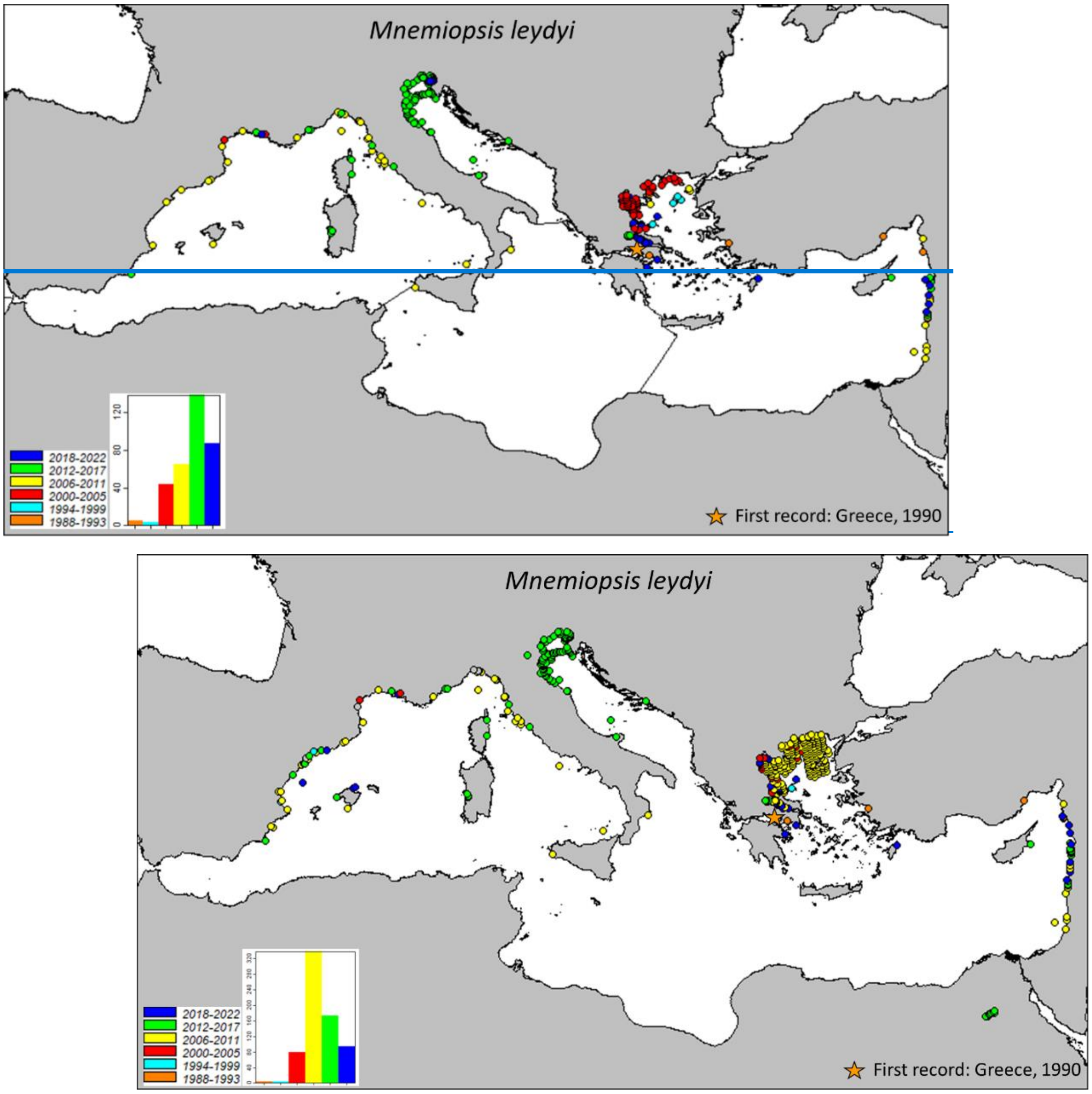
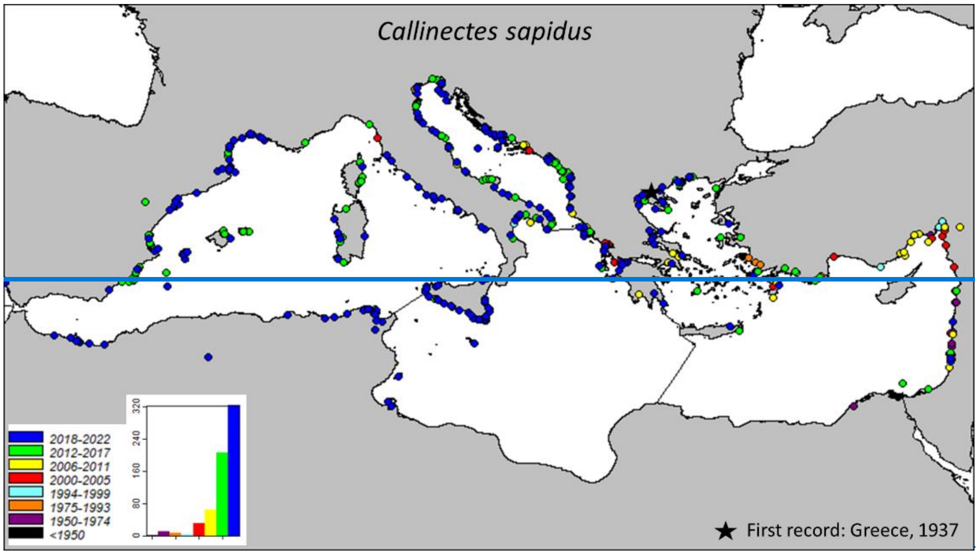


