Pilot Implementation for the MSFD Descriptor 4 Trophic Guilds Monitoring Programme

As per ERA requirements for SPD8/2021/016

Report

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1 INTRODUCTION

The Environment & Resources Authority (ERA) has been entrusted with designing the monitoring programme for marine trophic guilds (Food Webs, Descriptor 4). This requirement branches out from the objectives of the MARINE STRATEGY FRAMEWORK DIRECTIVE (MSFD, 2008/56/EC), whereby all Member States are required to achieve "good status" in Maltese waters, including coastal surface waters.

In line with the requirements of SPD8/2021/016, the project involves the preparation of three distinct reports, as outlined below:

Result 1: Report detailing the identification of the trophic guilds and constituent species best suited to be representative of local marine ecosystems, as well as relevant associated spatial scales and assessment methodologies to be applied in determining Good Environmental Status (GES) in relation to the Marine Strategy Framework Directive's (MSFD) (2008/56/EC) Descriptor 4, 'Food Webs', in accordance with the criteria and methodological standards detailed in Commission Decision (EU) 2017/848.

Result 2: A long-term data collection and monitoring strategy, including an assessment methodology to ensure:

a. Collection of sufficient and adequate data for the assessment of the identified trophic guilds and species, at the identified scale of assessment, being cognizant of existing data sets and collection strategies in effect;
b. Appropriate analysis and interpretation of data for the assessment of Good Environmental Status (GES) in relation to the Marine Strategy Framework Directive's (MSFD) (2008/56/EC) Descriptor 4, 'Food Webs'; in accordance with the criteria and methodological standards detailed in Commission Decision (EU) 2017/848.

Result 3: A report outlining details of the implementation of selected monitoring processes as identified through Result 2 and including raw and analysed data in relation to MSFD Descriptor 4 criteria as stipulated in Commission Decision 2017/848/EU.

This document represents Report 3, which henceforth is referred to as the Pilot Implementation report for assessment of MSFD Descriptor 4 in line with SPD8/2021/016.

2 ASSESSMENT OF ENVIRONMENTAL STATUS

2.1 EUROPEAN COMMISSION GUIDELINES

Deliverable 3 of SPD8/2021/016 will comprise the following items:

- A structured reporting of information, in Excel files: These files serve to assess the environmental status for different indicators and descriptors, and should be provided as an annex to the assessment report. Such files contain information on how to aggregate indicators, depending on the descriptors and the criteria.

- The national indicator assessments: The indicators and thresholds to be used in this process are included in Section 2.4, and will be assessed on a pilot basis in Deliverable 3. We have made use of, wherever possible, indicators measured in the existing national monitoring network. We have also referred to indicators which should be integrated into the national monitoring network for future data collection exercises.

- The supporting assessment datasets: This exercise falls outside the scope of SPD8/2021/016.

- Text-based national reports: This exercise falls outside the scope of SPD8/2021/016. Nevertheless, the report prepared as part of Deliverable 3 can be included in the national reports.

2.2 MARINE REPORTING UNITS

The monitoring network for Maltese waters is a complex mixture of MRUs, as required by the MSFD, and sampling stations for different environments (water, sediment, biota) and ecosystem components (plankton, macroalgae, seagrasses, macroinvertebrates) as well as other elements (such as litter).

Figure 1 presents the MRUs applicable to the assessment of Maltese waters in line with MSFD Descriptor 4 as part of SPD8/2021/016. In total, we will be assessing eleven MRUs:

- Nine coastal water bodies within the WFD, with sizes between 13 and 98 km^2, which are aggregated into a unique WFD MRU, covering 399 km^2
- Territorial waters, covering approximately 3,830 km^2
- Fisheries Management Zone, covering approximately 11,480 km^2

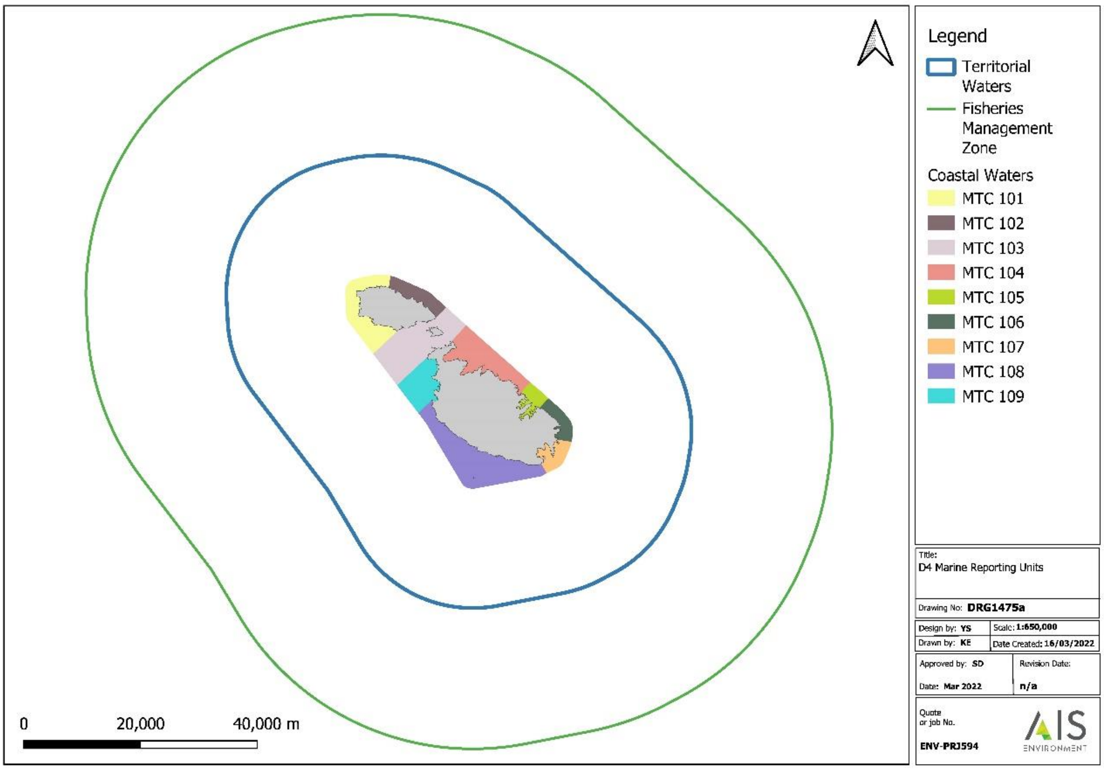

FIGURE 1: MAP SHOWING THE MALTESE MARINE REPORTING UNITS

2.3 ECOSYSTEM COMPONENTS

Since each indicator describes a specific ecosystem component, we have defined the following ecosystem components:

- Primary producers (chlorophyll, abundance, composition)
- Sub-apex demersal predators (abundance, MTI, LFI, weights-at-age, length, biomass)
- Apex predators (abundance, MTI, LFI, weights-at-age, length, biomass)

2.4 CRITERIA, INDICATORS & THRESHOLDS

Four criteria have been established for Descriptor 4:

- D4C1 – Primary: The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures.
- D4C2 – Primary: The balance of total abundance between the trophic guilds is not adversely affected due to anthropogenic pressures.
- D4C3 – Secondary: The size distribution of individuals across the trophic guild is not adversely affected due to anthropogenic pressures.
- D4C4 – Secondary (to be used in support of criterion D4C2, where necessary): Productivity of the trophic guild is not adversely affected due to anthropogenic pressures.

To select the indicators, we have followed as far as possible the criteria of the

European Commission (2017) decision.[1] In line with the guidance, primary criteria will be used to ensure consistency across the European Union. Proposals for assessment using secondary criteria have been put forward. Where necessary, implementation of these criteria should be decided by Member States. The purpose of implementing secondary criteria is to complement a primary criterion or when the marine environment is at risk of not achieving or not maintaining good environmental status for a particular criterion.

