DELIVERABLE 5.1

“Report with the final results and approaches of aggregation data”

Date: 15/01/2021

DISSEMINATION LEVEL: PUBLIC

MEDREGION

SUPPORT MEDITERRANEAN MEMBER STATES TOWARDS
IMPLEMENTATION OF THE MARINE STRATEGY FRAMEWORK DIRECTIVE
NEW GES DECISION AND PROGRAMMES OF MEASURES
AND CONTRIBUTE TO REGIONAL/SUBREGIONAL COOPERATION

Support Mediterranean Member States towards implementation of the MSFD new GES Decision and programmes of measures and contribute to regional/subregional cooperation

11.0661/2018/794286/SUB/ENV.C2

MEDREGION

SUPPORT MEDITERRANEAN MEMBER STATES TOWARDS IMPLEMENTATION OF THE MARINE STRATEGY FRAMEWORK DIRECTIVE NEW GES DECISION AND PROGRAMMES OF MEASURES AND CONTRIBUTE TO REGIONAL/SUBREGIONAL COOPERATION

Coordinator

Dr Kalliopi Pagou

Project start date and duration

1st February 2019, 24 months

www.medregion.eu

MEDREGION

SUPPORT MEDITERRANEAN MEMBER STATES TOWARDS IMPLEMENTATION OF THE MARINE STRATEGY FRAMEWORK DIRECTIVE NEW GES DECISION AND PROGRAMMES OF MEASURES AND CONTRIBUTE TO REGIONAL/SUBREGIONAL COOPERATION

The research leading to these results has received funding from the European Commission DG Environment] under grant agreement n° 11.0661/2018/794286/SUB/ENV.C2 – MEDREGION project (Support Mediterranean Member States towards implementation of the MSFD new GES Decision and programmes of measures and contribute to regional/subregional cooperation).

This Deliverable should be referenced as follows:

Borja, A., I. Menchaca, J.M. Garmendia, J. Franco, J. Larreta, Y. Sagarminaga, Y. Schembri, R. González, R. Antón, T. Micallef, S. Camilleri, O. Solaun, A. Uriarte, Mavrič, B., Orlando-Bonaca, M., France, J., Vidjak, O., Skejić, S., M.C. Uyarra, 2021. Report with the final results and approaches of aggregation data. Deliverable D5.1, MEDREGION project, 48 pp.

Contact author: Angel Borja (aborja@azti.es), María C. Uyarra (mcuyarra@azti.es)

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

1 Executive Summary

MEDREGION's Activity 5 intends to implement the new Good Environmental Status (GES) Decision (European Commission, 2017), for biodiversity descriptors (D) of the Marine Strategy Framework Directive (MSFD; European Commission, 2008), namely D1 (biodiversity) and D6 (seafloor integrity), proposing a method to integrate the monitoring information to assess the status.

Though different methods exist, as the integrated assessment results depend on aggregation method and framework structure, the decision on the way of integrating should be taken in agreement with stakeholders and in accordance with the final objectives of the assessment. Our initial proposal is to aggregate indicators using the *Nested Environmental status Assessment Tool* (NEAT).

Therefore, **the specific objectives of Activity 5 are**:

- O5.1: Selection of indicators (for D1, D6) based upon criteria established in the Commission Decision (European Commission, 2017).
- O5.2: Set reference conditions and thresholds (i.e., boundary between good/not good status).
- O5.3: Integration of multiple indicators, criteria, ecosystem components, and descriptors in multiple temporal and spatial scales.

In order to achieve these objectives, we should use official data from the Competent Authorities included in the project and propose a prototype for further evaluation. Hence, this Deliverable explains the prototype proposed and its further application to the Malta case study.

NEAT was developed within the EU project DEVOTES, to assess the status of marine ecosystems in an integrative way, including different sources of data, descriptors of the MSFD, ecosystem components, habitats and indicators. The aggregation can be done at different temporal and spatial scales, from small Marine Reporting Units (MRUs) to large regional and subregional seas. However, when NEAT was developed, the European Commission (2017) Decision was still not published. Hence, some criteria were not able to be included on it. In this exercise, we have adapted the tool to make an intermediate approach, allowing to the Competent Authorities to use NEAT to assess, following the current Decision guidelines, the environmental status at different levels: (i) MRUs, at subnational, national, subregion and regional scales; (ii) Ecosystem components, from phytoplankton to mammals, including all possible components; (iii) Descriptors, integrating all of them, or assessing the status at each descriptors level; (iv) Criteria, for each descriptor, either primary or secondary; and (v) Habitat.

We prepared a NEAT prototype, allowing the Competent Authorities to include their own indicators and official data and test the results, since the MRUs, ecosystem components, habitats, and criteria for each descriptor are already included (available as Annex 1). In order to test the viability of this prototype, we created an example (Annex 2), showing the results at different levels, using non-official data, due to the lack of availability of such data. However, after request to the Maltese authorities, the prototype has been tested on Maltese data to compare the results obtained in the official assessment and those obtained when applying NEAT. This Deliverable collates all these results.

We think that the results are positive and close to the assessments required by Member States. Thus, if they consider that this could be useful, in the future, NEAT could be adapted to these requirements for easier and direct use.

2 Introduction

Activity 5 intends to implement the new Good Environmental Status (GES) Decision (European Commission, 2017), for biodiversity descriptors (D) of the Marine Strategy Framework Directive (MSFD; European Commission, 2008), namely D1 (biodiversity) and D6 (seafloor integrity).

The specific objectives targeted within this activity are:

- Selection of criteria of Descriptors (D1, D6) according to Commission Decision (European Commission, 2017).
- Consideration of previous work on indicators/criteria, as from DEVOTES, PERSEUS, etc., and other regional projects (e.g., ActionMed, MEDCIS, etc.), as well as in ICES, OSPAR, HELCOM and UNEP studies.
- Set reference conditions and thresholds (i.e., boundary between good and moderate status). According to the criteria from the European Commission (2017), to put in order the preferred ways to determine these targets (in decreasing order of preference):
    - Is there any binding legal limit? e.g. (i) intercalibrated values within the WFD (EC, 2018), for different biological elements, which can be taken as model; (ii) other binding legislation (CFP, HD, UNEP, etc.)
    - Is there any agreed boundary, accepted by the scientific community or managers? e.g., Maximum Sustainable Yields (MSY), determined in STEF, ICES, ICCAT or other organizations; boundaries for different eutrophication status (eutrophic, mesotrophic, oligotrophic), etc.
    - Is there enough information from pristine areas, to be used as reference conditions?
    - Is there information from gradients of pressure, which could be used to set targets?
    - Is there past information (e.g., before any human pressure) which could be used as reference conditions?
    - Is it possible to model a target, considering expert experience? e.g., using habitat suitability models or others (Lynam et al., 2016)
    - Is there existing literature in similar habitats that could be used to set targets?
    - would it be possible for expert groups (e.g., within MEDCIS) to achieve a consensus on target values?
- Integration of multiple indicators, criteria, ecosystem components, and descriptors in multiple temporal and spatial scales.

Though different methods exist, as the integrated assessment results depend on aggregation method and framework structure, the decision on the way of integrating should be taken in agreement with stakeholders and in accordance with the final objectives of the assessment. Our initial proposal is to aggregate indicators, following the requirements from DG-Environment and EEA, using the *Nested Environmental status Assessment Tool* (NEAT) (which has been successfully used in different locations).

Therefore, **the specific objectives of Activity 5 are**:

- O5.1: Selection of indicators (for D1, D6) based upon criteria established in the Commission Decision (European Commission, 2017).
- O5.2: Set reference conditions and thresholds (i.e., boundary between good and moderate status).
- O5.3: Integration of multiple indicators, criteria, ecosystem components, and descriptors in multiple temporal and spatial scales.

In order to achieve these objectives, we needed to use official data from the Competent Authorities included in the project (by July 2019, after the proposal), and propose a prototype for further evaluation. The prototype should have been ready by month 10 of the project (November 2019), completed as Milestone 5.3. However, the necessary official data were not provided by the Competent Authorities. Hence, in the MEDREGION annual meeting, celebrated in February 2020 in Rome, it was decided to prepare the NEAT prototype (adapting NEAT to the new Decision) without using official data, only as a demonstration tool, and, as soon, as the data would become available, this could be updated and adapted for the needs of the project. The prototype proposed was completed on 24th March 2020.

Since the data from Competent Authorities were not provided, in the same MEDREGION annual meeting, it was decided to request permission to the Maltese authorities to use their official MSFD reported data to compare the results from the Malta assessment with those obtained using NEAT. This Deliverable collates all these results.

3 Building the prototype

3.1 NEAT description

The NEAT software (version 1.4) was developed within the framework of the European project DEVOTES (www.devotes-project.eu/neat) (Borja et al., 2016) (Figure 1), to serve for the implementation of the MSFD.

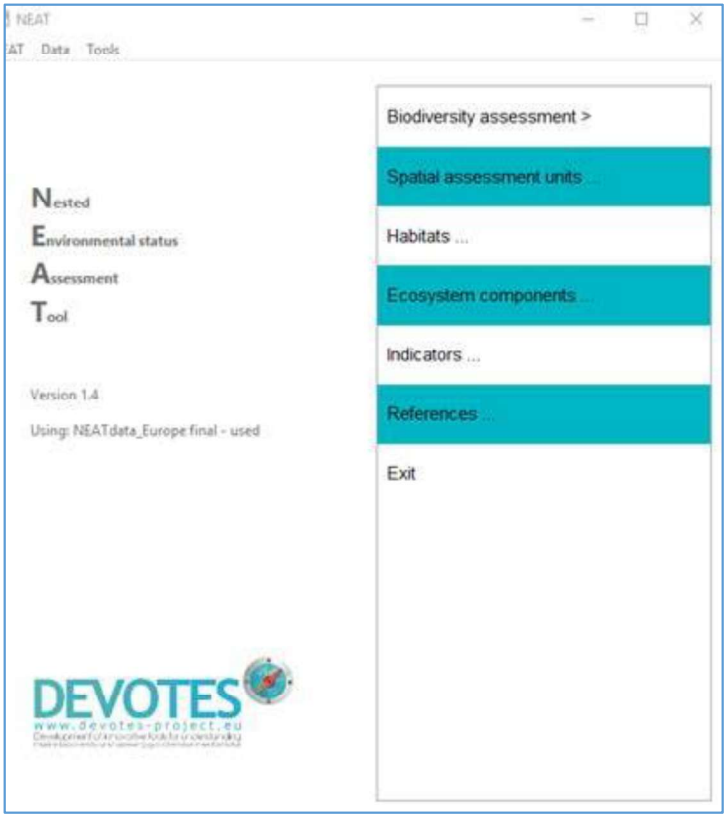


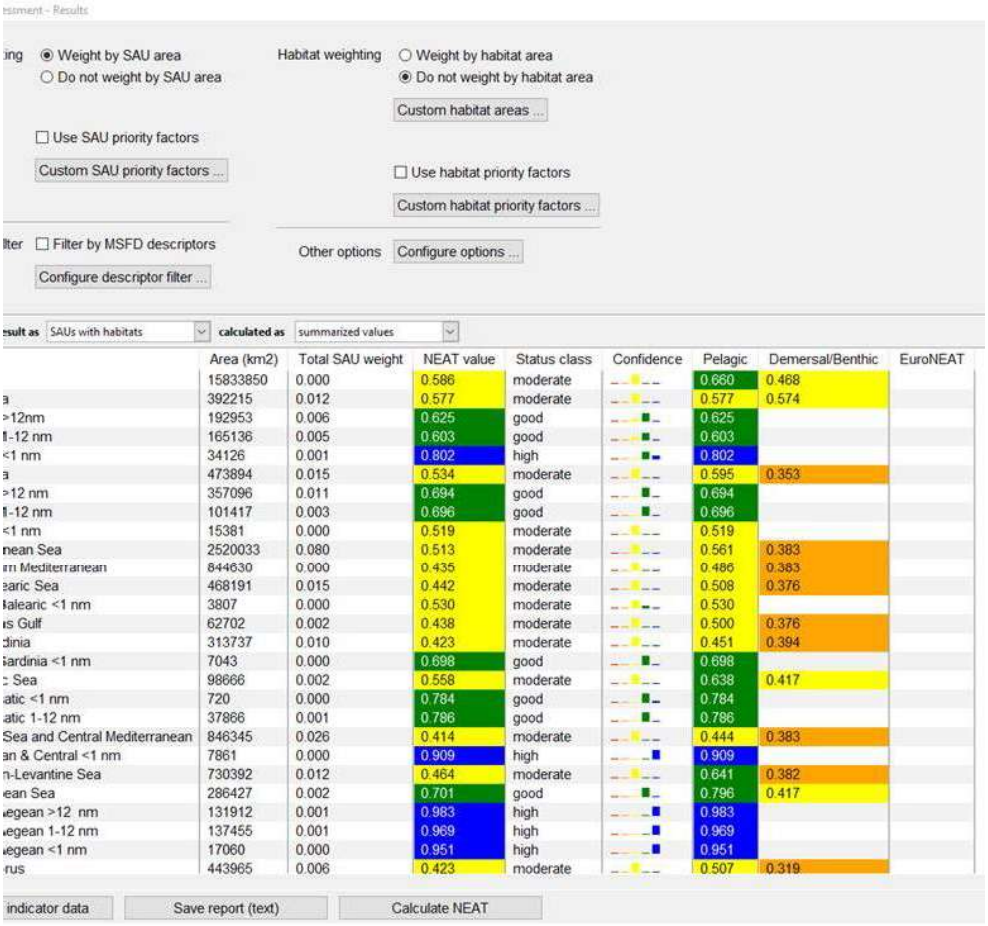
Figure 1: Initial screen of the NEAT software tool (Nested Environmental status Assessment Tool), developed within the framework of the European DEVOTES project.

NEAT was initially developed and validated in 10 case-study sites in Europe, evaluating areas from 1,000 km^2 to 1 million km^2 (in the Black Sea, in the Mediterranean Sea, in the Atlantic Ocean, in the Baltic Sea and in the Arctic) (Uusitalo et al., 2016). Later, it was used in the Iranian Caspian Sea, with new applications, such as the assessment of bathing waters (Nemati et al., 2017). It was also applied for the environmental status assessment of Maltese marine waters (Borja et al., 2018). Then, it was applied to the study of the spatial and temporal recovery of a Greek marine location after sanitation, within the MEDCIS project (Pavlidou et al., 2019). The most recent study covers the environmental status assessment of the whole Europe, based on three descriptors of the MSFD: commercial fisheries, contaminants and eutrophication, also within MEDCIS (Borja et al., 2019). Currently, there are other applications (and coming papers) on: (i) assessing the status of the deep-sea in the Atlantic, (ii) comparing the status of marine protected and

unprotected areas in the Mediterranean, and (iii) applying it to the Saudi Arabian waters, in the Persian Gulf.