Figure 10. Distribution of *Mnemiopsis leydyi* in the Mediterranean Sea. Details as in Figure 7.

~~34.~~38. ***Callinectes sapidus*** is believed to have been introduced multiple times in the Mediterranean through a variety of pathways, among which ballast water transfer and accidental escape or intentional release through live food trade and mariculture are the most likely (Nehring, 2011). Even though sporadically recorded for decades, the species exhibited a massive proliferation in the last decade (Figure 11), including in the western Mediterranean, with increasing and invasive populations, and it is gaining commercial importance throughout the basin (Kevrekidis & Antoniadou, 2018; López and Rodon, 2018). Aside from natural dispersal, anthropogenic secondary introductions are suspected in many cases (Zenetos et al., 2020).



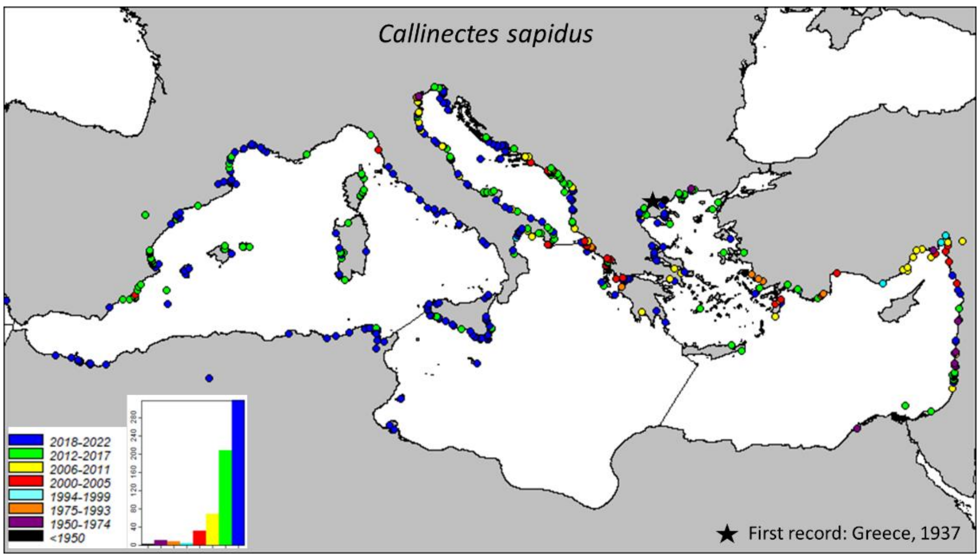


Figure 11. Distribution of *Callinectes sapidus* in the Mediterranean Sea. Details as in Figure 7.

~~35.~~39. ***Anadara transversa*** is a marine bivalve native to the Northwest Atlantic, that has been introduced to the Aegean and Adriatic Seas (Figure 12). Its first records from the Aegean Sea [Izmir Bay (Demir, 1977) and Bay of Thessaloniki (Zenetos, 1994)], were attributed to introduction in ships hulls. Very few records were reported until 2000 and then it was simultaneously found along a 200-km coastline from Venice to Ancona in the northern Adriatic Sea, its presence attributed to accidental introduction with oyster transfers. However, study of subfossil assemblages enabled Albano et al (2018) to disentangle the distinct stages of invasion of *A. transversa*. They concluded that the species was introduced in the 1970s but failed to reach reproductive size until the late 1990s because of metal contamination, resulting in an establishment and detection lag of 25 years. Very scarce records of the species exist after 2017 although the species is established in the Northern Adriatic. In fact, abundances reaching 42 ind. m−2 day−1 were documented in artificial collectors used for settlement analyses deployed at commercial mussel parks (Marčeta et al. 2022).