During the design of the monitoring strategy, we proposed the use of 42 indicators for assessment of Descriptor 4, corresponding to two priority and two secondary criteria. Their feasibility has been assessed on a pilot basis as part of SPD8/2021/016, and the list has been updated as part of Deliverable 3 of this project:

- D4C1 [Diversity within trophic guilds] – 2 indicators for primary producers; 5 indicators for sub-apex demersal predators; 5 indicators for apex predators
- D4C2 [Total abundance between trophic guilds] – 2 indicators for all three trophic guilds
- D4C3 [Size distribution within trophic guilds] – 1 indicator for primary producers; 8 indicators for sub-apex demersal predators; 8 indicators for apex predators
- D4C4 [Productivity within trophic guilds] – 1 indicator for primary producers; 5 indicators for sub-apex demersal predators; 5 indicators for apex predators

To make use of the indicators for the assessment of status, the results have been analysed, wherever possible, by comparing them to a threshold between good/not good environmental status. However, since assessment of EU Member States in relation to Descriptor 4 is still in the initial stages, thresholds for Descriptor 4 indicators are scarce. Consequently, scientific papers have been used to set thresholds. Wherever thresholds for good/not good environmental status were not available, trend analyses over a given time period have been performed to determine whether the conditions of the trophic guild deteriorated over time.

The indicators showed a range of variation (from worst to best values, i.e. reference conditions). These results have been compared against a threshold between good/not good status, as shown in Table 1. A summary of the assessment is visually presented in Figure 2 to Figure 4. Appendix I includes the list of TROPH values for MEDITS species, as extracted from literature.

[1] 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.

TABLE 1: INDICATORS, THRESHOLDS AND PRESSURES FOR THE ASSESSMENT OF DESCRIPTOR 4

INDICATOR	TROPHIC GUILD	TAXONOMIC GROUP	UNITS	THRESHOLDS/TREND	DATASET	TIME PERIOD	PRESSURES	COMPLETED?
D4C1: Diversity within trophic guilds								
Dia/Dino index	PP	Diatoms, dinoflagellates	Ratio	0.75 [4]	Existing national monitoring programme	2017-2019	Aquaculture, bunkering, sewage outfalls, agriculture, harbours, industrial areas	No (lack of long-term data)
Large microphytoplankton vs small microphytoplankton	PP	Large/small microphytoplankton	Ratio	Stable directional trend	Existing national monitoring programme	2017-2019	None, since this is a state indicator which does not provide a direct link to pressures	No (lack of data)
Abundance	SDP	*Illex coindetii*	Catch by 1km haul	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Abundance	SDP	*Octopus vulgaris*	Catch by 1km haul	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Abundance	SDP	*Mullus barbatus*	Catch by 1km haul	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Abundance	SDP	*Trachurus trachurus*	Catch by 1km haul	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Abundance	AP	*Squalus blainville*	Catch by 1km haul	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Abundance	AP	*Heptranchias perlo*	Catch by 1km hauls	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Abundance	AP	*Lophius piscatorius*	Catch by 1km haul	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Abundance	AP	*Coryphaena hippurus*	Catch by landing	Stable/increasing directional trend	Landings	2005-2017	Trawling, fishing	No (lack of data)
Marine Trophic Index (MTI)	SDP	All species with TROPH <4	None	Stable directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Marine Trophic Index (MTI)	AP	All species with TROPH ≥4	None	Stable directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
D4C2: Total abundance between trophic guilds[2]								
Relative abundance	PP, SDP, AP	All phytoplankton, All species with TROPH <4, All species with TROPH ≥4	Cells/l, Catch by 1km haul	Stable/increasing directional trend	Existing national monitoring programme, MEDITS	2005-2019	Trawling, fishing	Partly (lack of long-term PP data)

[2] Comparison between the trophic guilds will be done on a qualitative basis.

Indicator	Trophic Guild	Taxonomic Group	Units	Thresholds/Trend	Dataset	Time Period	Pressures	Completed?
Marine Trophic Index (MTI)	SDP, AP	All species with TROPH <4, All species with TROPH ≥4	None	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
D4C3: Size distribution within trophic guilds								
Large microphytoplankton vs small microphytoplankton	PP	Large/small microphytoplankton	Ratio	Stable directional trend	Existing national monitoring programme	2017-2019	None, since this is a state indicator which does not provide a direct link to pressures	No (lack of data)
Large fish indicator (LFI) 30	SDP	All fish species with TROPH <4	g	Stable/increasing directional trend for all fish species larger than 30cm	MEDITS	2005-2019	Trawling, fishing	Yes
Large fish indicator (LFI) 30	SDP	All fish species with TROPH <4	g	Stable/increasing directional trend for all fish species larger than 40cm	MEDITS	2005-2019	Trawling, fishing	Yes
Large fish indicator (LFI) 40	AP	All fish species with TROPH ≥4	g	Stable/increasing directional trend for all fish species larger than 30cm	MEDITS	2005-2019	Trawling, fishing	Yes
Large fish indicator (LFI) 40	AP	All fish species with TROPH ≥4	g	Stable/increasing directional trend for all fish species larger than 40cm	MEDITS	2005-2019	Trawling, fishing	Yes
Mean weights-at-age	SDP	All fish species with TROPH <4 and maturity 2/3	g	Stable/increasing directional trend of all fish species at maturity stage 2/3	MEDITS	2005-2019	Trawling, fishing	Yes
Mean weights-at-age	AP	All fish species with TROPH ≥4 and maturity 2/3	g	Stable/increasing directional trend of all fish species at maturity stage 2/3	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	SDP	All species with TROPH <4	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	SDP	*Illex coindetii*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	SDP	*Octopus vulgaris*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	SDP	*Mullus barbatus*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	SDP	*Trachurus trachurus*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	AP	All species with TROPH ≥4	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes

Indicator	Trophic Guild	Taxonomic Group	Units	Thresholds/Trend	Dataset	Time Period	Pressures	Completed?
Mean length	AP	*Squalus blainville*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	AP	*Heptranchias perlo*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	AP	*Lophius piscatorius*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Mean length	AP	*Coryphaena hippurus*	mm	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
D4C4: Productivity within trophic guilds								
90th percentile chlorophyll-a	PP	All phytoplankton	μg/l	Stable directional trend	Existing national monitoring programme	2017-2019	Aquaculture, bunkering, sewage outfalls, agriculture	No (lack of long-term data)
Biomass	SDP	All species with TROPH <4	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	SDP	*Illex coindetii*	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	SDP	*Octopus vulgaris*	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	SDP	*Mullus barbatus*	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	SDP	*Trachurus trachurus*	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	AP	All species with TROPH ≥4	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	AP	*Squalus blainville*	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	AP	*Heptranchias perlo*	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	AP	*Lophius piscatorius*	g	Stable/increasing directional trend	MEDITS	2005-2019	Trawling, fishing	Yes
Biomass	AP	*Coryphaena hippurus*	g	Stable/increasing directional trend	Landings	2005-2017	Trawling, fishing	No (lack of data)