NEAT software is a flexible and easy-to-use application that allows to incorporate all the descriptors included in the MSFD, as well as its multiple indicators and all the components of the ecosystem and habitats, at different spatio-temporal scales. The **five principles of NEAT** are:

- **Indicators**: they constitute the basis of the assessment. NEAT integrates an indicator catalogue (Teixeira et al., 2016) as a source for choosing predefined indicators for the biodiversity assessment. However, the tool is not limited to those indicators; it allows the addition of as many indicators as required (not only related to biodiversity, but any kind of indicator, specific to each assessment performed).
- **Weighting and hierarchies**: the central principle in the NEAT method is a hierarchical, nested structure of Marine Reporting Units (MRUs) and habitats. Thus, it avoids the dominance of certain indicators or habitats or spatial units by using a proper weighting procedure, which considers what information is available for different real spatial scales. That is, each indicator is related to a specific ecosystem component (e.g., fish), which lives in a certain habitat (e.g., water column), and information has been collected for a specific area or MRU (e.g., Saronikos Gulf). Thus, no bias is introduced into the assessment by the choice of the indicators.
- **Aggregation**: in order to aggregate indicators, the mean of each indicator is normalized to a scale of 0 (worst) to 1 (best), independently of their original scale, with the threshold between Good / Moderate at 0.6. Other limits are: High / Good, 0.8; Moderate / Poor, 0.4; and Poor / Bad, 0.2 (equivalent to the ecological quality ratio -EQR- of the WFD). For example, oxygen saturation can range from 0 to 140, but it is transformed at that scale. The specific limits of the indicators (for example, the limit between the moderate and good status) are also normalized, always being 0.6. By default, aggregation is done across all indicators belonging to a MRU. However, NEAT is designed to do aggregations to any other entity. For example, the method can be used to aggregate all indicators of a MRU and show the status divided among the different ecosystem components of the MRU.
- **NEAT value**: the outcomes of the aggregation are visualized into a number (NEAT value) and a colour, which corresponds to the status. This NEAT value is obtained for the whole assessed area, but it can be visualized in different forms. For example, it is possible to visualize how the information from the different ecosystem components (e.g., fish, phytoplankton, etc.) has contributed to the assessment, or how the information available to the different areas contributes to the overall assessment (Figure 2).
- **Confidence**: each NEAT value is accompanied by its quantitative estimate of the confidence of the result. This estimate is performed using the standard error (entered at the same time as the indicator value), and performance of Monte Carlo simulations (usually between 1,000 and 10,000 times) as a means to understand how this error propagates throughout the assessment.



	Area (km2)	Total SAU weight	NEAT value	Status class	Confidence	Pelagic	Demersal/Benthic	EuroNEAT
	15833850	0.000	0.586	moderate		0.660	0.468	
a	392215	0.012	0.577	moderate		0.577	0.574	
>12nm	192953	0.006	0.625	good		0.625		
l-12 nm	165136	0.005	0.603	good		0.603		
<1 nm	34126	0.001	0.802	high		0.802		
a	473894	0.015	0.534	moderate		0.595	0.353	
>12 nm	357096	0.011	0.694	good		0.694		
l-12 nm	101417	0.003	0.696	good		0.696		
<1 nm	15381	0.000	0.519	moderate		0.519		
nean Sea	2520033	0.080	0.513	moderate		0.561	0.383	
rn Mediterranean	844630	0.000	0.435	moderate		0.486	0.383	
earic Sea	468191	0.015	0.442	moderate		0.508	0.376	
laleario <1 nm	3807	0.000	0.530	moderate		0.530		
s Gulf	62702	0.002	0.438	moderate		0.500	0.376	
dinia	313737	0.010	0.423	moderate		0.451	0.394	
ardinia <1 nm	7043	0.000	0.698	good		0.698		
Sea	98666	0.002	0.558	moderate		0.638	0.417	
atic <1 nm	720	0.000	0.784	good		0.784		
atic 1-12 nm	37866	0.001	0.786	good		0.786		
Sea and Central Mediterranean	846345	0.026	0.414	moderate		0.444	0.383	
an & Central <1 nm	7861	0.000	0.909	high		0.909		
n-Levantine Sea	730392	0.012	0.464	moderate		0.641	0.382	
ean Sea	286427	0.002	0.701	good		0.796	0.417	
egean >12 nm	131912	0.001	0.983	high		0.983		
egean 1-12 nm	137455	0.001	0.969	high		0.969		
egean <1 nm	17060	0.000	0.951	high		0.951		
rus	443965	0.006	0.423	moderate		0.507	0.319	

Figure 2. Data structure necessary to be included in the NEAT tool.

3.2 Prototype description, adapted to the MSFD needs

This section aims at describing how NEAT can be adapted, so it can perform the environmental status assessment following the requirements of the new GES Decision, and therefore, the need of Member States. For the purpose of generating this prototype, three main sources of information have been collated:

- The new GES Decision (European Commission, 2017)
- The most recent guidelines document developed by the Working Group on Data, Information and Knowledge Exchange (WG DIKE), and entitled "Reporting on the 2020 update of Article 11 for the Marine Strategy Framework Directive (version 2.0)", from April 2019 (European Commission, 2019)
- The NEAT software and manual (Berg et al., 2017)

As indicated in Section 4, NEAT v.1.4. is capable to integrate indicators associated to different ecosystem components, habitats, descriptors and Spatial Assessment Units (i.e., MRUs). The weighting of the different indicators can be carried out at the level of MRUs and/or habitats, but not at the level of ecosystem components. That is, despite NEAT having the possibility to visualize the assessment by ecosystem components, there is not hierarchical integration of the data across ecosystem components.

The most recent guidelines for reporting, encourages Member States to perform an assessment by different features and elements; that is, species groups and habitats. Furthermore, such integration should also be carried out by descriptor criterion. The lists for the different species and habitat groups and that of descriptor criterion, are available in the "Reporting on the 2020 update of Article 11 for the Marine Strategy Framework Directive (version 2.0)" document and provided below. Since this Deliverable refers to Descriptor 1 (Biodiversity) and Descriptor 6 (Sea-floor integrity), Table 1 and

Table 2 only include the descriptors and criteria, and species and habitats relative to these two descriptors.

Table 1. List of ecosystem components and habitats associated to Descriptors (D) 1 and 6, and the criteria (C) to be assessed (reduced from European Commission, 2019). GES: Good Environmental Status. DHB: Directive Habitats and Birds.

GES component	Code	Label: Descriptor or criteria	Criteria Type
Descriptor	D1	D1 Biodiversity	
Descriptor	D1	D1 Biodiversity – birds	
Descriptor	D1	D1 Biodiversity – cephalopods	
Descriptor	D1	D1 Biodiversity - fish	
Descriptor	D1	D1 Biodiversity – mammals	
Descriptor	D1	D1 Biodiversity – reptiles	
Descriptor	D1	D1 Biodiversity – pelagic habitats	
Descriptor	D6/D1	D6 Sea-floor integrity/D1 Biodiversity - benthic habitats	
Criterion	D1C1	D1C1 Mortality rate from incidental by-catch	Primary
Criterion	D1C2	D1C2 Population abundance	Primary
Criterion	D1C3	D1C3 Population demographic characteristics	Primary (fish, cephalopods)
Criterion	D1C4	D1C4 Population distributional range and pattern	Primary (for Species in DHB)
Criterion	D1C5	D1C5 Habitat for the species	Primary (for Species in DHB)
Criterion	D1C6	D1C6 Pelagic habitat condition	Primary
Criterion	D6C1	D6C1 Physical loss of the seabed	Primary
Criterion	D6C2	D6C2 Physical disturbance to the seabed	Primary
Criterion	D6C3	D6C3 Adverse effects from physical disturbance	Primary
Criterion	D6C4	D6C4 Benthic habitat extent	Primary
Criterion	D6C5	D6C5 Benthic habitat condition	Primary

Table 2. Species groups and habitats to be considered in the assessment (reduced from European Commission, 2019).

Subject (Annex III table)	Theme	Sub-theme	Label: Features and elements	Code
Structure, functions and processes of marine ecosystems (Table 1)			All marine ecosystem elements	EcosysElemAll
	Species		All marine species	SppAll
		Birds	All birds	BirdsAll
			Grazing birds	BirdsGrazing
			Wading birds	BirdsWading
			Surface-feeding birds	BirdsSurfaceFeeding
			Pelagic-feeding birds	BirdsPelagicFeeding
			Benthic-feeding birds	BirdsBenthicFeeding
		Mammals	All mammals	MamAll
			Small toothed cetaceans	MamCetacSmall
			Deep-diving toothed cetaceans	MamCetacDeepDiving
			Baleen whales	MamCetacBaleenWhales
			Seals	MamSeals
		Reptiles	**Turtles**	RepTurtles
		Fish	All fish	FishAll
			Coastal fish	FishCoastal
			Pelagic shelf fish	FishPelagicShelf
			Demersal shelf fish	FishDemersalShelf
			Deep-sea fish	FishDeepSea
			Commercially exploited fish and shellfish	FishCommercial
		Cephalopods	All cephalopods	CephaAll
			Coastal/shelf cephalopods	CephaCoastShelf
			Deep-sea cephalopods	CephaDeepSea
	Habitats		All habitats	HabAll
		Benthic habitats	Benthic habitats	HabBenAll
			Benthic broad habitats	HabBenBHT
			Littoral rock and biogenic reef	HabBenLitRock
			Littoral sediment	HabBenLitSed
			Infralittoral rock and biogenic reef	HabBenInfralitRock
			Infralittoral coarse sediment	HabBenInfralitCoarSed
			Infralittoral mixed sediment	HabBenInfralitMxdSed
			Infralittoral sand	HabBenInfralitSand
			Infralittoral mud	HabBenInfralitMud
			Circalittoral rock and biogenic reef	HabBenCircalitRock
			Circalittoral coarse sediment	HabBenCircalitCoarSed
			Circalittoral mixed sediment	HabBenCircalitMxdSed
			Circalittoral sand	HabBenCircalitSand
			Circalittoral mud	HabBenCircalitMud
			Offshore circalittoral rock and biogenic reef	HabBenOffshRock
			Offshore circalittoral coarse sediment	HabBenOffshCoarSed
			Offshore circalittoral mixed sediment	HabBenOffshMxdSed

Subject (Annex III table)	Theme	Sub-theme	Label: Features and elements	Code
			Offshore circalittoral sand	HabBenOffshSand
			Offshore circalittoral mud	HabBenOffshMud
			Upper bathyal rock and biogenic reef	HabBenBathyalUpRock
			Upper bathyal sediment	HabBenBathyalUpSed
			Lower bathyal rock and biogenic reef	HabBenBathyalLowRock
			Lower bathyal sediment	HabBenBathyalLowSed
			Abyssal	HabBenAbyssal
			Other benthic habitats	HabBenOther
		Pelagic habitats	Pelagic habitats	HabPelagAll
			Pelagic broad habitats	HabPelBHT
			Variable salinity	HabPelagVarSalinity
			Coastal	HabPelagCoastal
			Shelf	HabPelagShelf
			Oceanic/beyond shelf	HabPelagOcean
			Other pelagic habitats	HabPelagOther
			Other habitat types	HabOther

Based on the information included in Tables 1 and 2, the NEAT prototype was developed, so it would be able to integrate official information from any (Mediterranean) country, marine region and subregion, and perform the specific assessments at the level of criterion and descriptor, for the different species groups and habitats, as well as the partial and full integration of all them.

The definition of the protype, from now on called MEDREGPROTO required four steps:

- Step 1. Definition of MRUs and hierarchy levels
- Step 2. Definition of habitats and species groups (and the associated criteria) and their hierarchy levels
- Step 3. Definition of ecosystem components and their hierarchy levels
- Step 4. Definition of indicators

3.2.1 Step 1. Definition of MRUs

For MEDREGPROTO, the MRUs hierarchies use those defined for the Mediterranean. For the Mediterranean region, there are four subregions defined. In addition, some of these subregions are shared by different countries. For this purpose, MEDREGPROTO includes an additional MRUs sublevel, which is the EU countries´ Exclusive Economic Zones (EEZ), as it is most likely that data may come directly from Member states and at a broader level, from the Regional Sea Convention (Barcelona Convention). Other lower levels can be defined, e.g., territorial water, Water Framework Directive waterbodies, etc. (Table 3).

Table 3. Mediterranean region, including the four subregions and the different European countries subdivisions for each subregion.

Region	Subregion	Subdivision	Area (km^2)	Source
Mediterranean (1,644,399 km^2)	Western Mediterranean (649,332 km^2)	Italy	310,530	Eionet
		France	111,318	Eionet
		Spain	227,484	Calculated
	Ionian Sea & Central Mediterranean (474,983 km^2)	Italy	214,653	Eionet
		Greece	184,352	Calculated
		Malta	75,978	Borja et al., 2018
	Adriatic Sea (197,856 km^2)	Croatia	55,505	Calculated
		Italy	62,138	Eionet
		Slovenia	214	Eionet
	Aegean-Levantine Sea (402,228 km^2)	Greece	304,166	Calculated
		Cyprus	98,062	Calculated

3.2.2 Step 2. Definition of habitats and species groups

Current version of NEAT allows for the definition of habitats and their data integration for the assessment, being able to assign areas to the different habitats, and perform the assessment and the integration considering such areas. In MEDREGPROTO, both habitats and species groups (provided in Table 2), have been hierarchically included (Figure 3).

For the habitats, benthic and pelagic (and all habitats) have been included, and for each type of habitat, different sub-habitats and criteria of the MSFD are applied. For benthic habitats, the five criteria for Descriptor 6 are included, whereas for pelagic habitats, only one criterion, coming from Descriptor 1, is provided. When indicators are to be applied to all habitats (i.e., HabAll), all criteria (six in total) are available.

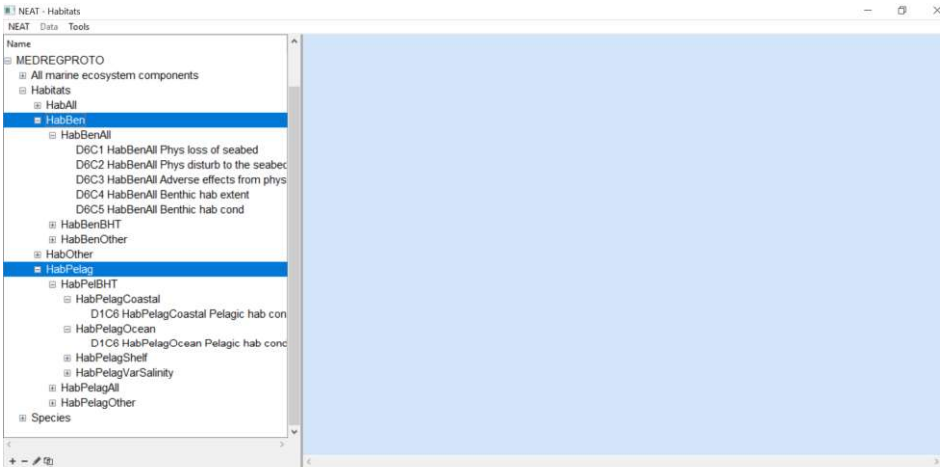


Figure 3. Screenshot corresponding to the hierarchy of habitats, for the individual assessment of different criterion and possible integration across all criteria and habitats.

On the species side, the hierarchy has also been created following that of Table 2 and considering five (out of six) of the criteria included under Descriptor 1 (D1C1-D1C5) (Figure 4). The way it has been done, allows NEAT to integrate outputs at the species level, which otherwise would not be possible with the current version.

With the species and habitats hierarchies defined, it would be possible to obtain an individual assessment of the different criteria, by species or habitats, but also the integrated assessment across species and across habitats. Furthermore, the assessment could be weighted by distribution area of habitats and species, if such information was to be officially provided by Member States.