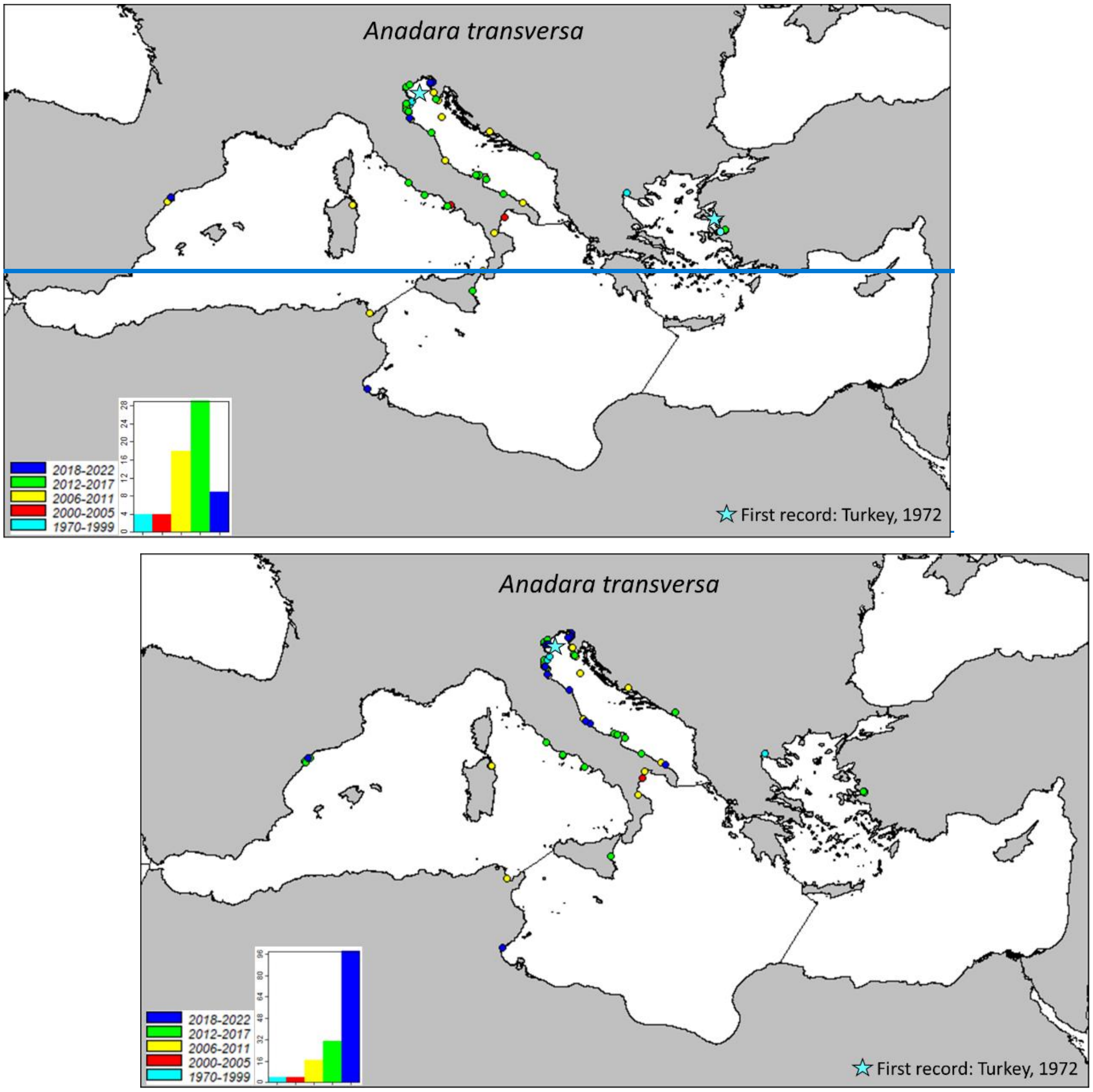


Figure 12. Distribution of *Anadara transversa* in the Mediterranean Sea. Details as in Figure 7.