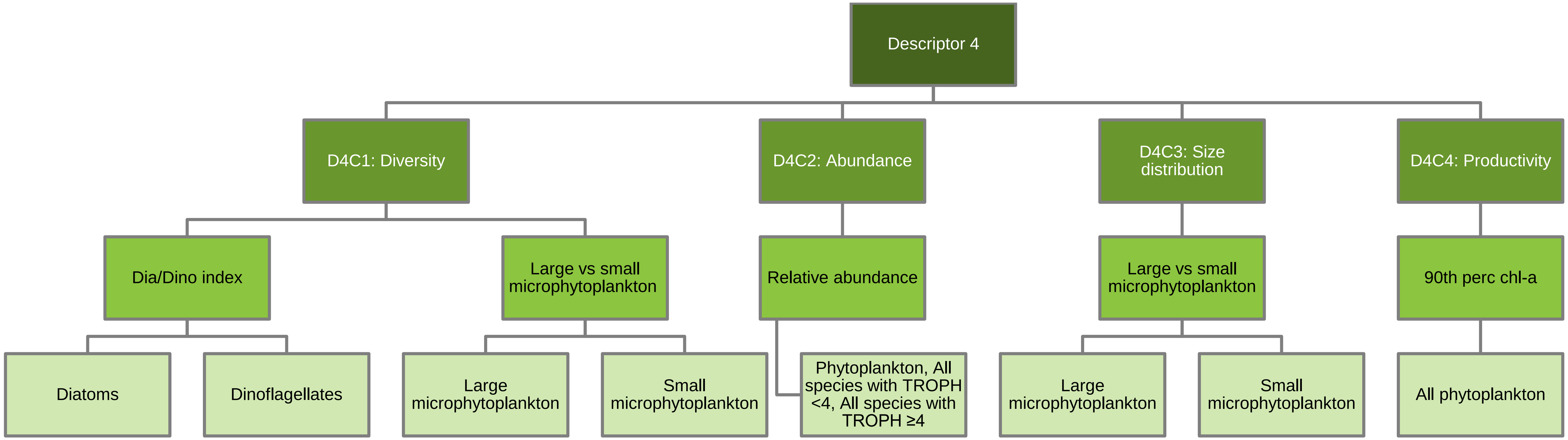

FIGURE 2: INDICATORS AND CRITERIA FOR DESCRIPTOR 4 ASSESSMENT OF PRIMARY PRODUCERS

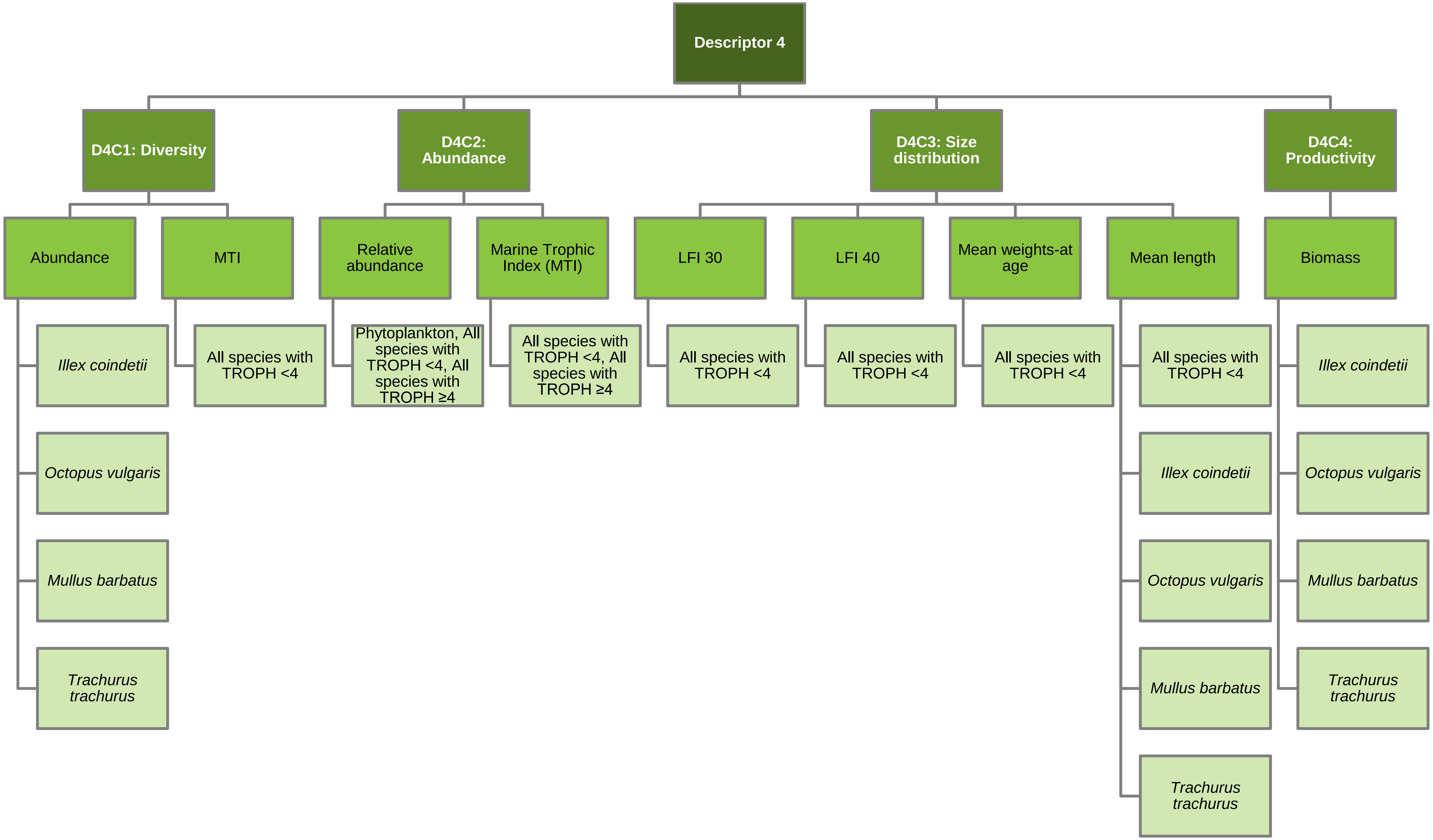

FIGURE 3: INDICATORS AND CRITERIA FOR DESCRIPTOR 4 ASSESSMENT OF SUB-APEX DEMERSAL PREDATORS

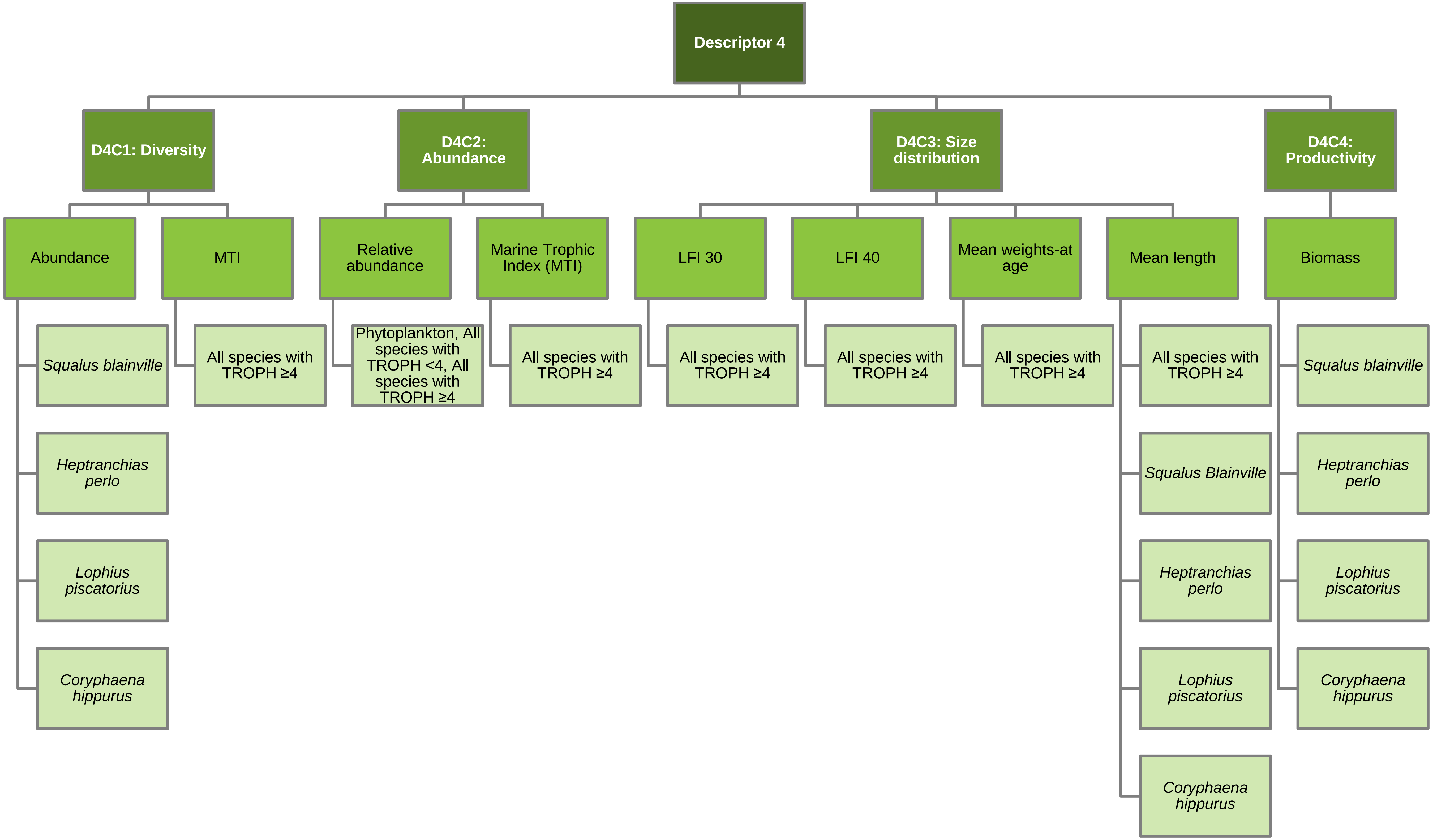

FIGURE 4: INDICATORS AND CRITERIA FOR DESCRIPTOR 4 ASSESSMENT OF APEX PREDATORS

2.5 D4C1: Diversity Within Trophic Guilds

2.5.1 Dia/Dino index

Diatoms and dinoflagellates have been selected as constituent groups for the assessment of primary producers in accordance with D4C1 of the MSFD. These organisms are the dominant phytoplankton taxonomic groups in the world's oceans, and therefore constitute the most important prey organisms for higher trophic levels. Furthermore, differences in diatom/dinoflagellate ratios (Dia/Dino index) may have ecosystem-wide consequences for energy transfer up the food web.[3] Differences in the dominance of these phytoplankton groups affects other trophic levels since their distribution in the water column, their quality as a food source for grazers and their period of occurrence generally differ.

Diatoms are r-strategists, growing and dying quickly. Consequently, diatom-dominated communities cause short bursts of large quantities of marine snow sinking to the bottom and becoming available to zoobenthos. Conversely, dinoflagellates are k-strategists, growing slower and surviving for longer. These organisms are more predominant in surface waters and are therefore more suitable prey for zooplankton. Furthermore, lower Dia/Dino indices may indicate low silicate availability due to eutrophication conditions.[3] Dinoflagellates prefer the water column to be stratified, therefore giving rise to lower Dia/Dino indices in the spring bloom, which occurs in Malta between March and May. Within Maltese waters, the largest phytoplankton bloom, generally observed in January-February, is attributed almost exclusively to diatoms, whilst the smaller phytoplankton bloom in autumn is generally attributed to dinoflagellates.[4]

2.5.1.1 Methodology

Dia/dino index was extracted from the monitoring data. This data represents ratios calculated on abundances (cells/L) of diatoms and dinoflagellates. The mean, minimum and maximum Dia/dino index values from all stations associated to each MRU were then extracted. These values were aggregated to MRU-level by calculating the mean value, or the percentage of areas achieving good status (computed as the proportion of monitoring stations which achieve good status). The principal pressure that affects this indicator is nutrient and organic matter enrichment, with eutrophic conditions indicating that the ecosystem is in bad ecological status in terms of Descriptor 4.

2.5.1.2 Results & analysis

Table 2 and Figure 5 provide the comparison of the Diat/Dino results to GES.