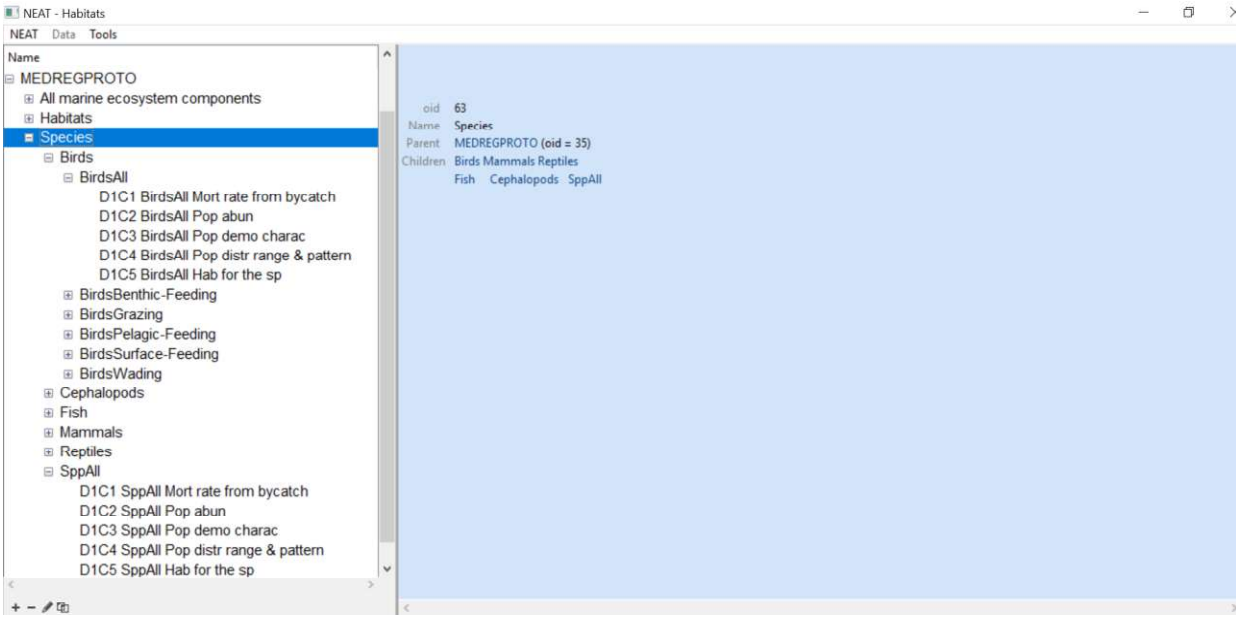


Figure 4. Screenshot corresponding to the hierarchy of species groups, for individual assessment of different criterion and possible integration across all criterion and species.

3.2.3 Step 3. Definition of ecosystem components

The definition of ecosystem components is to be defined with the aim of obtaining a simplified visualization. That is, rather than having so many individual assessment (e.g., one for each criterion and species/habitat), a visualization of the assessment by ecosystem components is possible. The list of ecosystem components includes the major “groups” of the habitats and species groups (Figure 5).

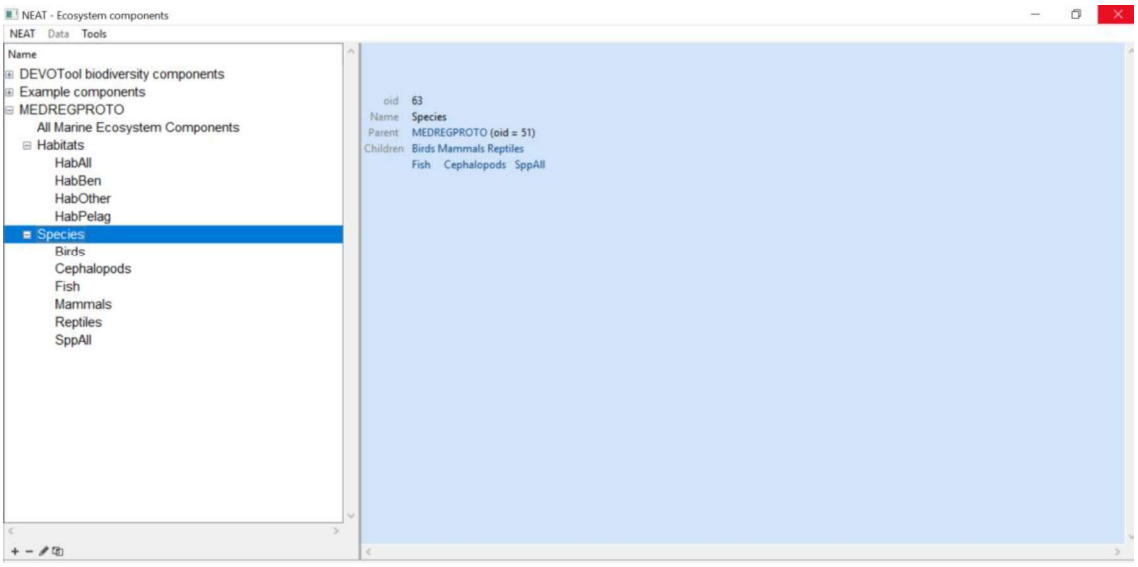


Figure 5. Screenshot corresponding to the list of ecosystem components to be used in a simplified visualization of assessment outputs.

3.2.4 Step 4. Definition of indicators

Finally, a list of general indicators (e.g., total abundance of seabirds) for which information is officially available needs to be created. To facilitate the use of indicators, a specific code is often used to precede the name of the indicator (in this case MEDREG) (Figure 6). It will be in the assessment when the specific indicators will be created (e.g., total abundance of seabirds – *Puffinus mauretanicus*), being each indicator assigned to a MRU, descriptor, criterion (species/habitat groups), ecosystem component, and thresholds and values are provided. A virtual example of this process is provided in Section 3.3.

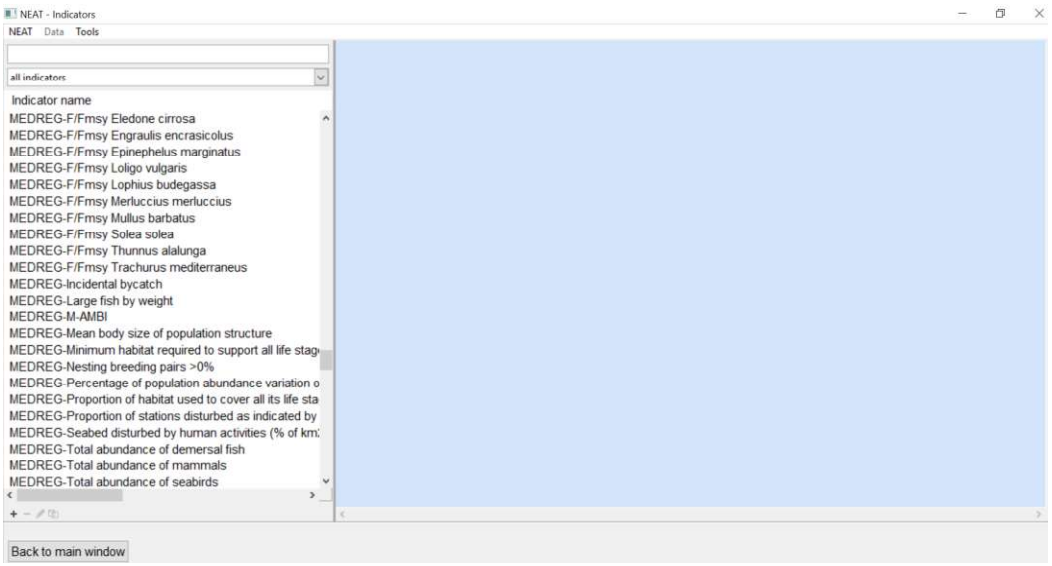


Figure 6. Screenshot including a potential list of general indicators, that are to be used in the assessment by defining specific indicators.

After these four steps, the NEAT user could directly move into the assessment, where specific indicators, associated to the different MRU, descriptor, criterion (species/habitat groups), ecosystem component, and thresholds, are included and used. Although the ultimate objective of NEAT is to integrate information, the outputs of NEAT allows for the visualization of outputs at different levels (i.e., Criterion, Species groups, Habitat groups, Habitats, Ecosystem components) and their possible combinations. Also, the results can be visualized within each MRU or aggregating hierarchically at country level, subregion level or the whole region. The results can be visualized individually or by integrated assessments. An example of how the prototype would work is presented in Section 3.3.

This prototype has been created by adapting the existing version of NEAT, but without modifying it, and it is provided in Annex 1 as a NEAT database. Since this is of high interest to Member States, the idea is that, if funding available, NEAT will be modified so these adaptations could be directly included in the software, and it is easy for Member States to integrate their data and perform the individual and integrated assessment according to the latest Decision.

3.3 Example of application of the prototype

3.3.1 Information used

Since no official data are available, we have developed a virtual example with no real data, which can serve to show the potentiality of the prototype and how to use it when official data was available (Annex 2).

- **MRUs**

We created, within a 'virtual Mediterranean', occupying 15,000 km^2, two subregions (SR): SR1, with 10,000 km^2, and SR2, with 5,000 km^2. Within each subregion, we included two countries: countries 1 (with 2,000 km^2) and 2 (with 8,000 km^2), in SR1; and countries 2 (same as in SR1, but occupying 3,000 km^2) and 3 (with 2,000 km^2), in SR2.

- **Habitats, species groups and criteria**

In order to have a certain variety of data, we created the habitats, species groups and criteria shown in Figure 7.

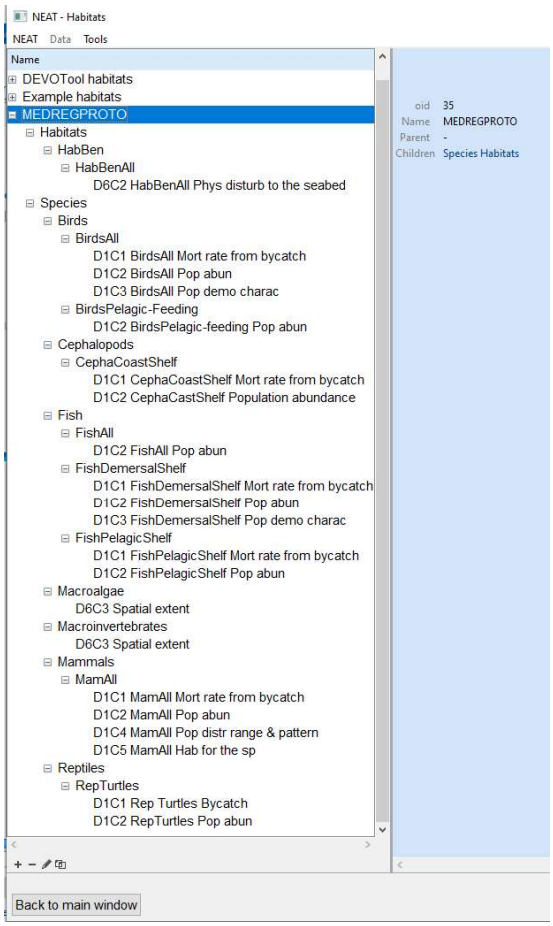


Figure 7. Screenshot corresponding to the habitats, species groups and criteria used in the example of NEAT application.

- **Ecosystem components**

As ecosystem components, we also used a certain variety: Fish, Cephalopods, Seabirds, Mammals, Reptiles, Macroalgae, Macroinvertebrates, and Benthic Habitats.

- **Indicators**

Not having official data, this was a tricky issue, since we 'created' information, by collating real data from AZTI, and adding other data. This has been done in order to have a certain gradient of good/not good status indicators, to show countries/regions, as well as criteria/ecosystem components, in different environmental status. This allowed to show different situations, showing to the stakeholders and competent authorities the potentialities of NEAT applied to the MSFD.

Hence, the indicators and the descriptors used were:

- Abundance of turtles, for reptiles (D1)
- B/B_{msy} (B: Biomass and MSY: Maximum Sustainable Yield) and F/F_{msy} (F: Mortality) for several fish (*Atherina boyeri, Conger conger, Dentex dentex, Dicentrarchus labrax, Diplodus sargus, Engraulis encrasicolus, Epinephelus marginatus, Lophius budegassa, Merluccius merluccius, Mullus*

barbatus, Solea solea, Thunnus alalonga, Trachurus mediterraneus) and cephalopod (*Eledone cirrhosa, Loligo vulgaris*) stocks (D1, D3).

- BENTIX (D6), M-AMBI (D6), Proportion of stations disturbed as indicated by AMBI (D1, D6), for macroinvertebrates
- EEI, for macroalgae (D1, D6)
- Incidental bycatch (D1)
- Large fish by weight (D1)
- Mean body size of population structure; Nesting breeding pairs > 0%, and Total abundance, for Seabirds (D1)
- Minimum habitat required to support all life stages; Percentage of population abundance variation over 10-year period; Proportion of habitat used to cover all its life stages; and total abundance, for mammals (D1)
- Seabed disturbed by human activities (percentage of km^2) (D1, D6)
- Total abundance of Demersal Fish (D1)

For each indicator, we used the worst and best values from literature and the good/not good threshold from intercalibration (e.g., BENTIX, M-AMBI), from literature (e.g., for stocks that from Froese et al., 2018; for some of the mammals that from Saavedra et al., 2018; etc.). In some cases, we have used arbitrary thresholds, just to show the example. An example on how the indicators and MRUs are presented, as well as the values included, can be seen in Figure 8.

Hence, the results from this exercise must be taken only as an orientation of the potentialities of NEAT, not as real results from any assessment.

All analyses were undertaken by weighting by the MRUs surface, and showing the confidence associated to each result.

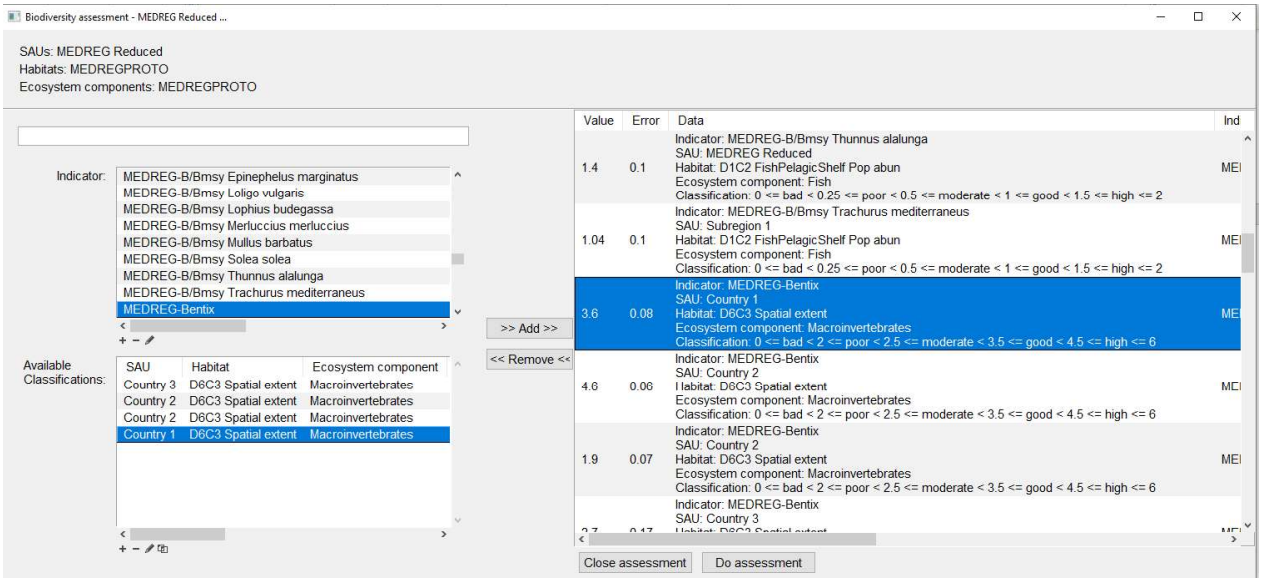


Figure 8. Example of the data included, indicators and Marine Reporting Units (SAU), before undertaken the analysis.

3.3.2 Results from the assessment

Some indicators were set at country level (e.g., those related with macroalgae or macroinvertebrates), but others could be at subregion level (e.g., seabirds, mammals, some fish stocks) and others could be at the whole sea level (e.g., some fish stocks). This explains why in Table 4 some species groups or criteria are empty at country level, but not at the subregion level. This table shows clearly which countries achieve or not GES (e.g., countries in subregion 2 are in worse status than in subregion 1) and then, which species groups or criteria show more problems (e.g., some indicators related to mortality produced by bycatch in cephalopods or mammals).

One question could be: why the whole sea is in worse status than subregion 1, if this is in good status and represents 67% of the total sea? (Table 4). The response is because, in addition to the moderate status of subregion 2 (which is 33% of the sea), there are some indicators associated to the whole sea (e.g., population abundance of all fish) which are in poor or moderate status. Hence, this makes the integrated value lower.