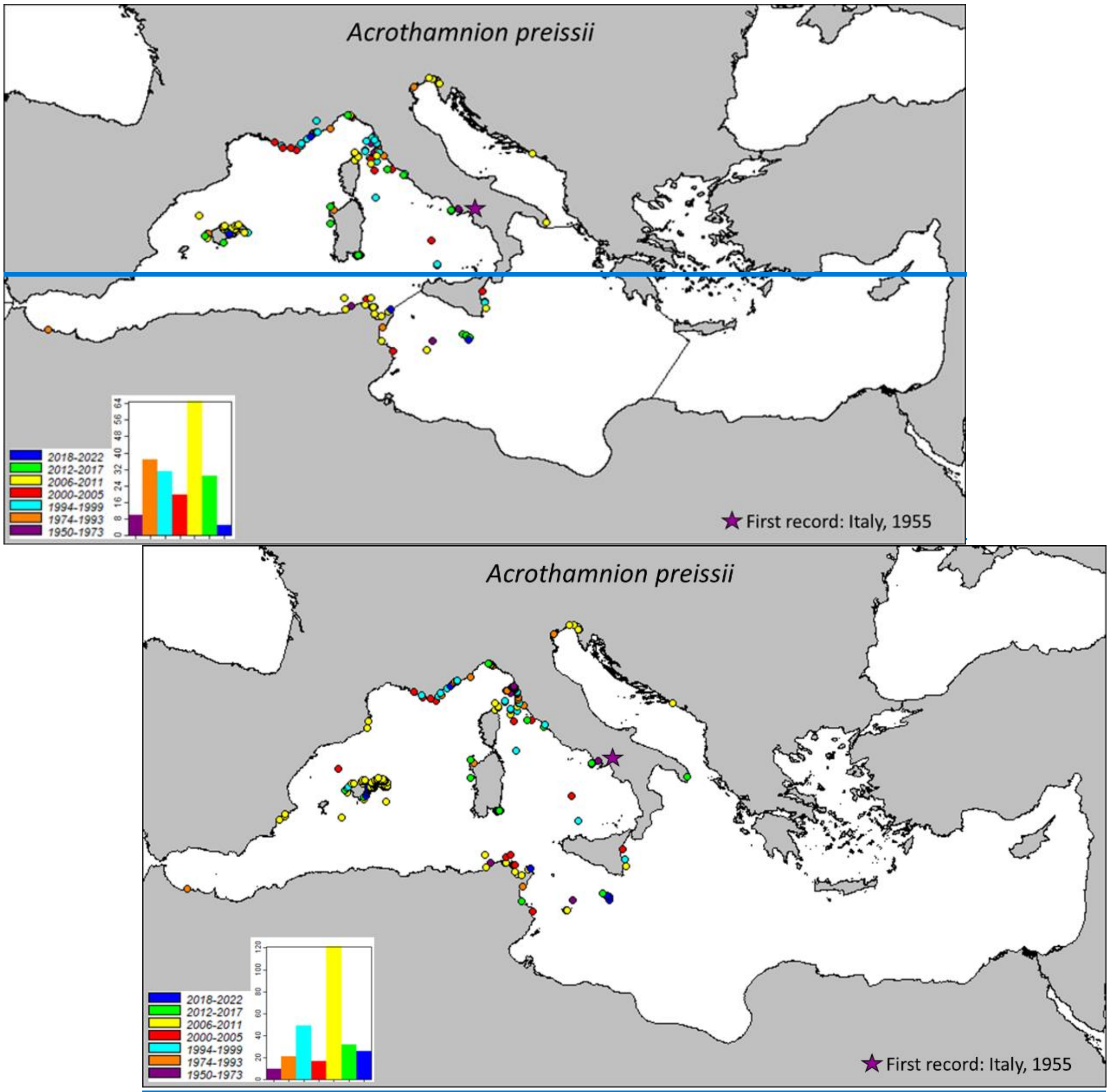


Figure 13. Distribution of *Acrothamnion preissii* in the Mediterranean Sea. Details as in Figure 7.

36.40. ***Acrothamnion preissii*** is a tropical rhodophyte of Indo-Pacific origin that was first reported in the Mediterranean Sea in 1955 from Naples, Italy, introduced presumably with vessels (Figure 13). It has become invasive in many localities, particularly in the western part of the basin (Verlaque et al. 2015). Its expansion in the Ligurian Sea in the 1994-1999 period may be linked to climate change in the 1980-90s (Bianchi et al., 2019). *Acrothamnion preissi* is classified among the ten worst invasive species in the Mediterranean, based on their negative impact score (accounting only for impacts on biodiversity) (Tsirintanis et al. 2022).

37.41. The green alga ***Codium fragile* subsp. *fragile*** is a global invader that originates from NW Pacific that was first detected in front of the Banyuls marine station (France). Observations of the species peakedA first wave of expansion took place in the period 1971-87 mostly in the northwestern Mediterranean and the Adriatic Sea (Figure 14). After that the spatial and temporal pattern, a peak in number of *Codium fragile* exhibits an almost even expansion with timeoccurrence records was observed between 2006-2011 presumably due to scientific effort as well as to citizen science. Along the Spanish coastline in particular, this peak is related to some extent to long-term monitoring data availability. The species is easy to identify as it forms dense sponge-like fronds of low height that become a major structural element of the invaded habitat and dominate the macroalgal community and thus it is not a surprise that many of the latest records (2018-22) have come from citizen scientists reporting to inaturalist. Its introduction has been attributed to vessels but accidental introduction with oysters is also suspected. It appears to be absent from the north-east African coasts, while in the Levantine Sea it was detected after 2000.