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[3] Wasmund, N., Kownacka, J., Göbel, J., Jaanus, A., Johansen, M., & Jurgensone, I. et al. (2017). The Diatom/Dinoflagellate Index as an Indicator of Ecosystem Changes in the Baltic Sea 1. Principle and Handling Instruction. *Frontiers In Marine Science*, *4*. https://doi.org/10.3389/fmars.2017.00022.

[4] Farrugia, H., Deidun, A., Gauci, A., & Drago, A. (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*(sp1), 632-636. doi: 10.2112/si75-127.1.

Although the results indicate that all three MRUs achieved GES, more data is required to assess status of Descriptor 4 using this indicator. Furthermore, the applicability of the thresholds used still needs to be confirmed.

TABLE 2: COMPARISON OF DIAT/DINO RESULTS TO GES

STATISTIC	INSHORE	TERRITORIAL	OFFSHORE
Mean	10.77	8.38	11.34
Minimum	0.09	0.14	0.49
Maximum	147.00	94.67	45.00
GES	0.75	0.75	0.75
Assessed?	Yes		
% achieving GES	93.04	92.31	95.00

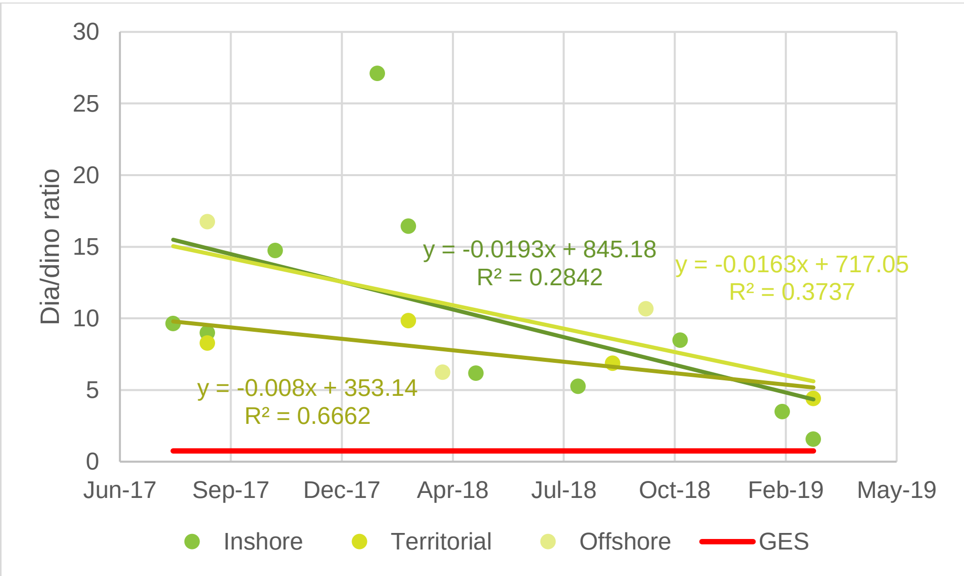

FIGURE 5: DIA/DINO RATIO TREND FOR PRIMARY PRODUCERS

2.5.1.3 Shortcomings & recommendations

Long-term data should be collected for this indicator. Thresholds for this indicator should be established through regional cooperation to enable quantitative assessment.

2.5.2 Large Microphytoplankton vs Small Microphytoplankton

Large microphytoplankton and small microphytoplankton have been selected as constituent groups for the assessment of primary producers in accordance with D4C1 of the MSFD. The ratio between these taxonomic groups serves as a size-based

indicator of the efficiency of energy flow to higher trophic levels.[5]
Microphytoplankton are classified into two groups as follows:

- Large microphytoplankton, >20 μm cells (not colonies)
- Small microphytoplankton (picoplankton & nanoplankton), <20 μm cells (not colonies)

The size structure of phytoplankton affects the trophic organisation of the trophic level and food web as a whole. In communities dominated by small phytoplankton, the dominant trophic pathway is the microbial food web, where most of the primary production is consumed by dinoflagellates, ciliates and heterotrophic nanoflagellates.[6] Little transfer to large organisms such as mesozooplankton or fish occurs and such systems are generally nutrient-impoverished, with phytoplankton with a high SA:Vol ratio (representing small-sized species) dominating assemblages due to their rapid rate of nutrient absorption from surrounding waters. Conversely, primary production produced by plankton communities dominated by large phytoplankton is available for higher trophic guilds such as mesozooplankton, a proportion of which is transported to deeper waters and higher trophic guilds.[6]

2.5.2.1 Methodology

Assessment for this indicator is not possible due to lack of available long-term data.