In Table 5 the results at the MRU level are exactly the same, but an aggregation of the results can be seen at the ecosystem component level. Again, it is possible to see how most components associated to biodiversity, such as fish, cephalopods, seabirds, mammals or reptiles do not achieve GES (although some are in GES in subregion 1), whilst macroalgae, macroinvertebrates or benthic habitats are in GES (Table 5). However, some of these ecosystem components represent only a small fraction of the sea (in some cases, data are coming from a single country), but they do not dominate at the global scale, and the picture is that the sea does not achieve GES.

The results can be seen in detail also integrated at the Descriptor level. Here, instead of showing all data (by species group, habitat, criteria, ecosystem component), we have included only the integration at MRU level by descriptor (Table 6). The picture for D1 (biodiversity) is very similar to the whole picture shown in Table 4 with all data. However, for D3 (fishing) the results are different, since the indicators are only at subregion or region level. In addition, some indicators, at the region level, are in GES, explaining why, despite the two subregions are in non-GES, the whole sea is in GES (Table 6). For D6 (seafloor integrity) there are clear differences between the two subregions and the whole sea (Table 6).

Table 4. NEAT assessment by each Marine Reporting Unit (MRU) included in this example. The results are shown at the level of the species groups, type of species and criteria (D1C1, D1, C2, etc.). Blue: High status; Green: Good status (both, High and Good, represent Good Environmental Status -GES-); Yellow: Moderate; Orange: Poor; Red: Bad (these three are non-GES).

						Fish						Cephalopods		Seabirds			Mammals				Reptiles		Macroalgae	
MRU	Area	Weight	NEAT	Status class	Confidence	Pelagic Shelf		Demersal Shelf			All	Coastal Shelf		All populations			All populations				Turtles			
	(km^2)				(%)	D1C1 Mortality (bycatch)	D1C2 Population abundance	D1C1 Mortality (bycatch)	D1C2 Population abundance	D1C3 Population demography	D1C2 Population abundance	D1C1 Mortality (bycatch)	D1C2 Population abundance	D1C1 Mortality (bycatch)	D1C2 Population abundance	D1C3 Population demography	D1C1 Mortality (bycatch)	D1C2 Population abundance	D1C4 Populations distribution range	D1C5 Habitat for the spp.	D1C1 Mortality (bycatch)	D1C2 Population abundance	D6C3 Spatial extent	
Mediterranean	15000	0.50	0.543	moderate	100.0	0.713	0.738	0.558	0.570	0.635	0.316	0.409	0.467	0.648	0.494	0.689	0.482	0.339	0.593	0.650	0.592	0.530	0.619	
Subregion 1	10000	0.17	0.654	good	92.3	0.643	0.610	0.695	0.696	0.635		0.520	0.560	0.722	0.621	0.689	0.597	0.723			0.592	0.500	0.619	
Country 1	2000	0.03	0.773	good	90.7																		0.842	
Country 2	8000	0.13	0.674	good	74.3																		0.591	
Subregion 2	5000	0.08	0.466	moderate	100.0	0.780	0.780	0.375	0.401			0.188	0.280	0.550	0.601		0.253	0.547				0.560		
Country 2	3000	0.05	0.394	poor	66.5																			
Country 3	2000	0.03	0.561	moderate	90.5																			

Table 5. NEAT assessment by each Marine Reporting Unit (MRU) included in this example. The results are shown at the level of the ecosystem component. Blue: High status; Green: Good status (both, High and Good, represent Good Environmental Status - GES-); Yellow: Moderate; Orange: Poor; Red: Bad (these three are non-GES).

MRU	Area (km^2)	Weight	NEAT	Status class	Confidence (%)	Fish	Cephalopods	Seabirds	Mammals	Reptiles	Macroalgae	Macroinvertebrates	Benthic Habitats
Mediterranean	15000	0.50	0.543	moderate	100.0	0.551	0.438	0.518	0.500	0.551	0.619	0.602	0.733
Subregion 1	10000	0.17	0.654	good	93.9	0.651	0.540	0.677	0.660	0.546	0.619	0.760	0.733
Country 1	2000	0.03	0.773	good	90.4						0.842	0.784	0.733
Country 2	8000	0.13	0.674	good	75.0						0.591	0.757	
Subregion 2	5000	0.08	0.466	moderate	100.0	0.584	0.234	0.576	0.400	0.560		0.461	
Country 2	3000	0.05	0.394	poor	67.2							0.394	
Country 3	2000	0.03	0.561	moderate	92.1							0.561	

Table 6. NEAT assessment by each Marine Reporting Unit (MRU) and Descriptor (D1, D3 and D6) included in this example. Blue: High status; Green: Good status (both, High and Good, represent Good Environmental Status -GES-); Yellow: Moderate; Orange: Poor; Red: Bad (these three are non-GES).

MRU	Area (km^2)	Weight	NEAT D1	Status class	Confidence (%)	NEAT D3	Status class	Confidence (%)	NEAT D6	Status class	Confidence (%)
Mediterranean	15000	0.50	0.532	moderate	100.0	0.627	good	98.6	0.616	good	64.7
Subregion 1	10000	0.17	0.624	good	71.6	0.592	moderate	93.2	0.694	good	87.3
Country 1	2000	0.03	0.769	good	86.9				0.773	good	89.8
Country 2	8000	0.13	0.591	moderate	40.0				0.674	good	76.7
Subregion 2	5000	0.08	0.485	moderate	100.0	0.409	moderate	81.0	0.461	moderate	100.0
Country 2	3000	0.05	0.459	moderate	100.0				0.394	Poor	66.6
Country 3	2000	0.03	0.627	good	100.0				0.561	moderate	91.2

4 Application to the Malta official dataset

4.1 Introduction

The MSFD aims at achieving the GES for all seas by 2020 or 2026, for which it requires Member States to carry out the implementation of marine monitoring networks, the assessment of seas and the definition of programmes of measures to minimize human impacts, in six-years management cycles (European Commission, 2008). The GES is based upon 11 qualitative descriptors (D), which includes: D1-Biodiversity, D2-Non-Indigenous Species, D3-Commercial fish, D4-Foodwebs, D5-Eutrophication, D6-Seafloor integrity, D7-Hydrography, D8-Contaminants in the environment, D9-Contaminants in seafood, D10-Litter, and D11-Noise/energy.

In the first MSFD management cycle, the implementation of the European Commission (2010) decision, which included the methodological standards to determine GES, revealed that there was insufficient detail and clarity to support the determination of GES (Palialexis et al., 2014); this leading to its revision a few years later (European Commission, 2017). This revision presented a more developed framework on the way in which the assessment should be undertaken during the second management cycle (European Commission, 2018a, 2019), including revised criteria and methodological standards for assessment. This framework includes the (i) species groups (i.e., seabirds, mammals, reptiles, fish, and cephalopods); (ii) habitat types; (iii) ecosystem structure, functions, and processes (i.e., physical, hydrological, chemical, and biological); and (iv) anthropogenic pressures (i.e., biological, physical, contaminants, litter, and energy/noise), to be considered when determining/assessing the GES.

Within the framework of the MSFD, GES has been progressively refined from its high-level definition in Art. 3(5), via the Descriptors of MSFD (Annex I), the elements of MSFD (Annex III), and the criteria and methodological standards of Art. 9(3); through to the more specific determinations of Art. 9(1). In line with Art. 9(3), the revised Commission Decision (European Commission, 2017) lays down set criteria (i.e., 'distinctive technical features that are closely linked to qualitative descriptors') and methodological standards for Member States to follow 'to ensure consistency and to allow for comparison between marine regions or subregions of the extent to which GES is being achieved'. Within this context, Member States were to define GES in their marine waters and select the most relevant elements to be included for their second assessment cycle (European Commission, 2020).

Furthermore, Member States must follow certain specifications/requirements in the GES assessment (European Commission, 2017, 2018a, 2019, 2020), including: (i) elements for assessment and indication of whether GES has been achieved for those; (ii) criteria for assessment of the elements, including parameters to be used; (iii) threshold values for assessing quality and trends (including distinguishing GES from non-GES); (iv) assessment scales (the so-called Marine Reporting Units or MRUs); (v) criteria to express the extent to which GES is achieved; (vi) approaches to and methods for data collection and monitoring; (vii) aggregation methods for the data (spatial, temporal) (Walmsey et al., 2017; European Commission, 2018a); and (viii) units of measurement for the criteria.

Both in the first and the second (which is currently underway) cycles, the number of Member States which have undertaken quantitative assessments (i.e., using quantitative thresholds), or aggregated the different criteria and/or descriptors in holistic assessments, remains low (Palialexis et al., 2014, European Commission, 2020). This is probably due to the few available tools that enable the aggregation of

information at different scales (spatial, temporal) and the integration of indicators of a different nature (Borja et al., 2016).

To demonstrate the possibilities of integrating indicators, criteria, and descriptors, the official MSFD data and reporting outcomes from a small Mediterranean country, Malta (ERA, 2020a, 2020b), have been used after authorisation. Since this country has quantitative data and adequate information from a relatively small number of MRUs, it constitutes a good candidate to compare the results obtained from the official evaluation and those obtained after performing an integrative assessment with the NEAT (Borja et al., 2016). As commented in Section 3, NEAT has been tested and validated in many locations around Europe (Uusitalo et al., 2016; Pavlidou et al., 2019), outside Europe (Nemati et al., 2017) and covering large regional seas (Kazanidis et al., 2020) or even the whole Europe (Borja et al., 2019c).

4.2 Methods

4.2.1 Malta official reporting for the MSFD: adaptions within the NEAT approach

Malta submitted the initial assessment of environmental status of its marine waters in October 2013[1], as part of the first MSFD implementation cycle. At that time, the report did not fully address the criteria for assessment of GES of marine waters, as stipulated by the first MSFD Commission Decision (European Commission, 2010). Shortcomings of such initial assessment were particularly related to the qualitative nature of the GES definitions, the limited ambition of the environmental targets and the limited reporting of pressure impacts. Hence, for the second implementation cycle, Malta implemented a monitoring and assessment programme, through an EU funded project, during the period 2017-2019 (Borja et al., 2019a, 2019b). This project provided updated datasets that enabled the review of the initial assessment of environmental status for Malta's marine waters, in accordance with the new MSFD requirements (European Commission, 2017). Such targeted data collection process facilitated the application of the criteria laid down by the European Commission (2017). In addition, data and information robustness and updated environmental targets, focusing on the main pressures that are considered to put achievement of GES at risk, resulted in an improved quantitative environmental status assessment (ERA, 2020a, 2020b).

Malta officially reported data on all 11 descriptors. Whilst quantitative assessment was undertaken for most of the descriptors, in some cases -D2 and D11- the assessment was based on qualitative information. Meanwhile possibilities for assessment for D4 and D7, are pending further developments of essential aspects such as indicators and baseline data. Therefore, for the purpose of the comparison between the official and the integrative assessment, descriptors 2, 4, 7 and 11 have been excluded from the assessment comparison with NEAT (Annex 3, Table S1). Hence, even if the focus of this activity was on D1 and D6 only, we have used indicators related to seven descriptors to perform the exercise, making the comparison more robust. For the purpose of this study, 19 out the 52 criteria[2] applied lacked data for Malta; meanwhile for nine criteria, either assessment method or thresholds of GES/non-GES were unavailable, as drawn from Malta's official report (ERA, 2020a). Further, it should be noted that in contrast to primary criteria (as defined in European Commission, 2017), not all secondary criteria were applied in view of their non-

[1] https://era.org.mt/en/Pages/MSFD-Initial-Assessment.aspx

[2] It should be noted that the number of criteria quoted here (52) is higher than what is enlisted in the revised European Commission Decision (European Commission, 2017); in view of differences in the application of criteria for D1 (biodiversity) -mammals, seabirds, fish, and cephalopods, within the NEAT approach.

mandatory nature. Hence, the quantitative assessment was finally based upon a total of 24 criteria, covering 7 descriptors (D1, D3, D5, D6, D8, D9 and D10), and including birds, mammals, reptiles, fish, cephalopods, and pelagic and benthic habitats (Annex 3, Table S1). The 24 criteria encompassed a total of 336 indicators. These indicators having also been applied within the national assessment reported to the European Commission (Annex 3, Table S2, information obtained from ERA, 2020a, 2020b).

4.2.2 Marine Reporting Units

The MRUs applied within the scope of the MSFD assessment and making up the Maltese waters are shown in Figure 9. These comprise of:

- Nine coastal water bodies of sizes ranging between 13 and 97 km^2 and covering a total area of 400 km^2. These are referred to as WFD waterbodies noting original designation under this directive.
- Territorial waters and internal waters, extending from the low-water coastline to the 12 nm (nautical mile) limit, and covering a total of 4,028 km^2.
- The Fisheries Management Zone (FMZ) and internal waters, extending from the low-water coastline to the 25 nm limit, and covering a total of 11,678 km^2.
- The designated area for hydrocarbon exploration and exploitation (referred to and HCexp within the scope of this study) and internal waters extending from the low water coastline to the outer limit of the continental shelf, and covering a total of 75,475 km^2.

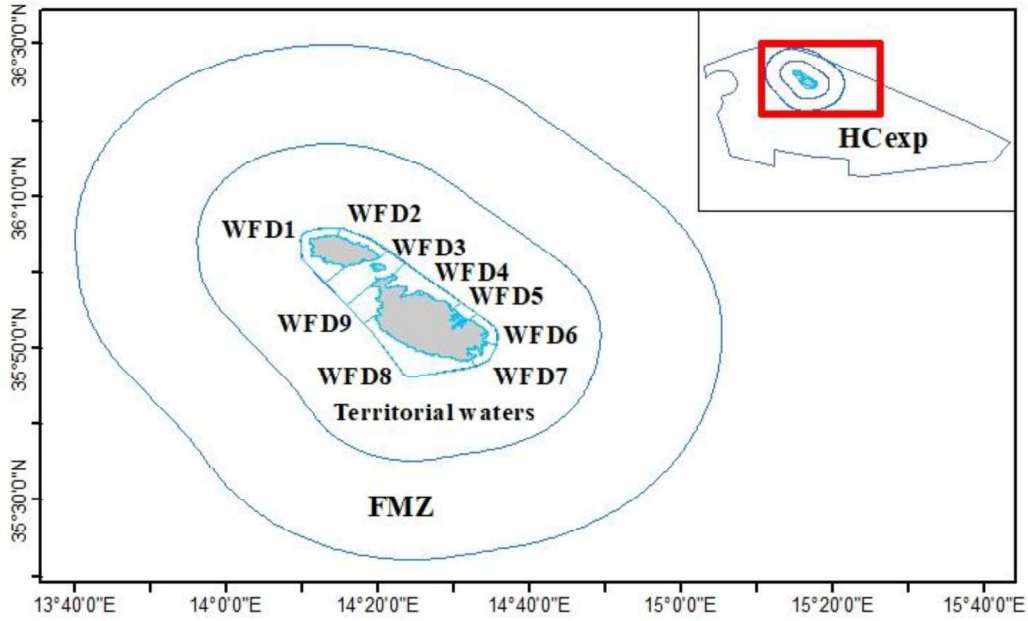


Figure 9. Map showing the Maltese Marine Reporting Units (MRUs), including nine coastal water bodies as designated under the Water Framework Directive (WFD 1 to WFD 9), Territorial waters and internal waters, the Fisheries Management Zone (FMZ) and internal waters, and the area designated for hydrocarbon exploration and exploitation (HCexp) and internal waters. The given acronyms are solely used within the scope of this study, for the benefit of legibility.

Indicators are associated to specific MRUs and then the MRUs are aggregated hierarchically, as indicated in Figure 10.