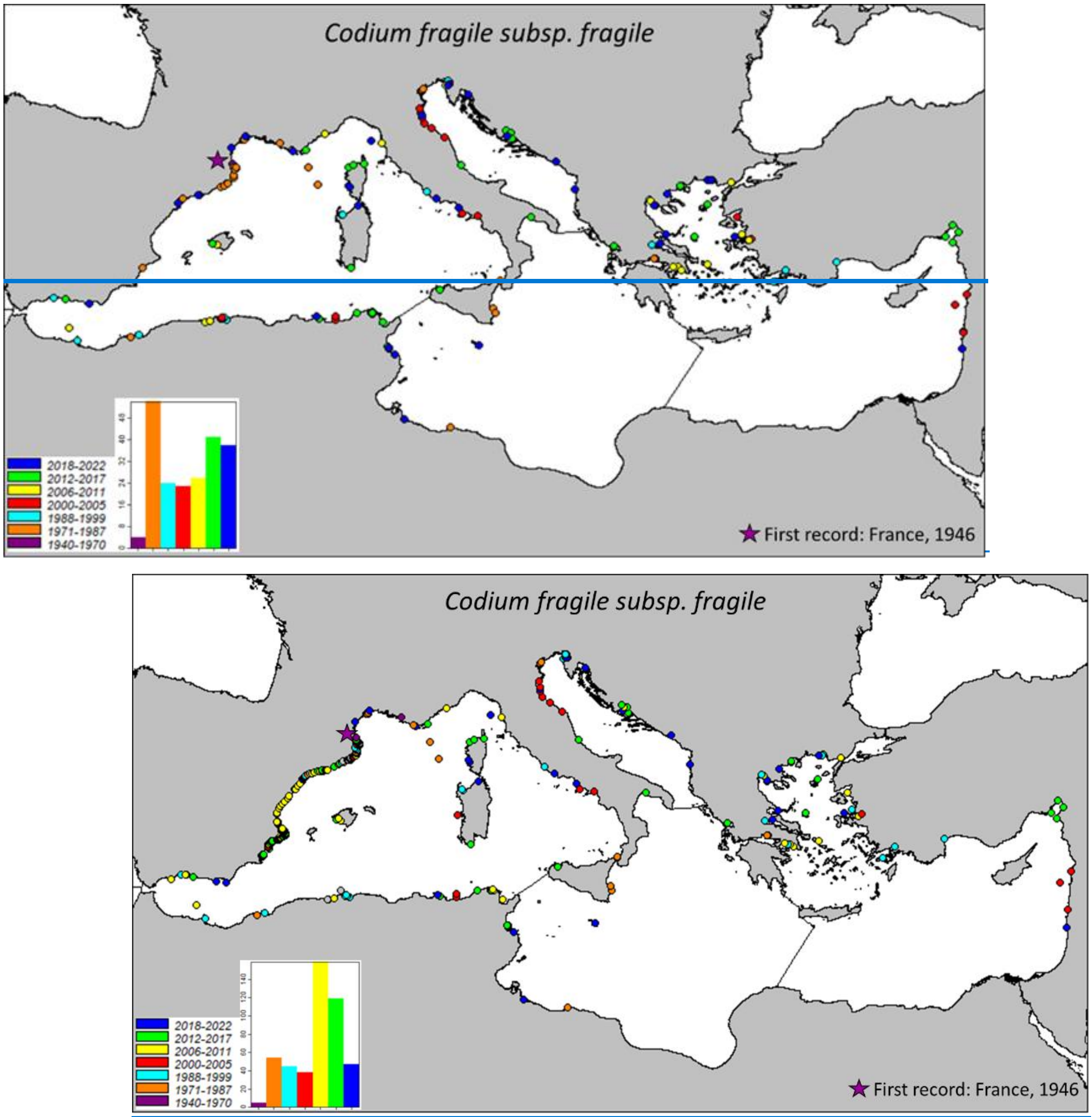


Figure 14. Distribution of *Codium fragile* subsp. *fragile* in the Mediterranean Sea. Details as in Figure 7.