Once the monitoring results become available, the large:small microphytoplankton ratio should be calculated by using abundances (cells/L) of both groups. The mean, minimum and maximum large:small microphytoplankton ratio values from all stations associated to each MRU should then be extracted. These values should be aggregated to MRU-level by calculating the mean value, or the percentage of areas achieving good status (computed as the proportion of monitoring stations which achieve good status). This is a state indicator which does not provide a direct link to pressures, and identification of thresholds through regional cooperation is necessary to enable quantitative assessment.

2.5.2.2 Results & analysis

Assessment for this indicator is not possible due to lack of available long-term data.

2.5.2.3 Shortcomings & recommendations

Long-term data should be collected for this indicator. Thresholds for this indicator should be established through regional cooperation to enable quantitative assessment.

2.5.3 Abundance of Sub-Apex Demersal Predators

Abundance trends of sub-apex demersal predators were assessed in accordance with

[5] OSPAR (2018). *Common indicator: PH1/FW5 Plankton lifeforms.* https://www.ospar.org/documents?v=39001.

[6] Marañón, E. (2009). Phytoplankton Size Structure. *Encyclopedia Of Ocean Sciences*, 445-452. https://doi.org/10.1016/b978-012374473-9.00661-5.

D4C1 of the MSFD. One of the primary pressures which give rise to cascading changes in food webs, visible throughout the trophic guilds, is fishing. The removal of commercial species from the food web would directly reduce the abundance of the respective trophic level, and indirectly affect the abundances of higher and lower trophic levels. This anthropogenic pressure directly affects target species, while indirectly affecting non-target components of food webs. Prey of exploited species tend to increase in numbers, while their predators tend to decrease.

2.5.3.1 Methodology

MEDITS data from all hauls in the FMZ were used to calculate the abundances of all representative species over the study time period as catch per 1km haul. The MEDITS data was queried as outlined in Table 3 then converted to catch per 1km haul using the swept area.

TABLE 3: DATA QUERIES FOR ABUNDANCE OF SUB-APEX DEMERSAL PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	*Illex coindetii, Octopus vulgaris, Mullus barbatus, Trachurus trachurus*

For each of the queried records, we extracted the total abundance for each representative species per year and divided it by the total swept area of the hauls carried out that year.

The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

2.5.3.2 Results & analysis

Figure 6 to Figure 9 show the abundance trend of each representative species for sub-apex demersal predators, while Table 4 compares the values to GES. *Illex coindetii* and *Mullus barbatus* all appear to be decreasing in abundance over time, which could be caused by:

- An increase in fishing pressure directly on these species;
- Other direct impacts such as habitat loss or introduction of alien species which outcompete the native species;
- A decrease in prey availability due to increased fishing pressure or indirect impacts such as habitat loss or alien species introduction; and/or
- An increase in predation due to a recovering predator population.

Conversely, *Trachurus trachurus* appears to be increasing in abundance over time, which could be caused by:

- A decrease in fishing pressure directly on these species;
- An increase in prey availability due to reduced fishing pressure; and/or
- A decrease in predation due to various possible impacts on apex predators, such as increased fishing pressure, habitat loss or alien species introduction.

Conversely, *Octopus vulgaris* appears to be relatively stable with time. Two of these indicators show decreasing trends with time, meaning they have failed to achieve GES. Two indicators show stable/increasing trends with time, meaning they have achieved GES.

TABLE 4: COMPARISON OF SDP ABUNDANCES TO GES

STATISTIC	*I. COINDETII*	*O. VULGARIS*	*M. BARBATUS*	*T. TRACHURUS*
Mean	1.45	0.05	3.02	7.26
Minimum	0.34	0.00	0.77	3.28
Maximum	2.99	0.18	6.31	17.40
GES	Stable/increasing directional trend			
Assessed?	Yes			
Achieved GES?	No	Yes	No	Yes