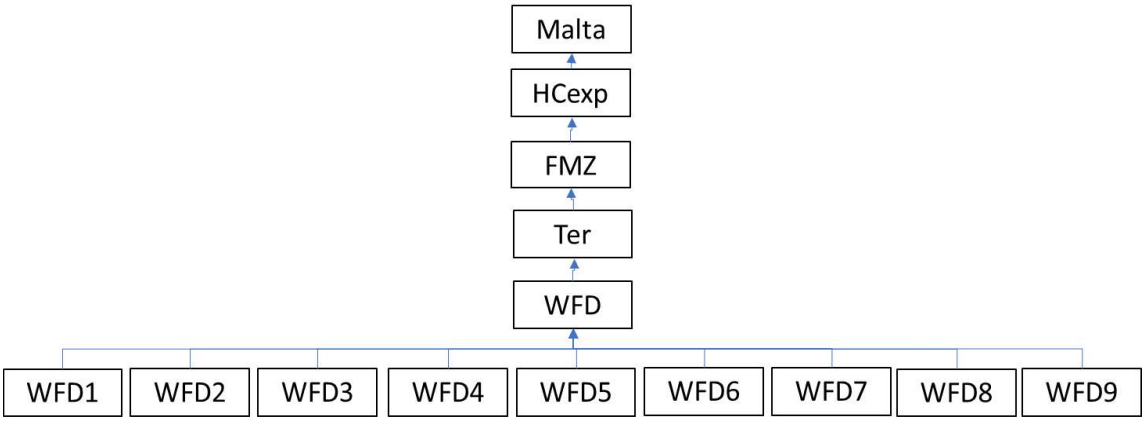


Figure 10. Nested aggregation of the Maltese Marine Reporting Units (MRUs) within NEAT. HCexp: area designated for hydrocarbon exploration and exploitation; FMZ: fisheries management zone; Ter: territorial waters; WFD: coastal water bodies as designated under the Water Framework Directive.

4.2.3 MSFD Criteria and ecosystem components: adaptations within the NEAT tool

The adaptation of NEAT to the New Decision was done within the "habitat" section of the NEAT tool (see Section 3). The starting point to define this hierarchy were the "Species, Habitats and All marine ecosystem components", as well as the "Criteria", included in the European Commission (2019) document. For an example, within the "species", birds, mammals, reptiles, fish, cephalopods, were included; for each of these ecosystem components, several species groups were defined at a lower level (e.g., for birds, the included groups were surface feeding, pelagic feeding, benthic feeding, grazing, and wading birds). Finally, each of these groups contained all the relevant descriptor criteria, which were coded as DXCY_name (e.g., Descriptor 1, Criteria 1_name of the indicator was D1C1_name). Following with the birds' example, each of the mentioned groups of birds, included criteria D1C1, D1C2, D1C3, D1C4 and D1C5. That is, for example, "Criterion D1C1 population abundance", would be available for all five groups of birds. Additional components were included in the hierarchy as appropriate, reflecting available data (e.g., crustaceans, seagrasses). Further detail on these adaptations to the NEAT tool can be consulted in the NEAT database provided (Annex 4; MEDREGPROTO_prototype-Malta.db).

Since each indicator describes a specific ecosystem component, a total of 12 ecosystem components have been defined: (1) water column (associated with nutrients, oxygen, contaminants in water, or floating litter); (2) seafloor (associated to loss or disturbance of the seabed, and litter); (3) sediment (contaminants); (4) macroalgae, including quality indices such as CARLIT (Ballesteros et al., 2007) or species such as Lythophyllum; (5) seagrasses, the *Posidonia* Rapid Evaluation Index (PREI) (Gobert et al., 2009); (6) macroinvertebrates, the Bentix quality index (Simboura and Zenetos, 2002); (7) Crustacea (indicators of quality, contaminants); (8) cephalopods (indicators of quality, contaminants); (9) fish (indicators of quality, contaminants); (10) reptiles; (11) birds; and (12) mammals. It is important to clarify that such grouping per

ecosystem component reflects the approach adopted when applying the NEAT and is not necessarily reflecting the revised Commission Decision (European Commission, 2017).

4.2.4 Indicators included and associated descriptors

To select the indicators, the criteria of the European Commission (2017) decision have been followed, as far as possible, as indicated in Annex 3, Table S1. In that table, primary criteria should be used to ensure consistency across the EU, and secondary criteria should be decided by Member States, where necessary, to complement a primary criterion or when, for a particular criterion, the marine environment is at risk of not achieving or not maintaining GES.

From the 336 indicators applied within the national assessment, 282 indicators have been used in the NEAT analyses (see Annex 3, Table S2). The remaining 54 were omitted in view of the absence of quantitative data or quantitative threshold values for the definition of status (Annex 3, Table S2). The dependence on quantitative data and thresholds can be considered as a shortcoming of NEAT approach, noting that the absence of such information for all criteria is a common occurrence for many of the EU member states, preventing the application of this tool in its entirety. The generic indicators used, the associated descriptors, criteria and other details can be consulted in Table 7.

Table 7. Numbers of indicators used/not-used in the NEAT analysis, to assess the environmental status in Malta, related to the seven qualitative descriptors of the Marine Strategy Framework Directive, the criteria (see Table S1 for description), type of criterion (P: primary, S: secondary), and number of species, habitats or matrices associated to each indicator.

Descriptor	Criteria	Type	Indicators	Used	Not used	Species/habitats
D1-Birds	D1C1	P	Incidental bycatch	3	0	3 seabirds
	D1C2	P	Population abundance	3	0	3 seabirds
	D1C3	S	Population demographics	2	0	2 seabirds
	D1C4	S	Distributional range	0	3	3 seabirds
D1-Mammals/reptiles	D1C1	P	Incidental bycatch	3	0	3 mammals
	D1C2	P	Population abundance	4	0	2 mammals, 1 reptile
	D1C4	P	Distributional range	1	0	1 reptile
	D1C5	P	Habitat extent	0	1	1 reptile
D1 - Fish/Cephalopods	D1C2	P	Population abundance	36	16	30 fish, 9 cephalopods
	D1C3	P	Population demographics	10	4	9 fish, 2 cephalopods
	D1C4	S	Distributional range	1	24	16 fish, 8 cephalopods
D1 – Pelagic habitats	D1C6	P	Composition and abundance	0	2	coastal and shelf
D1/D6 –Benthic habitats	D6C4	P	Habitat loss	7	0	7 habitats
	D6C5	P	Habitat disturbance	6	0	6 habitats
D3 – Commercial fish	D3C1	P	Fishing mortality	30	0	23 fish, 4 crustacea, 3 cephalopods
	D3C2	P	Spawning Stock Biomass	63	1	39 fish, 4 crustacea, 4 cephalopods
	D3C3	P	Size distribution	30	0	11 fish, 3 crustacea, 1 cephalopod
D5 - Eutrophication	D5C1	P	Nutrient concentration	4	0	4 nutrients
	D5C2	P	Chlorophyll a concentration	1	0	-
	D5C4	S	Transparency	1	0	-
	D5C5	P	Oxygen saturation	1	0	-
D8 - Pollutants	D8C1	P	Concentration of contaminants	47	3	22 in water, 13 sediments, 15 biota
D9 - Pollutants in seafood	D9C1	P	Concentration of contaminants	25	0	15 in fish, 6 crustacea, 4 cephalopods
D10 - Litter	D10C1	P	Amount of litter	4	0	beach, floating, seabed (shallow, deep)
			TOTAL	282	54	

For the NEAT analyses, each of the used indicators has a range of variation (from worst to best values, i.e., reference conditions), and at least a threshold between GES/non-GES (i.e., moderate) status. In most cases (257 out of the 282 indicators used), the threshold values included in the NEAT calculations were those set in the official assessment (Annex 3, Table S2; ERA, 2020a). The origin of those thresholds is varied, including national thresholds intercalibrated with other Member States (European Commission, 2018b); regional thresholds for nutrients and baselines for litter as set for the Mediterranean; or European thresholds for contaminants in the environment or in seafood, among others (Annex 3, Table S2, columns K and L). In few cases (e.g., in D6, for habitat loss and habitat disturbance), the thresholds used were like those proposed by Kazanidis et al. (2020). Finally, in 15 cases, referred mostly to incidental bycatch and population abundance of seabirds and mammals, the thresholds were based on expert judgment, but supported on information and data from ERA (2020a) and the Habitats and Birds Directive. In some cases (e.g., indicators intercalibrated within the WFD, such as chlorophyll, Bentix, PREI, CARLIT, etc.; European Commission, 2018b), there are also additional thresholds (High/Good, Moderate/Poor, Poor/Bad), and these have been used in the calculations. When these intermediate thresholds are not available, NEAT calculates them by interpolation with the reference conditions (Berg et al., 2017). It should be noted that this approach has been used only in NEAT, but not in the official assessment.

As commented above, although data is available for some descriptors (D2, D4, D7, and D11), this information has not been used due to the absence of thresholds.

4.2.5 Assessment of the environmental status

The assessment has been done in accordance with Annex III of MSFD and with the criteria and methodological standards in the new Commission Decision (European Commission, 2017).

The database of the Malta monitoring programme was interrogated for each indicator, obtaining the mean and standard error value of each station associated to the different MRUs, for the period June 2017 to June 2019. For indicators that were not included in the monitoring programme, such as those associated to D1 (biodiversity of birds, reptiles, mammals, fish, and cephalopods) and D3 (commercial fish), the information was extracted from the Malta MSFD report (ERA, 2020a, 2020b) and the calculation was undertaken following the same procedure. The mean and standard error of each indicator were included in NEAT, with each indicator associated to a descriptor, a type of species/habitat, an ecosystem component, a criterion of those in Table 7, and a MRU (see details in Annex 3, Table S2).

Once all indicators were included in NEAT, the following calculations were carried out: (i) by weighting for MRU surface, by ecosystem component and criteria, including all descriptors; (ii) without weighting by MRU surface, by ecosystem component and criteria, including all descriptors; and (iii) by each of the descriptors independently.

The NEAT assessments are carried out at different MRUs, at Malta level, but also integrating the descriptors studied, and individually for each descriptor. The assessment can be consulted also at each ecosystem component level (i.e., macroinvertebrates, macroalgae, etc.), looking for those which may need management measures, if the status is not good. The confidence associated to each assessment and scale is also presented, based on 1000 Monte-Carlo iterations.

All the information included in the NEAT software is available in the database provided as Supplementary Material, that can be opened using NEAT (Annex 4, MEDREGPROTO_prototype-Malta.db).

4.3 Results

All the calculation results of NEAT assessment can be consulted in Annex 3: weighting and non-weighting by MRU area (Tables S3 and S4, respectively); weighting and non-weighting by MRU area and sorted by ecosystem components (Tables S5 and S6, respectively); and weighting by MRU area and sorted by each descriptor (D1/D6: Table S7; D1: Table S8; D3: Table S9; D5: Table S10; D6: Table S11; D8: Table S12; D9: Table S13; and D10: Table S14). This information has been summarized in Annex 3, Table S15, showing the results by weighting and non-weighting by MRU area, and for each of the criterion and ecosystem components.

4.3.1 Comparison of weighting by MRU and non-weighting in the NEAT analysis

Taking into account the surface area of each MRU when nesting the results at the level of the WFD areas, territorial waters, FMZ and HCexp, and integrating to the whole Malta waters, filters (weighting and non-weighting by MRU) have been used. When comparing the outputs between weighting by the MRUs and non-weighting using NEAT, the status assessment of descriptors is very similar except for the Biodiversity and Marine litter descriptors (D1 and D10) (Figure 11).

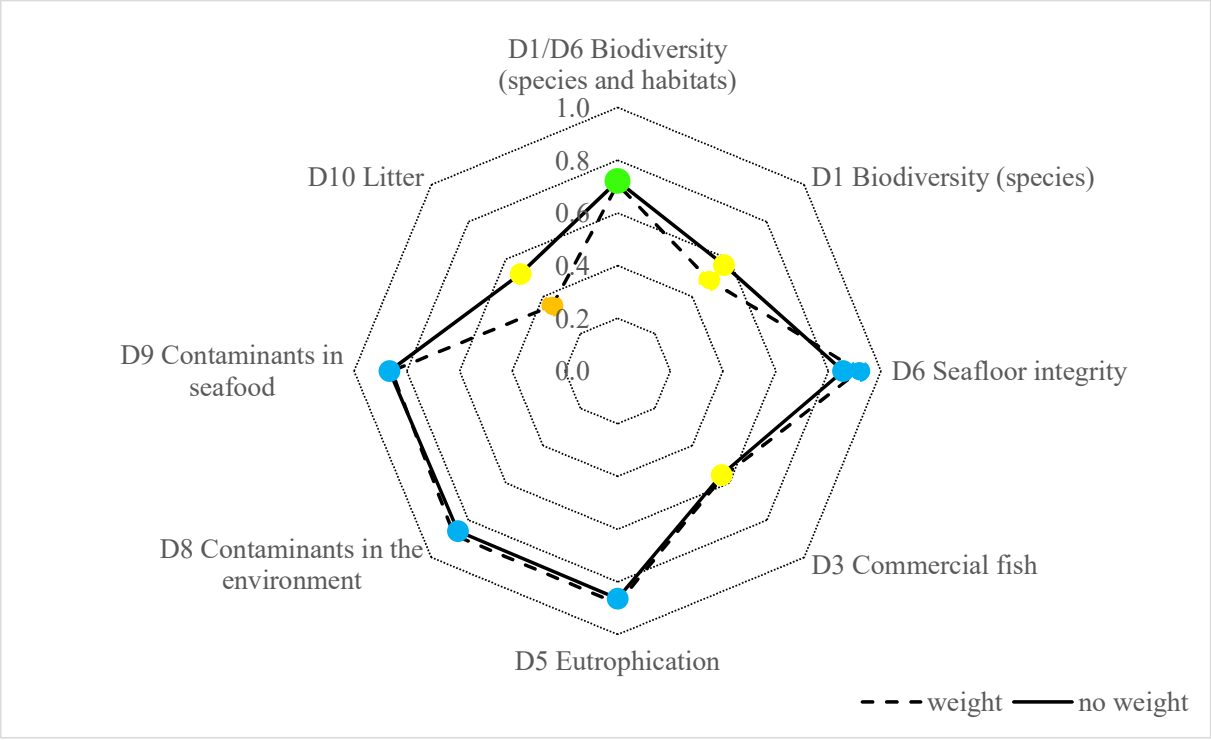


Figure 11. Comparison of the environmental status, at descriptor (D) level, when weighting by the Marine Reporting Units surface area and non-weighting, using NEAT. Blue: high status; Green: good status; Yellow: moderate status; Orange: poor status.

Similarly, when comparing the two assessments at the ecosystem component level, the outputs are highly similar, with some differences (including change of quality class) in sediment and macroalgae (Figure 12).