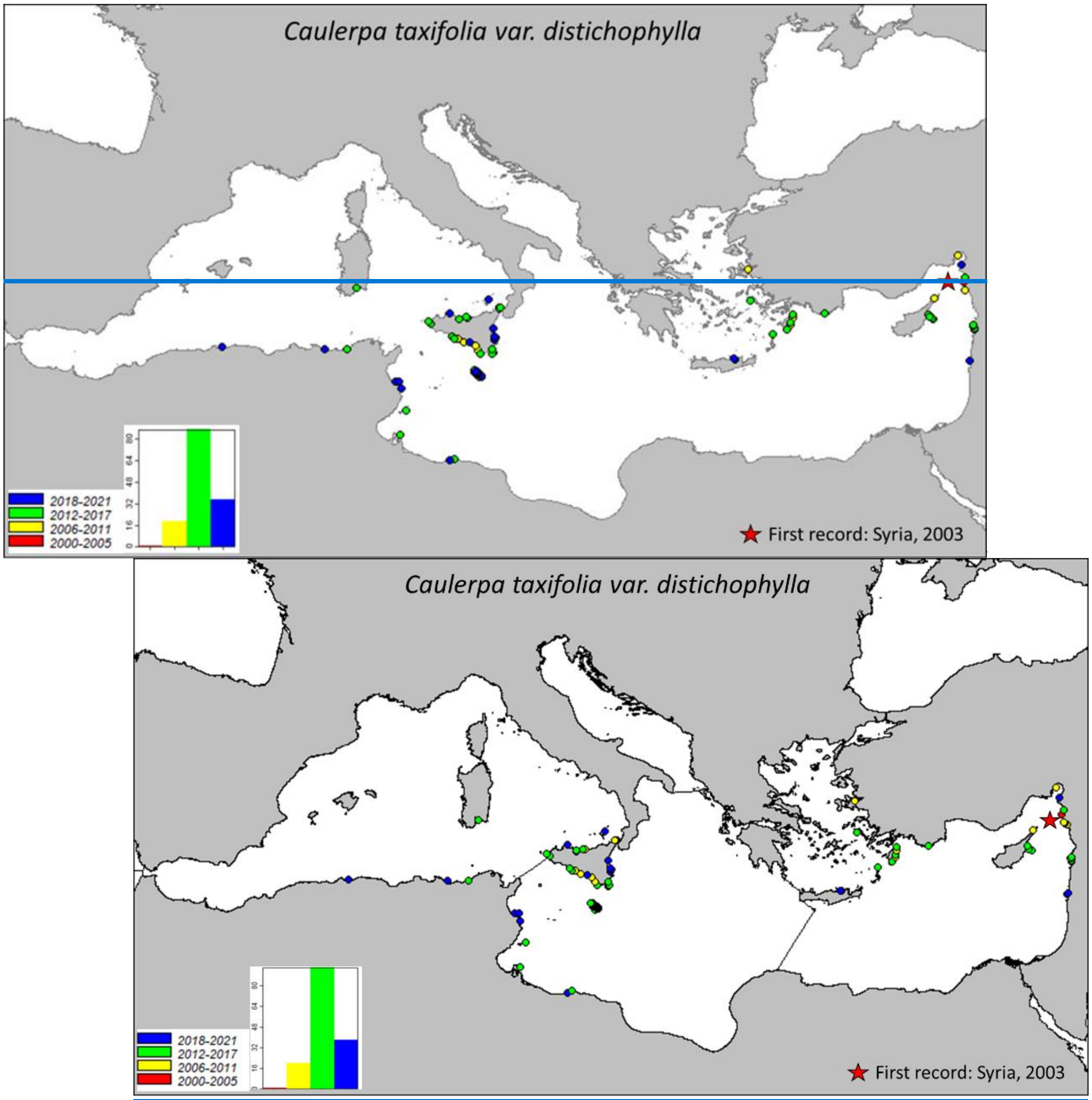


Figure 15. Distribution of *C. taxifolia var. distichophylla* in the Mediterranean Sea. Details as in Figure 7.

~~38.~~42. The temporal distribution ~~*C.*~~***Caulerpa* taxifolia var. distichophylla** does not follow any obvious pattern but is rather a typical example of research effort combined with taxonomic expertise. Initially reported as *C. mexicana* from Syria in 2003 (Bitar et al. 2017) and as *C. taxifolia* from Iskenderun in 2006 (Cevik et al., 2007), identification of this slender *Caulerpa taxifolia* strain was proposed by Jongma et al. (2012). Subsequently in the period 2012-17 many records of the species have been published and this continued as the scientific effort increased in the Western and eastern Mediterranean populations of *C. taxifolia var. distichophylla* are probably the result of introduction events from southwestern Australia. Although the vector of primary introductions remains unknown (aquarium trade or shipping), maritime traffic appears to be the most likely vector of secondary dispersal. *Caulerpa taxifolia var. distichophylla* is closely related to *C. taxifolia*, hence interbreeding with the other *C. taxifolia* strains in the Mediterranean Sea might be expected to occur.

~~39.~~43. With only one record since its first finding in 2002, presumably resulting from shellfish transfers, the brown alga ~~*R.*~~***Rugulopteryx* okamurae** was considered as locally established in France (Verlaque et al

(2015). Following a record in Ceuta in 2015, a massive expansion was observed within the strait of Gibraltar and the Alboran Sea coasts of Spain in 2017 and the species became invasive in record time (García-Gómez et al. 2020). The lifecycle of this species, its ecological characteristics such as its euthermia and allelopathy as well and high competitiveness over other native and invasive species may be highly responsible of its invasive behaviour (García-Gómez et al., 2018). In the period 2020-21, *R. okamurae* extended its distribution in Morocco, France and Spain, reaching Madeira (Bernal-Ibáñez et al., 2022). In France, despite occurring for 20 years in the Thau lagoon, *R. okamurae* has not displayed an invasive ~~behavior~~behaviour in the area. Conversely, in Marseille, with the winter sea surface temperature usually above 13 ~~°~~°C, this alga persists throughout the winter, and therefore, rapidly spreading when conditions are favourable (Ruitton et al. 2021). The new Commission Implementing Regulation (EU) 2022/1203 of 12 July 2022 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern now includes *Rugulopteryx okamurae*.