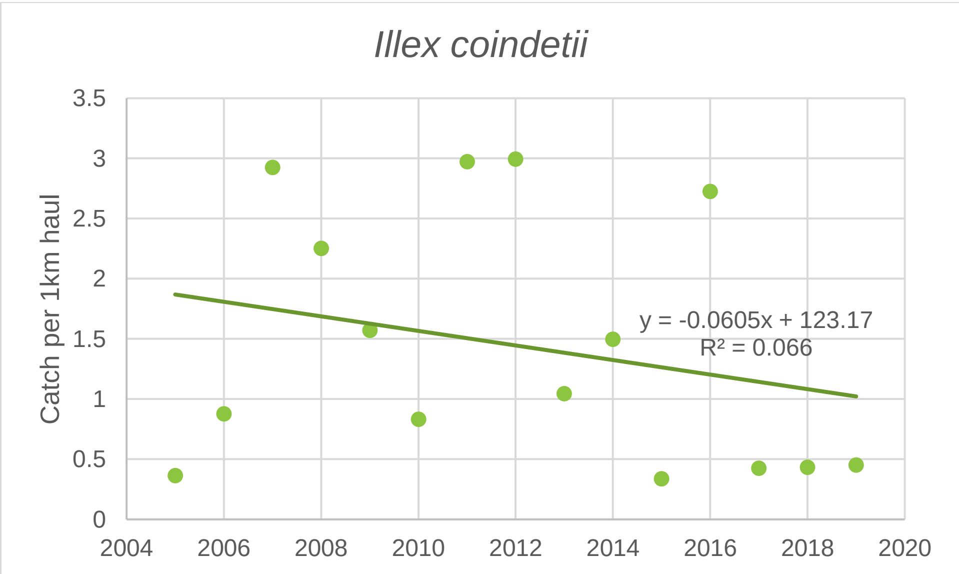

FIGURE 6: ABUNDANCE TREND FOR *ILLEX COINDETII*

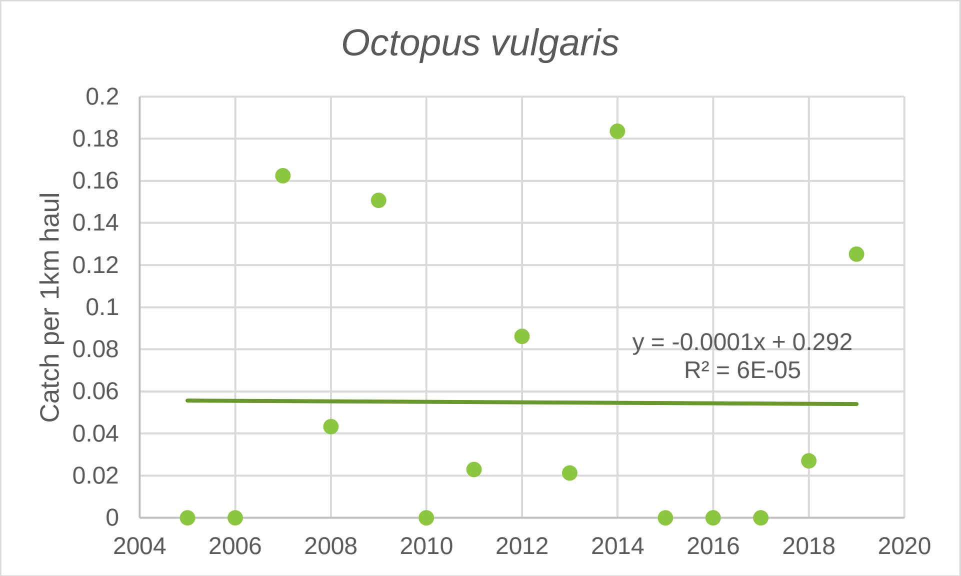

FIGURE 7: ABUNDANCE TREND FOR *OCTOPUS VULGARIS*

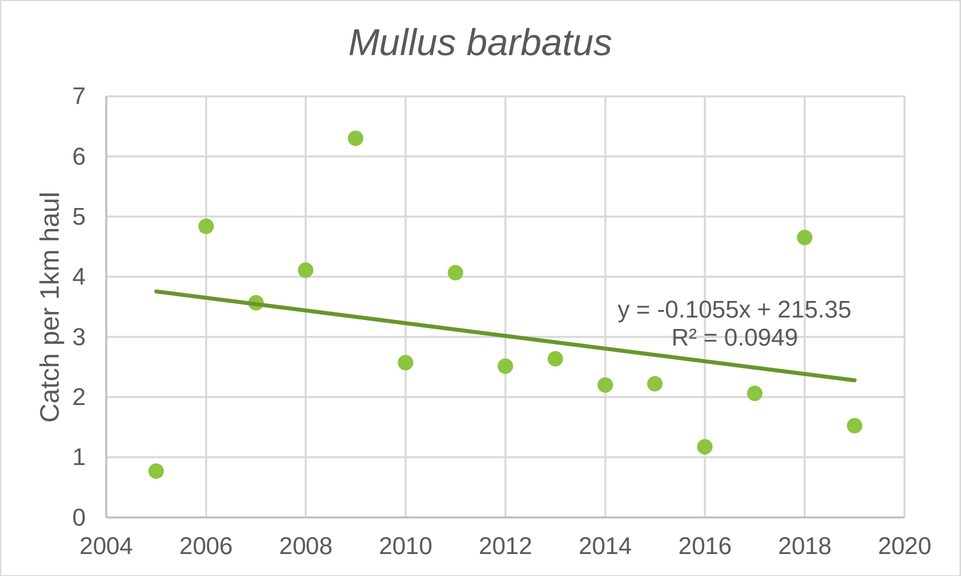

FIGURE 8: ABUNDANCE TREND FOR *MULLUS BARBATUS*

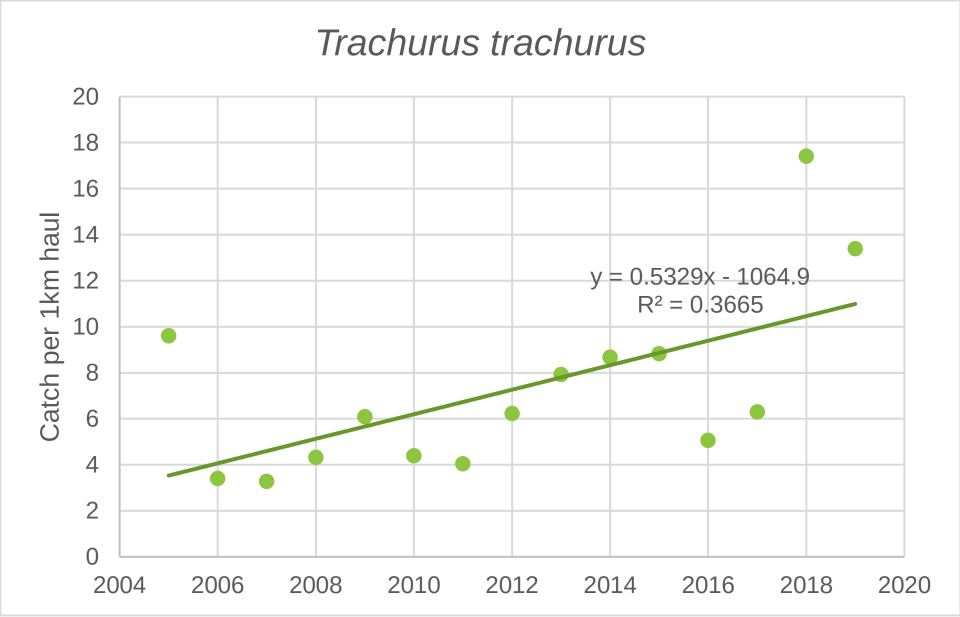

FIGURE 9: ABUNDANCE TREND FOR *TRACHURUS TRACHURUS*

2.5.3.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.5.4 Abundance of Apex Predators

Abundance trends of apex predators was assessed in accordance with D4C1 of the MSFD. One of the primary pressures which give rise to cascading changes in food webs, visible throughout the trophic guilds, is fishing. The removal of commercial species from the food web would directly reduce the abundance of the respective trophic level, and indirectly affect the abundances of lower trophic levels. This anthropogenic pressure directly affects target species, while indirectly affecting non-target components of food webs. Prey of exploited species tend to increase in numbers.

MEDITS data from all hauls in the FMZ was used to calculate the abundances of *Squalus blainville*, *Heptranchias perlo*, and *Lophius piscatorius*. Landings data did not include the parameters required to enable the application of this indicator, to *Coryphaena hippurus* over the study time period. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

2.5.4.1 Methodology

MEDITS data from all hauls in the FMZ were used to calculate the abundances of all representative species over the study time period. The MEDITS data was queried as outlined in Table 5.

TABLE 5: DATA QUERIES FOR ABUNDANCE OF APEX PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	*Squalus blainville, Heptranchias perlo, Lophius piscatorius*

For each of the queried records, we extracted the total abundance for each representative species per year and divided it by the total swept area of the hauls carried out that year.

The analysis could not be performed on the landings data due to the lack of abundance values per haul.

2.5.4.2 Results & analysis

Figure 10 to Figure 12 show the abundance trend of each representative species for apex predators, while Table 6 compares the values to GES. All three representative species appear to be increasing in abundance over time, which could be caused by:

- A decrease in fishing pressure directly on this trophic guild; and/or
- An increase in prey availability due to reduced fishing pressure.

Although the 15-year trend shows that these representative populations are unstable, the possible causes for the increase in apex predator populations are favourable. Consequently, this indicator has achieved GES.

TABLE 6: COMPARISON OF AP ABUNDANCES TO GES

STATISTIC	*S. BLAINVILLE*	*H. PERLO*	*L. PISCATORIUS*
Mean	0.84	0.04	0.02
Minimum	0.00	0.00	0.00
Maximum	3.68	0.16	0.10
GES	Stable/increasing directional trend		
Assessed?	Yes		
Achieved GES?	Yes	Yes	Yes