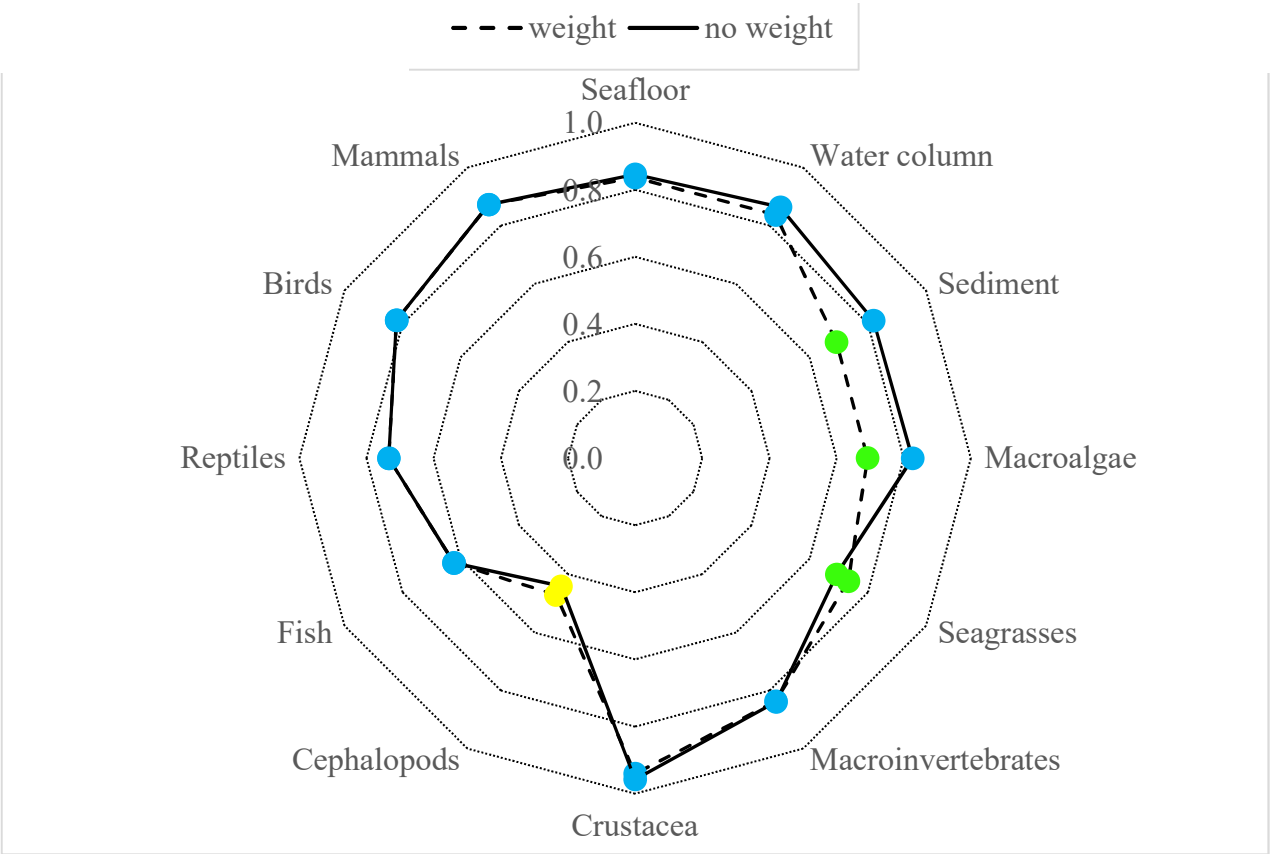


Figure 12. Comparison of the environmental status, at ecosystem component level, when weighting by the Marine Reporting Units surface area and non-weighting, using NEAT, using NEAT. Blue: high status; Green: good status; Yellow: moderate status; Orange: poor status.

4.3.2 Global results when weighting by MRU

Taking into account the results from previous section, the results after weighting by MRU surface have been investigated. In this case, more weight is given to indicators associated with MRUs with a large spatial coverage. Thus, the overall assessment of Malta is a weighted average of indicators. In Table 8, each MRU is integrated by column, including criteria and descriptors, and each criteria and descriptor is integrated by row, including all MRUs.

The global status of Malta is good, which is mainly driven by the GES of the HCexp MRU, which represents the total Malta's marine area, since most of the other MRUs are in high status (Table 8). The confidence of the result is near 100% in all cases, but FMZ MRU, which is 61.1% (Table 8).

In general, from NEAT results, the status of coastal MRUs seems to be better than that in offshore MRUs; there are fewer indicators and criteria associated to the WFD areas, with none or few indicators for descriptors 1, 6, 3, 9 and 10 (Table 8). However, within coastal MRUs, WFD5 and WFD6 show lower NEAT values for some criteria, including few in non-GES, such as habitat condition based on *Posidonia oceanica* (D6C5), chlorophyll concentration (D5C2) or sediments (Table 8).

Table 8. Environmental status values, using NEAT (Nested Environmental status Assessment Tool), weighted by Marine Reporting Units (MRU) area, for each MRU, criteria (C) and descriptor (D) of the Marine Strategy Framework Directive, as well as for each ecosystem component. Key: HCexp: Hydrocarbon exploration; FMZ: fisheries management zone; Ter: territorial waters; WFD: Water Framework Directive water bodies; UPBT: Ubiquitous, Persistent, Bioaccumulative and Toxic substances. Blue: high status; Green: good status; Yellow: moderate status; Orange: poor status.

MRU	Malta	HCexp	FMZ	TER	WFD	WFD1	WFD2	WFD3	WFD4	WFD5	WFD6	WFD7	WFD8	WFD9
Area (km^2)	75475	75475	11678	4028	400	50.1	22.9	86.1	57.9	13.3	16.8	17.6	97.4	38.3
Total MRU weight	0	0.825	0.127	0.044	0.002	0	0	0.001	0	0	0	0	0.001	0
NEAT value	0.733	0.714	0.810	0.851	0.827	0.844	0.849	0.863	0.850	0.765	0.819	0.840	0.857	0.833
Confidence (%)	100	100	61.1	100	100	100	100	100	100	98.7	93.2	100	100	94.6
D1/D6 Biodiversity (species and habitats)	0.709	0.712	0.662		0.721	0.805	0.801	0.857	0.853	0.821	0.765	0.789	0.850	0.767
D1 Biodiversity (species)	0.495	0.466	0.662											
D1C1 Birds Pelagic-Feeding bycatch	1.000		1.000											
D1C1 Cetacean Small bycatch	1.000		1.000											
D1C2 Birds Pelagic-feeding Pop abun	0.816		0.816											
D1C2 Cephalopods Coast Shelf Pop abun	0.434	0.436	0.358											
D1C2 Cephalopods Deepsea Pop abun	0.425	0.433	0.283											
D1C2 Fish Coastal Pop abun	0.393		0.393											
D1C2 Fish Deepsea Pop abun	0.504	0.502	0.544											
D1C2 Fish Demersal Shelf Pop abun	0.392	0.388	0.486											
D1C2 Cetacean Small Pop abun	0.744		0.744											
D1C2 Turtles Pop abun	0.794		0.794											
D1C3 Birds Pelagic-feeding Pop demo	0.647		0.647											
D1C3 Cephalopods Coast Shelf Pop demo	0.467		0.467											
D1C3 Fish Deepsea Pop demo	0.581	0.580	0.616											
D1C3 Fish Demersal Shelf Pop demo	0.582	0.584	0.544											
D1C4 Cephalopods Coast Shelf Pop distr	0.383		0.383											
D1C4 Turtles Pop distr	0.674		0.674											
D6 Seafloor integrity	0.916	0.917			0.721	0.805	0.801	0.857	0.853	0.821	0.765	0.789	0.850	0.767
D6C4 Bathyal Upper Rock habitat extent	0.996	0.996												
D6C4 Circalittoral Coarse Sed habitat Extent	1.000	1.000												
D6C4 Infralit Mixed Sed habitat extent	0.996	0.996												
D6C4 Infralit Rock Benthic habitat extent	0.996	0.996												
D6C4 Littoral Biogenic Rock habitat extent	1.000	1.000												
D6C4 Littoral Rock habitat extent	0.957	0.957												
D6C4 Other Benthic habitat extent	0.998	0.998												
D6C5 Benthic habitat condition	0.912				0.912	0.944	1.000	0.888	0.928	0.832	0.872	0.747	0.960	0.840
D6C5 Bathyal Upper Rock habitat condition	0.632	0.632												
D6C5 Circalittoral Coarse Sed habitat cond	0.322	0.322												
D6C5 Infralit Mixed Sed habitat condition	0.837				0.837		0.773	0.875	0.953	0.810	0.838	0.963	0.767	0.747
D6C5 Infralittoral Rock habitat condition	0.613				0.613									
D6C5 Other Benthic habitat condition	0.733				0.733	0.666	0.630	0.809	0.676		0.584	0.657	0.824	0.714
D3 Commercial fish	0.566	0.568	0.524											
D3C1 Mortality rate	0.632	0.633	0.618											
D3C2 Spawning stock biomass	0.466	0.470	0.382											
D3C3 Population age/size distribution	0.576	0.576	0.573											
D5 Eutrophication	0.883		0.888	0.871	0.827	0.819	0.832	0.813	0.816	0.737	0.815	0.816	0.835	0.810
D5C1 Nutrient concentrations	0.972		0.973	0.972	0.957									
D5C2 Chlorophyll-a concentration	0.860		0.850	0.937	0.867	0.908	0.920	0.873	0.859	0.525	0.838	0.808	0.894	0.877
D5C4 Transparency	0.914		0.954	0.843	0.723									
D5C5 Oxygen saturation	0.803		0.823	0.763	0.803	0.790	0.802	0.798	0.801	0.807	0.807	0.818	0.816	0.787
D8 Contaminants in the environment	0.880	0.887		0.792	0.929	0.951	0.954	0.952	0.914	0.737	0.909	0.967	0.909	0.977
D8C1 Non UPBTs Contaminants	0.985	0.988		0.947	0.935	0.949	0.935	0.948	0.939	0.787	0.908	0.952	0.923	0.973
D8C1 UPBTs Contaminants	0.775	0.785		0.637	0.923	0.953	0.973	0.957	0.888	0.687	0.910	0.981	0.895	0.982
D9 Contaminants in seafood	0.858	0.857		0.865	0.958			0.958						
D9C1 Contaminants Seafood	0.858	0.857		0.865	0.958			0.958						
D10 Litter	0.350	0.343			0.968									
D10C1 Litter (excluding micro litter)	0.350	0.343			0.968									
Ecosystem components														
Seafloor	0.836	0.836			0.968									
Water column	0.842	0.775	0.888	0.874	0.841	0.850	0.850	0.840	0.837	0.772	0.844	0.842	0.852	0.838
Sediment	0.689			0.666	0.924	0.986	0.986	0.987	0.902	0.556	0.865	0.989	0.898	0.992
Macroalgae	0.692				0.692	0.944	1.000	0.888	0.928	0.832	0.872	0.747	0.960	0.840
Seagrasses	0.733				0.733	0.666	0.630	0.809	0.676		0.584	0.657	0.824	0.714
Macroinvertebrates	0.837				0.837		0.773	0.875	0.953	0.810	0.838	0.963	0.767	0.747
Crustacea	0.940	0.939	0.507	0.978	0.963			0.963						
Cephalopods	0.469	0.476	0.344											
Fish	0.623	0.626	0.503	0.665	0.950			0.950						
Reptiles	0.734		0.734											
Birds	0.821		0.821											
Mammals	0.872		0.872											

Despite NEAT application results on a global good status, some descriptors do not achieve GES. For example, D1 (biodiversity) is in moderate status mainly due to cephalopods and fish in coastal and/or deep sea for criterion D1C2 (population abundance), D1C3 (population demographic characteristics), and D1C4 (population distribution range) (Table 8).

D6 (seafloor integrity) is in high environmental status, however, the benthic habitat condition (D6C5) for the circalittoral coarse sediment is in poor status (Table 8), based on the indicator for extent of disturbed seafloor. Meanwhile, commercial fish and shellfish (D3) is in moderate status, based on the moderate status for the spawning stock biomass (D3C2) and population age/size distribution (D3C3), but good status of fishing mortality rate (D3C1), in this case close to the threshold of good/not good (Table 8).

On the other hand, D5 (eutrophication), D8 (contaminants in the environment) and D9 (contaminants in seafood) are in high environmental status globally and in most of the MRUs (Table 8).

Finally, the poor environmental status of D10 (marine litter), detected by NEAT, is mainly associated with the poor status of floating and seafloor litter in the HCexp MRU, which contrasts with the high status of beach litter in the WFD MRUs (Table 8).

Looking at the ecosystem components, practically all are in good or high status (i.e., achieving GES), excepting cephalopods in HCexp and FMZ, fish and crustacea in FMZ, seagrasses in WFD6 and sediments in WFD5 (Table 8).

4.3.3 Comparison between the official assessment and NEAT assessment

Malta official reporting was carried out in most cases at the indicator level, integrating quantitative outcomes for indicators/criteria per descriptor where possible, and complimenting with qualitative evaluation where necessary. It is therefore difficult to compare the official assessment and the results obtained using NEAT, except at lower levels on the integration hierarchy (i.e., indicators, criteria). An attempt to do this comparison is done in Table 9, in which the results for the integrated assessment done using NEAT (per criterion, per descriptor and for all descriptors, at Malta level) is shown aside a comparative classification of the status (good *vs.* not good *vs.* not assessed) of the indicators as per the NEAT assessment, and as per Malta's official assessment[3].

The MRUs applied in the NEAT approach for the specific indicators reflect the MRUs applied within the national assessment, with some exceptions. Within Malta's national assessment, species under D1 (Fish) and D3 (Commercial fish and shellfish) were assessed at the FMZ scale and at the scale of the General Fisheries Commission for the Mediterranean (GFCM) geographical sub-area (GSA) 15, the latter reflecting the regional scale for fisheries data collection. Meanwhile, within the NEAT approach, in addition to assessment at FMZ, indicators for these descriptors were instead assessed at HCexp scale. In doing so, it was assumed that data for the GSA 15 area was also representative for the HCexp area.

[3] For both classifications, these numbers reflect indicators considered within the scope of this study (as reflected in Annex 3, Table S2) and do not represent the national assessment in its entirety.

Table 9. Malta environmental status values, using NEAT (Nested Environmental status Assessment Tool), for each criterion (C) and descriptor (D) of the Marine Strategy Framework Directive; and a comparison of the classification of indicators as per results in NEAT vs. classification of indicators as per results in the official assessment. Indicators 'Not assessed' in the NEAT assessment represent those omitted in view of the absence of quantitative data or quantitative threshold values. For indicators listed as 'Not assessed' in Malta's official assessment, a proper assessment was not possible in view of data limitations. For both classifications, these numbers reflect indicators considered within the scope of this study (as reflected in Annex 3, Table S2) and do not represent the national assessment in its entirety. Key: NEAT values: Green-good status, Red-not good; Classification of indicators: Green: highest number of indicators in good status, Red: highest number of indicators in 'not good' status, Yellow: equal numbers of indicators in good/not good status OR indicators not assessed. UPBT: Ubiquitous, Persistent, Bioaccumulative and Toxic substances; NA: not assessed.