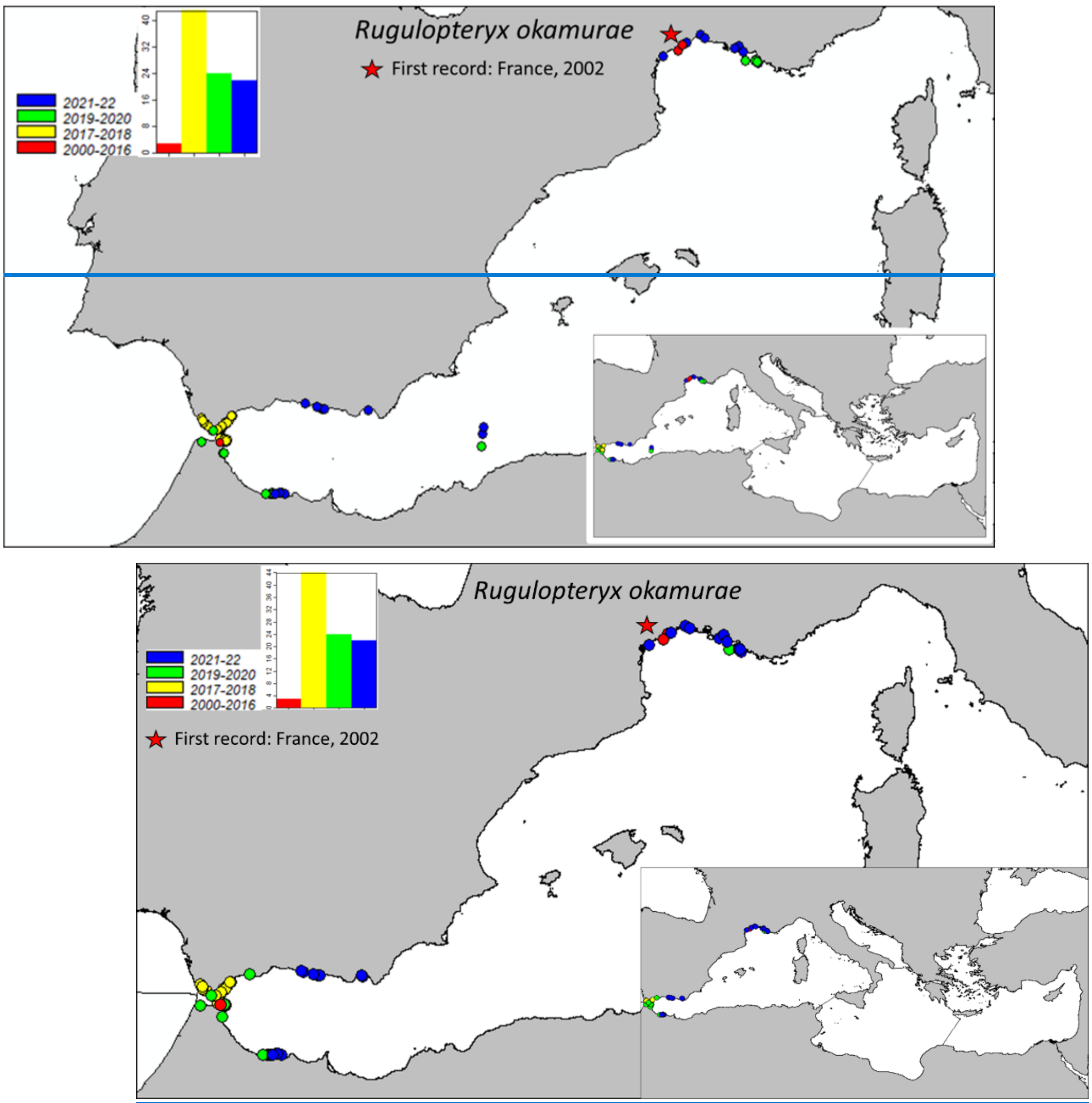


Figure 16. Distribution of *Rugulopteryx okamurae* in the Mediterranean Sea. Details as in Figure 7.

4.3 GES Assessment for the EO / alternative assessment for EO

~~40.~~44. For EO2, identical with CI6. Summary of GES using traffic-light system, per CI.

Table 5. Example to interrelate DPSIR and GES assessment for CI6. (~~Currently based~~Based on the findings in Table 3~~, possibility to be refined with subregional info in the next draft~~).