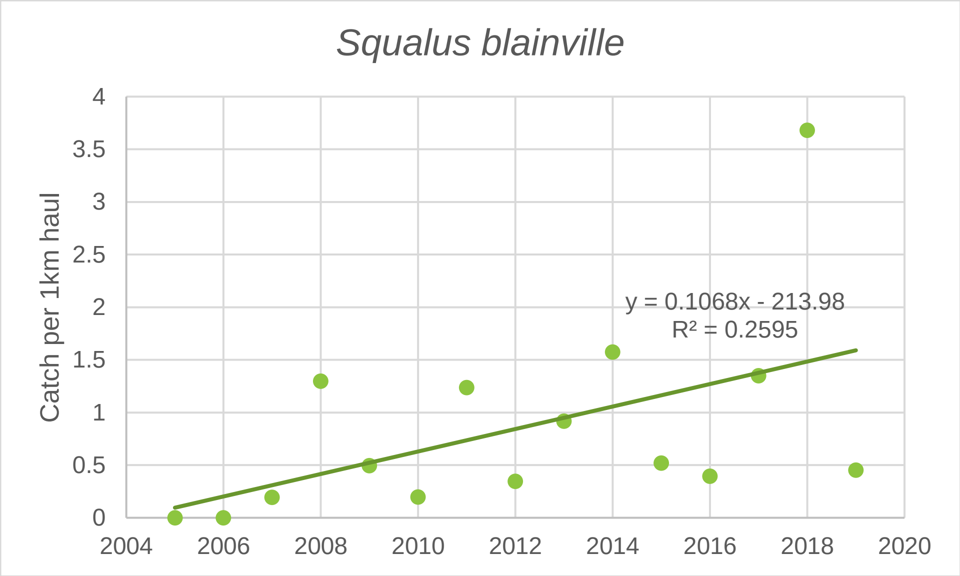

FIGURE 10: ABUNDANCE TREND FOR *SQUALUS BLAINVILLE*

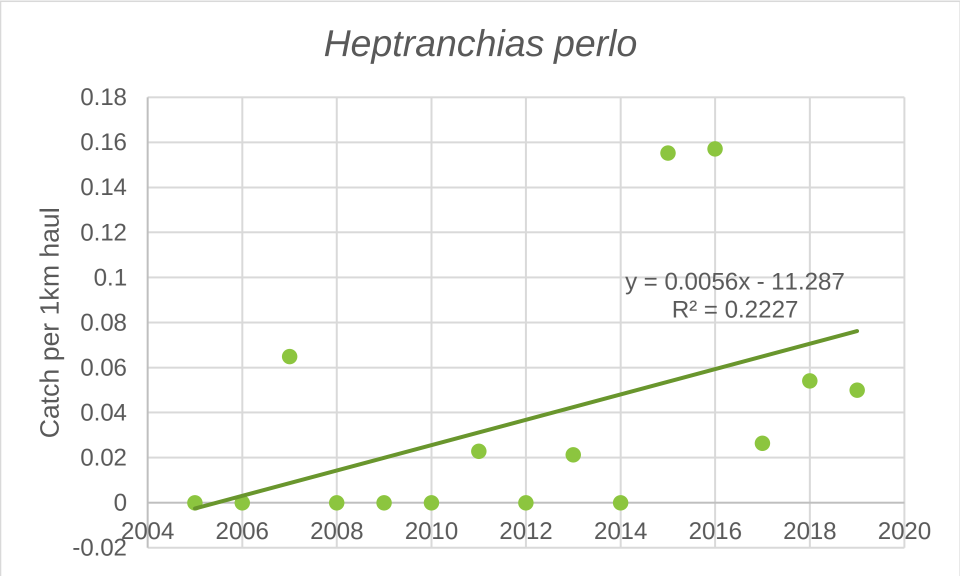

FIGURE 11: ABUNDANCE TREND FOR *HEPTRANCHIAS PERLO*

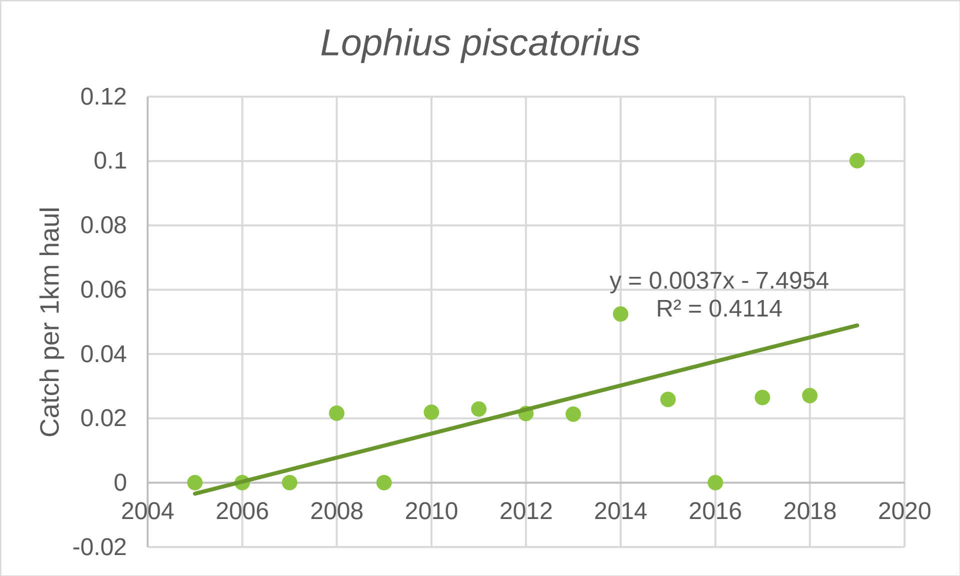

FIGURE 12: ABUNDANCE TREND FOR *LOPHIUS PISCATORIUS*

2.5.4.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.5.5 Marine Trophic Index of Sub-Apex Demersal Predators

The marine trophic index (MTI) was assessed in accordance with D4C1 of the MSFD. The MTI is an indicator representative of the ecological state of the trophic guild. The index is a product of the TROPH of a group/species (i.e. the position of the organism in the food chain) and its abundance.[7] The TROPH represents the number of energy transfer steps to that level and ranges between 1 for primary producers and 5.5 for apex predators. Herbivores (i.e. primary consumers) have a TROPH of about 2, while carnivores range in TROPH between 3 and 5. For the purposes of this assessment, sub-apex demersal predators constitute all demersal consumers with a TROPH of 4 or less.[8] This threshold is being drawn along arbitrary lines, taking into consideration the existing range of TROPHs for the Mediterranean Sea. Ideally, once data from other methodologies emerges (e.g. stable isotope analysis, fatty acid analysis), the recommended threshold should be reassessed for possible revision. These thresholds should also be discussed and agreed on a regional basis.

TROPHs are closely related to organism size, meaning changes in MTI mirror changes in food chain position and size composition. Since overfishing primarily targets large high-trophic level species, it leads to a deterioration in the ecosystem structure, reflected as a declining MTI.

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[7] UNEP (2004). *Indicators for Assessing Progress Towards the 2010 Target: Marine Trophic Index.* https://www.cbd.int/doc/meetings/sbstta/sbstta-10/information/sbstta-10-inf-18-en.pdf.

[8] Essington, T., Beaudreau, A., & Wiedenmann, J. (2006). Fishing through marine food webs. *Proceedings of the National Academy of Sciences, 103*(9), 3171-3175. https://doi.org/10.1073/pnas.0510964103.

2.5.5.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the MTI for all sub-apex demersal species in the catch over the time period. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 7.

Table 7: Data Queries for Marine Trophic Index of Sub-Apex Demersal Predators

Year	Haul	Species
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All species with TROPH <4

For each of the queried records, we calculated the total abundance of the species per swept area. We multiplied this value by the TROPH value for the particular species. We then calculated the MTI per year, which takes into consideration the abundances for all sub-apex demersal predators, as follows:

$$\text{MTI} = \frac{\sum(\text{TROPH} \times \text{abundance})}{\sum(\text{abundance})}$$

2.5.5.2 Results & analysis

Figure 13 show the MTI trend for sub-apex demersal predators, which appears to be slightly increasing over time, while Table 8 compares the values to GES. The variation is relatively minimal (<0.1), indicating that the MTI of this trophic guild is stable.

Considering that the 15-year trend shows that the MTI is stable, this indicator has achieved GES.

Table 8: Comparison of SDP Marine Trophic Index to GES

Statistic	Marine Trophic Index
Mean	3.64
Minimum	3.59
Maximum	3.72
GES	Stable directional trend
Assessed?	Yes
Achieved GES?	No

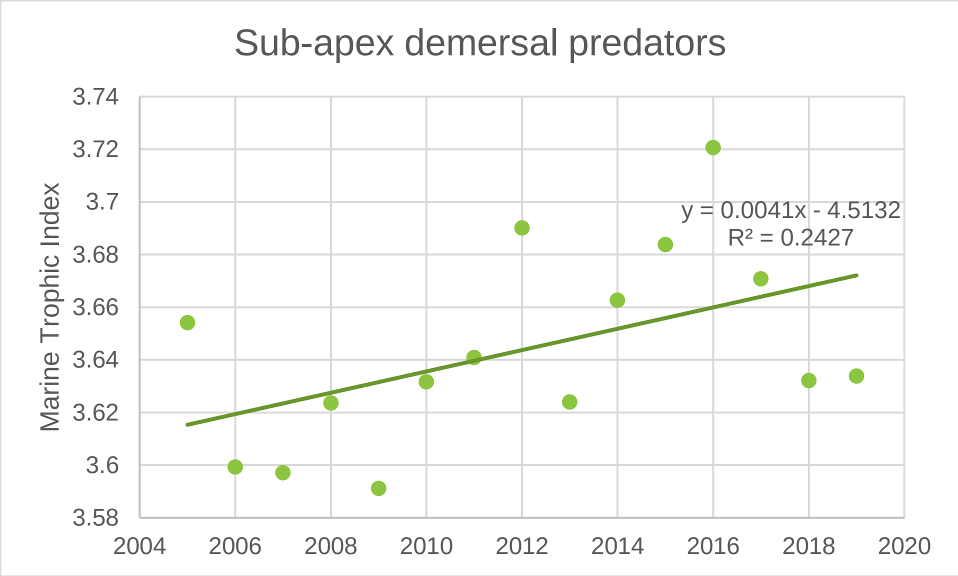

FIGURE 13: MARINE TROPHIC INDEX TREND FOR ALL SUB-APEX DEMERSAL PREDATORS

2.5.5.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.5.6 Marine Trophic Index of Apex Predators