Descriptors and criteria	NEAT values	Classification of selected indicators as per results in NEAT (nr)			Classification of selected indicators as per results in Malta's official assessment (nr)		
		Good	Not good	NA	Good	Not good	NA
STATUS IN MALTA, BASED ON ALL DESCRIPTORS=	**0.733**	**159**	**123**	**31**	**175**	**135**	**3**
D1/D6 Biodiversity (species and habitats)	**0.709**	**36**	**39**	**28**	**49**	**51**	**3**
D1 Biodiversity (species)	**0.495**	**24**	**38**	**28**	**38**	**51**	**1**
D1C1 Birds Pelagic-Feeding Mortality rate from bycatch	1.000	3			3		
D1C1 Cetacean Small Mortality rate from bycatch	1.000	3			3		
D1C2 Birds Pelagic-feeding Population abundance	0.816	3			3		
D1C2 Cephalopods Coastal Shelf Population abundance	0.434	1	10	1	2	10	
D1C2 Cephalopods Deepsea Population abundance	0.425		2			2	
D1C2 Fish Coastal Population abundance	0.393		2	2	1	3	
D1C2 Fish Deepsea Population abundance	0.504	3	10	3	6	10	
D1C2 Fish Demersal Shelf Population abundance	0.392	3	5	10	10	8	
D1C2 Cetacean Small Population abundance	0.744	2		1	2		1
D1C2 Turtles Population abundance	0.794	1			1		
D1C3 Birds Pelagic-feeding Population demography characteristics	0.647	2			2		
D1C3 Cephalopods Coastal Shelf Population demography characteristics	0.467		1	1		2	
D1C3 Fish Deepsea Population demography characteristics	0.581	2	2		2	2	
D1C3 Fish Demersal Shelf Population demography characteristics	0.582		5	3		8	
D1C4 Cephalopods Coastal Shelf Popul distributional range & pattern	0.383		1	7	2	6	
D1C4 Turtles Population distributional range & pattern	0.674	1			1		
D6 Seafloor integrity	**0.916**	**12**	**1**		**11**		**2**
D6C4 Bathyal Upper Rock Benthic habitat extent	0.996	1			1		
D6C4 Circalittoral Coarse Sediment Benthic Habitat Extent	1.000	1			1		
D6C4 Infralittoral Mixed Sediments Benthic habitat extent	0.996	1			1		
D6C4 Infralittoral Rock Benthic habitat extent	0.996	1			1		
D6C4 Littoral Biogenic Rock Benthic habitat extent	1.000	1			1		
D6C4 Littoral Rock Benthic habitat extent	0.957	1			1		
D6C4 Other Benthic habitat extent	0.998	1			1		
D6C5 Benthic habitat condition	0.912	1			1		
D6C5 Bathyal Upper Rock Benthic Habitat Condition	0.632	1					1
D6C5 Circalittoral Coarse Sediment Benthic Habitat Condition	0.322		1				1
D6C5 Infralittoral Mixed Sediment Benthic habitat condition	0.837	1			1		
D6C5 Infralittoral Rock Benthic habitat condition	0.613	1			1		
D6C5 Other Benthic habitat condition	0.733	1			1		
D3 Commercial fish	**0.566**	**47**	**76**	**1**	**48**	**76**	
D3C1 Fish Commercial Fishing mortality rate	0.632	11	19		11	19	
D3C2 Fish Commercial Spawning stock biomass	0.466	25	38	1	26	38	
D3C3 Fish Commercial Population age/size distribution	0.576	11	19		11	19	
D5 Eutrophication	**0.883**	**7**			**7**		
D5C1 Nutrient concentrations	0.972	4			4		
D5C2 Chlorophyll-a concentration	0.860	1			1		
D5C4 Transparency	0.914	1			1		
D5C5 Oxygen saturation	0.803	1			1		
D8 Contaminants in the environment	**0.880**	**45**	**3**	**2**	**47**	**3**	
D8C1 Non UPBTs Contaminants in environment	0.985	22	1	1	23	1	
D8C1 UPBTs Contaminants in environment	0.775	23	2	1	24	2	
D9 Contaminants in seafood	**0.858**	**23**	**2**		**23**	**2**	
D9C1 Contaminants in Seafood	0.858	23	2		23	2	
D10 Litter	**0.350**	**1**	**3**		**1**	**3**	
D10C1 Litter (excluding micro litter)	0.350	1	3		1	3	

When integrating the NEAT values of all seven descriptors, the good status (0.73) of Malta coincides with 56% of indicators in GES in both cases (159 out of 282 indicators assessed in NEAT, and 175 out of 310 indicators assessed in the official assessment; Table 9). When looking at descriptor level, the seven descriptors coincide in the integrated assessment using NEAT with the higher number of indicators in GES, both in those used to calculate NEAT and those used in the official assessment (Table 9). The only disagreement is when integrating D1 and D6, for species and habitats, which NEAT value shows good status (0.71), and the number of indicators in non-GES is higher (52%) than in GES for NEAT assessment, and those used in the official assessment are more or less similar (Table 9). The differences come mainly from the high status of D6.

When comparing the different criteria, 38 out of 40 from D1, D3, D5, D6, D8, D9 and D10 show a status similar to those expected from the number of selected indicators used in NEAT and in the official assessment. When the criteria are in GES, the percentage of indicators in GES is very high (92-100%) (Table 9). Despite this fact, for D9 (contaminants in seafood), mercury in *Xiphias gladius* and *Merluccius merluccius* are above the environmental quality standards, while for D8 (contaminants in the environment), mercury in fish, and benzo(a)pyrene and fluoranthene in sediments are also above the standards (Annex 3, Table S2).

When the criteria show non-GES, the percentage of indicators in non-GES ranges from 59 to 100% (Table 9). In the case of D1 (biodiversity), the number of indicators not in GES is high in some habitats and criteria, including species from several genera, such as e.g., *Diplodus, Epinephelus, Mustelus, Chimaera, Coelorinchus,* or *Etmopterus*, in fish, and *Illex, Octopus, Eledone, Scaeurgus, Sepia* or *Todarodes,* in cephalopods (Annex 3, Table S2).

In turn, there are only three disagreements between the NEAT assessment and the official assessment (Table 9):

- In the population abundance of demersal fish in the shelf (D1C2), the NEAT value (not good status: 0.39) reflects the number of indicators in non-GES under the NEAT assessment. In contrast the case of the official assessment, the number of indicators in GES is higher (10) than those in non-GES (8). This difference is however explained by the fact that in NEAT, 10 indicators were excluded due to the absence of quantitative thresholds.
- The population demography in deep-sea fish (D1C3) shows 'not good' status (0.58, close to the threshold of 0.6), calculated with NEAT, and, in the case of the official assessment, the number of indicators in GES (*Chimaera monstruosa* and *Galeus melastomus*, in FMZ) and non-GES (*Etmopterus spinax* and *Galeus melastomus*, in HCexp) is the same (Annex 3, Table S2); and
- In the case of fishing mortality (D3C1), the environmental status, calculated using NEAT, is good (close to the threshold of 0.6), but in the case of the official assessment, 63% of the indicators are in 'not good' status.

4.4 Discussion

Despite the progress made in assessing marine health in an integrative way (Borja et al., 2016; Inniss et al., 2016), some authors (Borja et al., 2019a) have identified six barriers that managers and policy-makers confront when undertaking MSFD assessments, namely the lack of indicators; absence of suitable reference conditions or thresholds; difficulty in aggregating indicators; absence of criteria on the number

of indicators to be used; use of the 'One-Out, All-Out' (OOAO) principle (Borja and Rodríguez, 2010); and lack of traceability of the problems when integrating.

Hence, Malta government (ERA, 2020a), following EU level decisions (European Commission, 2017), undertook the official MSFD assessment, including proportion of indicators achieving GES under each MRUs. In that report, well-known indicators and criteria were used, together with legally binding thresholds, based upon international decisions, e.g., intercalibration exercises within the WFD (European Commission, 2018b) and Environmental Quality Standards (European Commission, 2013), etc. In the absence of suitable reference conditions and thresholds values, it is not possible to undertake quantitative environmental assessments (Borja et al., 2012). Hence, when those binding thresholds were not available, Malta authorities used agreed boundaries, accepted by the scientific community or at the regional/sub-regional level, e.g., thresholds for fish and shellfish stocks (Froese et al., 2018) and UNEP/MAP baselines for marine litter. Most of the threshold values employed within Malta's assessment were also used within the NEAT assessment, together with some additional ones proposed by other authors (e.g., Kazanidis et al., 2020) or expert judgment. However, still some thresholds are not available, resulting in discrepancies in the values obtained by NEAT and in NEAT/national assessment comparisons (e.g., in criterion D1C2 for fish demersal shelf population abundance, as shown in Table 3). It would be worth for countries sharing the same regional sea (or subregion within a sea), to agree in the threshold values to be used in the MSFD assessment, especially when those are based in expert judgment. This will ensure comparability across Member States, facilitating the design of common management measures to achieve GES, in states sharing similar pressures (Gorjanc et al., 2020; Murillas-Maza et al., 2020).

Taking into account the scientific knowledge obtained from the application of NEAT to the Mediterranean (Borja et al., 2019c; Pavlidou et al., 2019), and the availability of suitable indicators data and thresholds, it has been possible to apply NEAT to data from Malta's waters. An integrative assessment for Malta was performed, with a high confidence in the final result, suggesting that Maltese marine waters globally achieved GES.

Despite this global environmental status, the use of NEAT allowed to identify that the MRU WFD5, wherein Valletta city and harbour are located, presents a lower NEAT value (still good), but with some ecosystem components in moderate status and others close to the threshold between GES/non-GES. All these observations indicate that the urban and harbour activities (e.g., discharges, shipping, dredging, etc.) are downgrading the quality of the MRU, as determined in some previous studies (Romeo et al., 2015). Therefore, it could need specific management measures for the components not achieving GES, as identified in the official report (ERA, 2020a).

On the other hand, within the largest MRUs, FMZ and HCexp, whilst achieving GES when integrating the assessments, some criteria and descriptors are in non-GES. A number of such criteria are linked to fishing pressure, which is a general concern in the Mediterranean, with many stocks under the sustainable exploitation limits (Raicevich et al., 2017; Froese et al., 2018; Borja et al., 2019c; Reker et al., 2019). With respect to criteria reflecting the status of fish stocks, the shortcomings of assessing such stocks at the scales referred to in Section 3.3 must be noted, whilst highlighting the importance of complimenting assessments of stocks at the regional scale.

In addition, the circalittoral seabed is affected by fish trawling, with 62.4% of this type of benthic habitat exposed to such activity to a lesser or a greater degree (ERA, 2020a), as in other Mediterranean areas (de Juan et al., 2011; Reker et al., 2019). Such quantification is, however, a reflection of the extensive seafloor

area exposed to trawling activities, and it is considered an overestimation of the extent of the actual impact. This is because the intensity with which trawling occurs is highly variable across the reported areas, cumulative dynamics between pressures may exist and there is no data based on which pressure to impact extrapolations can be made (ERA, 2020a). Even though the main objective of our research is to determine the pros and cons of the official NEAT approaches, this kind of information illustrates the challenges when using datasets of different sources to assess the status of large areas, which can be hampered by issues of scale, data accuracy and knowledge gaps.

It is known that the pressure over fish translate into commercial fish and shellfish exploitation, with many stocks in the Mediterranean in non-GES for fishing mortality, spawning stock biomass or population age/size distribution criteria (de Juan et al., 2011; Reker et al., 2019), as also observed in Malta. This status requires measures to achieve GES in the future, but probably at a higher geographical level than Maltese waters; that is, these measures should cover the whole distribution area of the stocks within the Mediterranean, until sustainable exploitation limits are achieved (Raicevich et al., 2017).

In addition, it is also known that fishing pressure (from D3) also effects other ecosystem components in the Mediterranean (Coll et al., 2006, 2009), and this has been shown in the case of NEAT for several biodiversity components (in D1), especially fish and cephalopods. Another descriptor in non-GES shown in the case of NEAT, marine litter, has the main problems in circalittoral and deep bottoms. Although an attempt was made to correlate its presence with fishing activities and environmental variables, no interpretable correlations were found (Mifsud et al., 2013), implying that litter abundance and distribution depends on factors other than those considered, which could include land-based sources, transport from outside Malta and littering from shipping.

In the case of contaminants (D8 and D9), among 68 indicators, the only ones that did not achieved GES were benzo(a)pyrene, fluoranthene, and mercury in matrices such as sediments, biota (fish) and seafood. Mercury is a substance of concern in the whole Europe (Višnjevec et al., 2014; Kuenen et al., 2018) in water, sediment, biota, as well as in seafood. There is a chronic contamination by this metal in many European locations and it seems that the solution, if existing, would probably not be at national but at European level (Kuenen et al., 2018). For the remaining contaminants, some of them could be related to the bunkering activities, but this should be proven with additional sampling in future applications of the monitoring network (Borja et al., 2019a). Finally, in light of these results, D9 assessments brought to light the need to ensure representative sampling of fish and cephalopods for future assessments.

According to Borja et al. (2019b), between 76.2 and 100% of the Maltese waters achieved GES for D8, and 83.3% achieved GES for D9. However, using the OOAO principle (as suggested by some Member States), these descriptors failed to achieve GES. The use of the OOAO principle has been repeatedly criticised (Moss et al., 2003; Moss, 2008; Caroni et al., 2013; Langhans et al., 2014), because it tends to downgrade the quality of assessed locations unjustifiably, depending on the number of indicators included in the assessment, as demonstrated elsewhere (Borja and Rodríguez, 2010; Borja et al., 2019c). Although this principle is consistent with the precautionary principle, at the same time, it tends to inflate Type I errors (concluding that the assessed area is below good status, even if the real status is good). In fact, it has been demonstrated that integrative assessments are more suitable in showing improvements in the quality of marine areas after applying management measures, whilst using the OOAO there is no trend in the improvement because of the probabilities of having individual indicators below the good status (Borja and Rodríguez, 2010). This means that there is a risk of implementing additional management measures to

revert the situation where they are not really needed (Borja and Rodríguez, 2010). Hence, the OOAO principle increases the likelihood of misclassifying to a lower status class by sheer randomness (Hering et al., 2010). Borja et al. (2019c) demonstrated that, increasing the number of indicators, ecosystem components or descriptors for the MSFD, the possibility of downgrading the quality status in the assessment increases exponentially.

Despite the clear human activities and pressures in Malta (e.g., high population density, massive tourism in summer, fishing, shipping, bunkering, aquaculture, etc.) (ERA, 2020a), only some areas and descriptors can be considered as severely affected, with some areas which can be considered near pristine and with most of the marine surface as highly oligotrophic (Farrugia et al., 2016).

In this study, it has been demonstrated that, even if it could be difficult to aggregate indicators from different spatial and temporal frameworks, different descriptors, and ecosystem components, as debated elsewhere (Borja et al., 2014; Langhans et al., 2014; Link and Browman, 2014; Probst and Lynam, 2016), it could be done effectively. Using NEAT, the flexibility and customization possibilities are ensured, as shown by Uusitalo et al. (2016), Nemati et al. (2017), Borja et al. (2019c) and Pavlidou et al. (2019), but also in this study, in which the software was adapted to accommodate the criteria under the MSFD and obtain assessments at the levels required by the European Commission (2017, 2018a).

Authorities often find difficulty in tracing the origin of problems when assessing status through aggregated data, preventing the adoption of management measures to address the impacts detected. However, Pavlidou et al. (2019) demonstrated that the use of NEAT, spatially and temporally, allows linking the assessment with the human pressures and the measures taken to reverse a degraded situation. Here, we have shown the ecosystem components, descriptors, or criteria, which need some management measures to achieve GES.

Using the European Commission (2018a) guidelines in the official reporting of the assessment for the MSFD can be done at indicator level, but the integration at criterion, descriptor or global level is not possible without transparent rules, as those included in NEAT. This is a lesson learnt using adequate data from a small country like Malta, but this could be extended to remaining EU Member States.

5 Synthesis and conclusion

NEAT is a tool developed within the EU project DEVOTES, to assess the status of marine ecosystems, in an integrative way, taking into account different sources of data, different descriptors of the MSFD, different ecosystem components, habitats and indicators. The aggregation can be done at different temporal and spatial scales, from small MRUs to large regional and subregional seas.

However, when NEAT was developed, the European Commission Decision (2017) was still not published. Hence, some criteria were not included in its development. In this exercise, we have made an intermediate approach, allowing to the Competent Authorities to use NEAT to assess the environmental status at different levels, following the new GES Decision:

- MRUs, at subnational, national, subregion and regional scales
- Ecosystem components, from phytoplankton to mammals, including all possible components
- Descriptors, integrating all of them, or assessing the status at each of the 11 descriptors level
- Criteria, for each descriptor, either primary or secondary
- Habitats

We have prepared a NEAT prototype, allowing the Competent Authorities to include their own indicators and official data and test the results, since the MRUs, ecosystem components, habitats, and criteria for each descriptor are already included (available as Annex 1). In order to test the viability of this prototype, we have created a "fake" example (Annex 2), showing the results at different levels, using non-official data, due to the lack of availability of such data. However, in Annex 3, we have used official data from Malta to illustrate the use of this prototype, comparing the results obtained from the official assessment with those obtained with NEAT, integrating at different levels, including criteria from the MSFD and ecosystem components, as well as different MRUs.

We think that the results are positive and close to the assessments required by Member States. Thus, if they consider that this could be useful, in the future NEAT could be adapted, including aforementioned requirements in the software for easier and direct use.

6 References

Ballesteros, E., X. Torras, S. Pinedo, M. García, L. Mangialajo, M. De Torres, 2007. A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. Marine Pollution Bulletin, 55: 172-180.

Berg, T., C. Murray, J. Carstensen,J.H. Andersen, 2017. NEAT - Nested Environmental Status Assessment Tool - Manual Version 1.3. DEVOTES Project. (38 pp).

Borja, Á., J. G. Rodríguez, 2010. Problems associated with the 'one-out, all-out' principle, when using multiple ecosystem components in assessing the ecological status of marine waters. Marine Pollution Bulletin, 60: 1143-1146.