	Subregions	Assessment Result	Shipping	Ports/harbours	Navigational dredging	Man-made maritime canals	Fisheries	Live food trade	Ornamental trade	Rearing & display in large aquaria (public or private)	Shellfish (and finfish) culture	Shellfish translocations for seeding, ongro	Oil & gas extraction and associated infrastructure	Aggregate extraction	Offshore energy devices	Recreational boating	Associated infrastructure (marinas, piers, p	Solid waste production and disposal, particularly of plastic	Industrial units, production of energy/goods	Climate change
	Western Mediterranean	non-GES																		
	Adriatic	non-GES																		
CI6	Central Mediterranean	non-GES																		
	Eastern Mediterranean	non-GES																		
	Mediterranean	non-GES																		

5. Key findings for CI6

~~41.~~45. To the extent that Good Environmental Status in relation to CI6 is defined as “Introduction and spread of NIS linked to human activities are minimised, in particular for potential IAS” it is concluded that GES has not been achieved in any of the Mediterranean subregions. The results of trends analyses indicate that for the past 15-20 years new NIS introduction rates have been relatively stable in the West Mediterranean and the Adriatic, close to levelling off in the East Mediterranean but increasing in the Central Mediterranean. In none of the subregions has a reduction in new NIS introductions been observed based on data up to 2020. The appearance of some new NIS in each subregion is the result of range expansion from different subregions where they were initially introduced, as evidenced by the increasing proportion of NIS shared among all Mediterranean subregions. Nevertheless, and in contrast with the other subregions, the proportion of unique new NIS is steadily rising in the Central Mediterranean, thus the increasing new NIS introduction rates there cannot be solely attributed to natural dispersal from the other subregions. Furthermore, a number of invasive, high-impact NIS have displayed an increased geographic expansion in the last decade or so, which can be deduced even behind the “noise” of increased detection and reporting. NIS species of warm affinities with long-range pelagic dispersal appear to have been favoured by climate change and increased seawater temperatures to penetrate the cooler regions of the Mediterranean, secondary anthropogenic dispersal however still plays an important role in the spread of the more sedentary species.

~~42.~~46. Clear interpretation of these trends is hampered by the lack of long-term standardised monitoring data, as it is not possible to disentangle the confounding effects of differential recording efforts spatially and temporally from real changes in pathway pressure or vector management. An additional challenge, also pertinent to the DPSIR analysis for NIS, is that spatially explicit, quantitative pathway pressure data are not uniformly available throughout the Mediterranean, such that any attempted correlations would be skewed or incomplete. This was already identified in UNEP/MED WG.502/Inf.11 (2021) and emerges as a priority in order to strengthen further GES assessments of CI6.

~~43.~~47. Trends in abundance were not assessed as they require long time series of standardised monitoring data from the same locations, the collection and collation of which at the regional level is not sufficiently co-ordinated. Furthermore, an agreed methodology has not been developed for a formal quantification of changes in spatial distribution, which cannot be properly assessed without true presence-absence data.

~~44.~~ With regards to NIS impacts, even though assessment and mapping have been conducted at the regional level (Katsanevakis et al., 2014; 2016), there is plenty of scope for refinement and improvement as most reported impacts are still based on weak evidence (Tsirintanis et al., 2022). Thus, conducting manipulative and field experiments to examine impacts on species, habitats and ecosystems remains a priority for NIS research. Moreover, considering that species distributions have changed since the first Mediterranean-wide CIMPAL, but also new information has emerged regarding impact strength, NIS impacts need to be re-evaluated. ~~(Some more comments will be added in the next draft when CIMPAL is added to the assessment)~~

6. Measures and actions required to achieve GES

~~45.~~48. With regards to suitable data availability, the majority of the CPs have developed, and many are already implementing IMAP-compliant monitoring programmes. Furthermore, the IMAP Data and Information System is operational and has already started receiving NIS data, such that standardised time series are anticipated to be available for the next assessment cycle. This should make possible the formal quantification of abundance and spatial distribution changes and increase our confidence in the assessment of trends in temporal occurrence. If CPs have not already initiated the process, IMAP can assist in co-ordinating the development of priority NIS lists for monitoring of abundance through risk analysis and risk assessment. Early detection and early warning systems can be informed by regularly updating the spatial distribution information entered into MAMIAS and the IMAP Info System.

~~46.~~49. Threshold values for trends in temporal occurrence have not been set yet but methodologies and approaches are under discussion through regional co-operation. Quantifying/modelling pathway pressure can assist in specifying quantitative targets (percentage reduction) by introduction pathway. Importantly, all these methodological steps need to be adapted for GES assessment at the national level. The effect of reporting lags on new NIS data and trends analysis in this assessment was circumvented by not using the data of the last 3 years (2018-2020), however it would be beneficial to adopt a commonly agreed methodology to deal with this issue in order to avoid loss of information.

~~47.~~50. Next important steps for GES assessment of NIS include the elaboration of the remaining aspects of CI6 that relate to impacts, by further developing assessment criteria and quantitative targets for the most vulnerable/important species and habitats at risk. This is work that ideally should be co-ordinated with the implementation of EO1 Common Indicators CI1 and CI2 and EO6 on sea floor integrity.

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