Borja, Á., D. M. Dauer, A. Grémare, 2012. The importance of setting targets and reference conditions in assessing marine ecosystem quality. Ecological Indicators, 12: 1-7.

Borja, Á., T. Prins, N. Simboura, J. H. Andersen, T. Berg, J. C. Marques, J. M. Neto, N. Papadopoulou, J. Reker, H. Teixeira, L. Uusitalo, 2014. Tales from a thousand and one ways to integrate marine ecosystem components when assessing the environmental status. Frontiers in Marine Science, 1: 72. doi: 10.3389/fmars.2014.00072.

Borja, A., M. Elliott, J. H. Andersen, T. Berg, J. Carstensen, B. S. Halpern, A.-S. Heiskanen, S. Korpinen, J. S. S. Lowndes, G. Martin, N. Rodriguez-Ezpeleta, 2016. Overview of integrative assessment of marine systems: the Ecosystem Approach in practice. Frontiers in Marine Science, 3: doi: 10.3389/fmars.2016.00020.

Borja, A., J. Franco, J. M. Garmendia, J. Larreta, I. Menchaca, Y. Sagarminaga, Y. Schembri, O. Solaun, A. Uriarte, 2018. Assessment of environmental status of Malta's Marine Waters, using NEAT. Report from M3C Consortium for ERA, 52 pp.

Borja, A., J. Franco, J. M. Garmendia, J. Larreta, I. Menchaca, Y. Sagarminaga, A. Uriarte, M.C. Uyarra, Y. Schembri, R. Antón, R. González, 2019a. Monitoring report and update to existing monitoring programme. Final report from M3C for ERA (EU project EMFF 8.3.1), 188 pp.

Borja, A., J. Franco, J. M. Garmendia, J. Larreta, I. Menchaca, Y. Sagarminaga, Y. Schembri, O. Solaun, A. Uriarte, M.C. Uyarra, 2019b. Assessment of environmental status of Malta's Marine Waters. As per Tender for the Implementation and Updating of Marine Monitoring Programmes, Assessment of Environmental Status and Development of a Marine Database System. Report from M3C for ERA (EU project EMFF 8.3.1), 70 pp.

Borja, A., J. M. Garmendia, I. Menchaca, A. Uriarte, Y. Sagarmínaga, 2019c. Yes, We Can! Large-Scale Integrative Assessment of European Regional Seas, Using Open Access Databases. Frontiers in Marine Science, 6: 10.3389/fmars.2019.00019.

Caroni, R., W. Bund, R. T. Clarke, R. K. Johnson, 2013. Combination of multiple biological quality elements into waterbody assessment of surface waters. Hydrobiologia, 704: 437-451.

Coll, M., L. J. Shannon, C. L. Moloney, I. Palomera, S. Tudela, 2006. Comparing trophic flows and fishing impacts of a NW Mediterranean ecosystem with coastal upwelling systems by means of standardized models and indicators. Ecological Modelling, 198: 53-70.

Coll, M., I. Palomera, S. Tudela, 2009. Decadal changes in a NW Mediterranean Sea food web in relation to fishing exploitation. Ecological Modelling, 220: 2088-2102.

de Juan, S., M. Demestre, P. Sánchez, 2011. Exploring the degree of trawling disturbance by the analysis of benthic communities ranging from a heavily exploited fishing ground to an undisturbed area in the NW Mediterranean. Scientia Marina, 75: 507-516.

ERA, 2020a. Update on Articles 8, 9, and 10 of the Marine Strategy Framework Directive (2008/56/EC) in Malta's Marine Waters. Environment and Resources Authority, 540 pp. https://era.org.mt/wp-content/uploads/2020/06/MSFD-Art.-17-Update-Malta_FINAL.pdf

ERA, 2020b. Update on Articles 8, 9, and 10 of the Marine Strategy Framework Directive (2008/56/EC) in Malta's Marine Waters. Second assessment report-annexes. Environment and Resources Authority: 223 pp. https://era.org.mt/wp-content/uploads/2020/06/MSFD-Art.-17-Update-Annexes_FINAL.pdf

European Commission, 2008. Directive 2008/56/EC of the European Parliament and of the Council establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, L164: 19-40.

European Commission, 2010. Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (notified under document C(2010) 5956)(2010/477/EU). Official Journal of the European Union, L232: 12-24.

European Commission, 2013. Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy Official Journal of the European Union, L226: 1-17.

European Commission, 2017. Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU Official Journal of the European Communities, L125: 43-74.

European Commission, 2018a. Reporting on the 2018 update of articles 8, 9 & 10 for the Marine Strategy Framework Directive version 4.2. DG Environment, Brussels, 66 pp. (MSFD Guidance Document 14).

European Commission, 2018b. Commission Decision (EU) 2018/229 of 12 February 2018 establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications as a result of the intercalibration exercise and repealing Commission Decision 2013/480/EU. Official Journal of the European Communities, L47: 1-91.

European Commission, 2019. Reporting on the 2020 update of Article 11 for the Marine Strategy Framework Directive (version 2.0, draft). Brussels. 41 pp.

European Commission, 2020. Report from the Commission to the European Parliament and the Council on the implementation of the Marine Strategy Framework Directive (Directive 2008/56/EC) Brussels, 25.6.2020 COM(2020) 259 final; {SWD(2020) 60 final} - {SWD(2020) 61 final} - {SWD(2020) 62 final}: 307 pp.

Farrugia, H., A. Deidun, A. Gauci, A. Drago, 2016. Defining the Trophic Status of Maltese (Central Mediterranean) Coastal Waters through the Computation of Water Quality Indices Based on Satellite Data. Journal of Coastal Research, 75: 632-636.

Froese, R., H. Winker, G. Coro, N. Demirel, A. C. Tsikliras, D. Dimarchopoulou, G. Scarcella, M. Quaas, N. Matz-Lück, 2018. Status and rebuilding of European fisheries. Marine Policy, 93: 159-170.

Gobert, S., S. Sartoretto, V. Rico-Raimondino, B. Andral, A. Chery, P. Lejeune, P. Boissery, 2009. Assessment of the ecological status of Mediterranean French coastal waters as required by the Water Framework Directive using the Posidonia oceanica Rapid Easy Index: PREI. Marine Pollution Bulletin, 58: 1727-1733.

Gorjanc, S., K. Klančnik, A. Murillas-Maza, M. C. Uyarra, N. K. Papadopoulou, T. Paramana, C. Smith, O. Chalkiadaki, M. Dassenakis, M. Peterlin, 2020. Coordination of pollution-related MSFD measures in the Mediterranean - Where we stand now and insights for the future. Marine Pollution Bulletin, 159: 111476.

Hering, D., A. Borja, J. Carstensen, L. Carvalho, M. Elliott, C. K. Feld, A.-S. Heiskanen, R. K. Johnson, J. Moe, D. Pont, A. L. Solheim, W. v. de Bund, 2010. The European Water Framework Directive at the age of 10: A critical review of the achievements with recommendations for the future. Science of The Total Environment, 408: 4007-4019.

Inniss, L., A. Simcock, A. Y. Ajawin, A. C. Alcala, P. Bernal, H. P. Calumpong, P. Eghtesadi Araghi, S. O. Green, P. Harris, O. K. Kamara, K. Kohata, E. Marschoff, G. Martin, B. Padovani Ferreira, C. Park, R. A. Payet, J. Rice, A. Rosenberg, R. Ruwa, J. T. Tuhumwire, S. Van Gaever, J. Wang, J. M. Węsławski, 2016. The First Global Integrated Marine Assessment World Ocean Assessment I. United Nations General Assembly, 1751 pp.

Kazanidis, G., C. Orejas, A. Borja, E. Kenchington, L.-A. Henry, O. Callery, M. Carreiro-Silva, H. Egilsdottir, E. Giacomello, A. Grehan, L. Menot, T. Morato, S. Á. Ragnarsson, J. L. Rueda, D. Stirling, T. Stratmann, D. van Oevelen, A. Palialexis, D. Johnson, J. M. Roberts, 2020. Assessing the environmental status of selected North Atlantic deep-sea ecosystems. Ecological Indicators, 119: 106624.

Kuenen, J., C. Hendriks, A. Visschedijk, T. Smit, J. Vermeulen, 2018. Mercury in Europe's environment. A priority for European and global action. European Environment Agency Report, 11: 72 pp.

Langhans, S. D., P. Reichert, N. Schuwirth, 2014. The method matters: A guide for indicator aggregation in ecological assessments. Ecological Indicators, 45: 494-507.

Link, J. S., H. I. Browman, 2014. Integrating what? Levels of marine ecosystem-based assessment and management. ICES Journal of Marine Science, 71: 1170-1173.

Lynam, C., L. Uusitalo, J. Patrício, C. Piroddi, A. Queiros, H. Teixeira, A. Rossberg, Y. Sagarminaga, K. Hyder, N. Niquil, C. Möllmann, C. Wilson, G. Chust, I. Galparsoro, R. Forster, H. Verissimo, L. Tedesco, M. Revilla, S. Neville, 2016. Uses of innovative modelling tools within the implementation of the marine strategy framework directive. Frontiers in Marine Science, 3: 10.3389/fmars.2016.00182.

Moss, B., 2008. The Water Framework Directive: Total environment or political compromise? Science of The Total Environment, 400: 32-41.

Moss, B., D. Stephen, C. Alvarez, E. Becares, W. V. D. Bund, S. E. Collings, E. V. Donk, E. D. Eyto, T. Feldmann, C. Fernández-Aláez, M. Fernández-Aláez, R. J. M. Franken, F. García-Criado, E. M. Gross, M. Gyllström, L.-A. Hansson, K. Irvine, A. Järvalt, J.-P. Jensen, E. Jeppesen, T. Kairesalo, R. Kornijów, T. Krause, H. Künnap, A. Laas, E. Lill, B. Lorens, H. Luup, M. Rosa Miracle, P. Nõges, T. Nõges, M. Nykänen, I. Ott, W. Peczula, E. T. H. M. Peeters, G. Phillips, S. Romo, V. Russell, J. Salujõe, M. Scheffer, K. Siewertsen, H. Smal, C. Tesch, H. Timm, L. Tuvikene, I. Tonno, T. Virro, E. Vicente, D. Wilson, 2003. The determination of ecological status in shallow lakes — a tested system (ECOFRAME) for implementation of the European Water Framework Directive. Aquatic Conservation: Marine and Freshwater Ecosystems, 13: 507-549.

Murillas-Maza, A., M. C. Uyarra, K. N. Papadopoulou, C. J. Smith, S. Gorjanc, K. Klancnik, T. Paramana, O. Chalkiadaki, M. Dassenakis, M. Pavicic, 2020. Programmes of measures of the marine strategy framework directive: Are they contributing to achieving good environmental status in the Mediterranean? Marine Pollution Bulletin, 161: 111715.

Nemati, H., M. R. Shokri, Z. Ramezanpour, G. H. Ebrahimi Pour, I. Muxika, Á. Borja, 2017. Using multiple indicators to assess the environmental status in impacted and non-impacted bathing waters in the Iranian Caspian Sea. Ecological Indicators, 82: 175-182.

Palialexis, A., V. Tornero, E. Barbone, D. Gonzalez, G. Hanke, A. C. Cardoso, N. Hoepffner, S. Katsanevakis, F. Somma, N. Zampoukas, 2014. In-Depth Assessment of the EU Member States' Submissions for the Marine Strategy Framework Directive under articles 8, 9 and 10. JRC Scientific and Policy Reports, EUR 26473 EN: 153 pp.

Pavlidou, A., N. Simboura, K. Pagou, G. Assimakopoulou, V. Gerakaris, I. Hatzianestis, P. Panayotidis, M. Pantazi, N. Papadopoulou, S. Reizopoulou, C. Smith, M. Triantaphyllou, M. C. Uyarra, I. Varkitzi, V. Vassilopoulou, C. Zeri, A. Borja, 2019. Using a holistic ecosystem-integrated approach to assess the environmental status of Saronikos Gulf, Eastern Mediterranean. Ecological Indicators, 96: 336-350.

Probst, W. N., C. P. Lynam, 2016. Integrated assessment results depend on aggregation method and framework structure – A case study within the European Marine Strategy Framework Directive. Ecological Indicators, 61, Part 2: 871-881.

Raicevich, S., P. Battaglia, T. Fortibuoni, T. Romeo, O. Giovanardi, F. Andaloro, 2017. Critical Inconsistencies in Early Implementations of the Marine Strategy Framework Directive and Common Fisheries Policy Objectives Hamper Policy Synergies in Fostering the Sustainable Exploitation of Mediterranean Fisheries Resources. Frontiers in Marine Science, 4: 10.3389/fmars.2017.00316.

Reker, J., C. Murray, E. Royo Gelabert, K. Abhold, S. Korpinen, M. Peterlin, D. Vaughan, J. H. Andersen, 2019. Marine Messages II. Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem-based approach. European Environment Agency, EEA Report, 17/2019: 82 pp.

Romeo, T., M. D'Alessandro, V. Esposito, G. Scotti, D. Berto, M. Formalewicz, S. Noventa, S. Giuliani, S. Macchia, D. Sartori, A. Mazzola, F. Andaloro, S. Giacobbe, A. Deidun, M. Renzi, 2015. Environmental quality assessment of Grand Harbour (Valletta, Maltese Islands): a case study of a busy harbour in the Central Mediterranean Sea. Environmental Monitoring and Assessment, 187: 747.

Saavedra, C., T. Gerrodette, M. Louzao, J. Valeiras, S. García, S. Cerviño, G. J. Pierce, M. B. Santos, 2018. Assessing the environmental status of the short-beaked common dolphin (Delphinus delphis) in North-western Spanish waters using abundance trends and safe removal limits. Progress in Oceanography, 166: 66-75.

Simboura, N., A. Zenetos, 2002. Benthic indicators to use in ecological quality classification of Mediterranean soft bottom marine ecosystems, including a new biotic index. Mediterranean Marine Science, 3/2: 77-111.

Teixeira, H., T. Berg, L. Uusitalo, K. Fürhaupter, A.-S. Heiskanen, K. Mazik, C. Lynam, S. Neville, J. G. Rodriguez, N. Papadopoulou, S. Moncheva, T. Churilova, O. Krivenko, D. Krause-Jensen, A. Zaiko, H. Verissimo, M. Pantazi, S. Carvalho, J. Patrício, M. C. Uyarra, A. Borja, 2016. A Catalogue of marine biodiversity indicators. Frontiers in Marine Science, 3: 10.3389/fmars.2016.00207.

Uusitalo, L., H. Blanchet, J. Andersen, O. Beauchard, T. Berg, S. Bianchelli, A. Cantafaro, J. Carstensen, L. Carugati, S. Cochrane, R. Danovaro, A.-S. Heiskanen, V. Karvinen, S. Moncheva, C. Murray, J. Neto, H. Nygård, M. Pantazi, N. Papadopoulou, N. Simboura, G. Srėbalienė, M. C. Uyarra, A. Borja, 2016. Indicator-based assessment of marine biological diversity – lessons from 10 case studies across the European Seas. Frontiers in Marine Science, 3: 10.3389/fmars.2016.00159.

Višnjevec, A. M., D. Kocman, M. Horvat, 2014. Human mercury exposure and effects in Europe. Environmental Toxicology and Chemistry, 33: 1259-1270.

Walmsley, S.F., A. Weiss, U. Claussen, D. Connor, 2017. Guidance for Assessments Under Article 8 of the Marine Strategy Framework Directive, Integration of assessment results. ABPmer Report No R.2733, produced for the European Commission, DG Environment.

7 Annexes

Annex 1: NEAT prototype containing all Marine Reporting Units, habitats, species groups, criteria and ecosystem components to include the indicators and official data from each country and undertake the environmental assessment.

Annex 2: NEAT example with virtual data to show how the prototype in Annex 1 works.

Annex 3: Tables summarizing the data used from Malta and the main results using the NEAT prototype.

Annex 4: NEAT prototype containing the data used in Malta (MEDREGPROTO_prototype-Malta.db).