The marine trophic index (MTI) was assessed in accordance with D4C1 of the MSFD. The MTI is an indicator representative of the ecological state of the trophic guild. The index is a product of the TROPH of a group/species (i.e. the position of the organism in the food chain) and its abundance.[7] The TROPH represents the number of energy transfer steps to that level and ranges between 1 for primary producers and 5.5 for apex predators. Herbivores (i.e. primary consumers) have a TROPH of about 2, while carnivores range in TROPH between 3 and 5. For the purposes of this assessment, apex predators constitute all consumers with a TROPH above 4.[Error! Bookmark not defined.] This threshold is being drawn along arbitrary lines, taking into consideration the existing range of TROPHs for the Mediterranean Sea. Ideally, once data from other methodologies emerges (e.g. stable isotope analysis, fatty acid analysis), the recommended threshold should be reassessed for possible revision. These thresholds should also be discussed and agreed on a regional basis.

TROPHs are closely related to organism size, meaning changes in MTI mirror changes in food chain position and size composition. Since overfishing primarily targets large high-trophic level species, it leads to a deterioration in the ecosystem structure, reflected as a declining MTI.

2.5.6.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the MTI for all apex species in the catch. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 9.

TABLE 9: DATA QUERIES FOR MARINE TROPHIC INDEX OF APEX PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All species with TROPH ≥4

For each of the queried records, we calculated the total abundance of the species per swept area. We then multiplied this value by the TROPH value for the particular species. We then calculated the MTI per year, which takes into consideration the abundances for all apex predators, as follows:

$$\mathrm{MTI} = \frac{\sum(\mathrm{TROPH} \times \mathrm{abundance})}{\sum(\mathrm{abundance})}$$

2.5.6.2 Results & analysis

Figure 13 show the MTI trend for apex predators, which appears to be slightly decreasing over time, while Table 10 compares the values to GES. The variation is relatively minimal (<0.1), indicating that the MTI of this trophic guild is stable.

Considering that the 15-year trend shows that the MTI is stable, this indicator has achieved GES.

TABLE 10: COMPARISON OF AP MARINE TROPHIC INDEX TO GES

STATISTIC	MARINE TROPHIC INDEX
Mean	4.17
Minimum	4.15
Maximum	4.19
GES	Stable directional trend
Assessed?	Yes
Achieved GES?	Yes

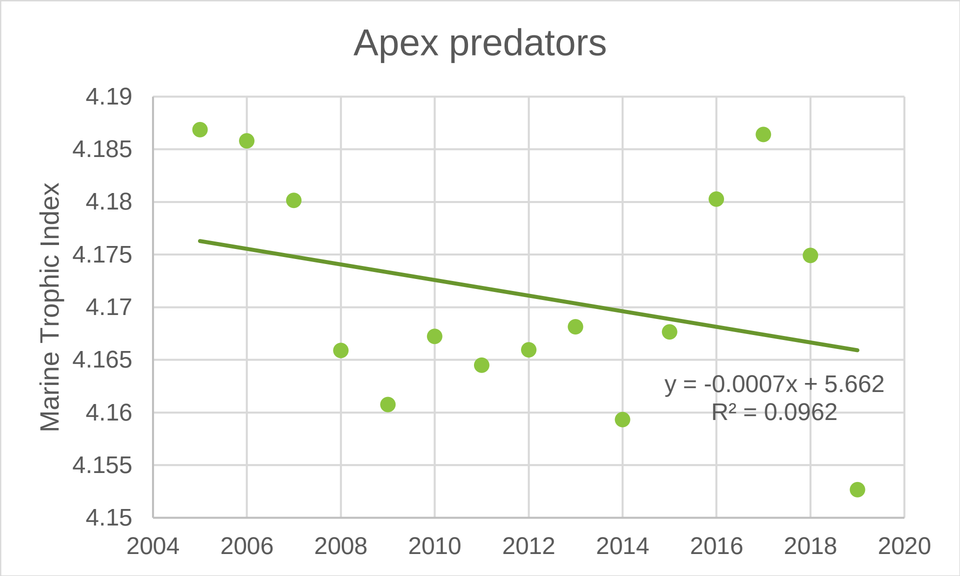

FIGURE 14: MARINE TROPHIC INDEX TREND FOR ALL APEX PREDATORS

2.5.6.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.6 D4C2: ABUNDANCE BETWEEN THE TROPHIC GUILDS

2.6.1 Abundance

D4C2 of the MSFD assesses the ecological status of food webs based on the relationship between the different trophic guilds. Considering the cascading nature of effects through trophic levels, issues in a particular guild may be visible in one/both other guilds. The abundance trends between the trophic guilds were compared on a qualitative basis.

2.6.1.1 Methodology

Phytoplankton data from all stations was used to calculate the abundance (cells/l). The principal pressure that affects this indicator is nutrient and organic matter enrichment. MEDITS data from all hauls in the FMZ were used to calculate the abundances of all sub-apex demersal predators and apex predators per swept area over the study time period. The abundance trends of all three trophic guilds were plotted on a graph to enable comparison.

The phytoplankton and MEDITS datasets were queried as outlined in Table 11.

TABLE 11: DATA QUERIES FOR ABUNDANCE BETWEEN TROPHIC GUILDS

YEAR	STATION	SPECIES
2017-2019	All inshore, territorial and offshore stations (EMFF 8.3.1)	All phytoplankton
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79 (MEDITS hauls)	All species with TROPH <4

YEAR	STATION	SPECIES
		All species with TROPH ≥4

2.6.1.2 Results & analysis

Figure 15 shows the abundance trend of the three trophic guilds, while Table 12 compares the values to GES. The graph shows that the data for primary producers is limited to a total of two years, spread from August 2017 to March 2019. Phytoplankton abundance fluctuates seasonally. Considering that the 2017 and 2019 phytoplankton datasets cover two seasons each, the sharp decline in abundance between 2017 and 2019 is more likely to be a reflection of the incomplete coverage of the respective year, rather than a real decline in annual phytoplankton abundance. Furthermore, the data only covers a total period of 2 years, which is too short a time to assess annual trends. Consequently, this data is unusable for the assessment of phytoplankton in terms of D4C2.

When comparing the abundance patterns between abundance of sub-apex demersal predators and apex predators, the graphs indicate that the abundances for both groups fluctuated annually. There is a clear relationship between the abundance patterns for the two trophic guilds, with a slight delay for apex predators. These represent direct prey-predator relationship trends, where the increase in sub-apex predators causes a subsequent increase in apex predators, and vice versa. The abundances of both guilds appear to be increasing slightly, which could be caused by:

- A decrease in fishing pressure directly on these guilds;
- An increase in prey availability due to reduced fishing pressure on the prey community; and/or
- Reduced indirect impacts such as habitat loss or alien species introduction.

Considering that the 15-year abundance trend shows that the sub-apex predator and apex predator guilds are related and on a slight increase, this indicator has partly achieved GES. The inclusion of primary producers in the assessment was not possible due to a lack of long-term data.

TABLE 12: COMPARISON OF ABUNDANCES BETWEEN TROPHIC GUILDS TO GES

STATISTIC	PP	SDP	AP
Mean	1783.03	65.20	11.55
Minimum	697.25	33.65	2.83
Maximum	2557.79	103.82	25.36
GES	Stable/increasing directional trend between trophic guilds		

STATISTIC	PP	SDP	AP
Assessed?	Partly (lack of long-term PP data)		
Achieved GES?	SDP & AP: Yes SDP & PP: Not assessed PP & AP: Not assessed		

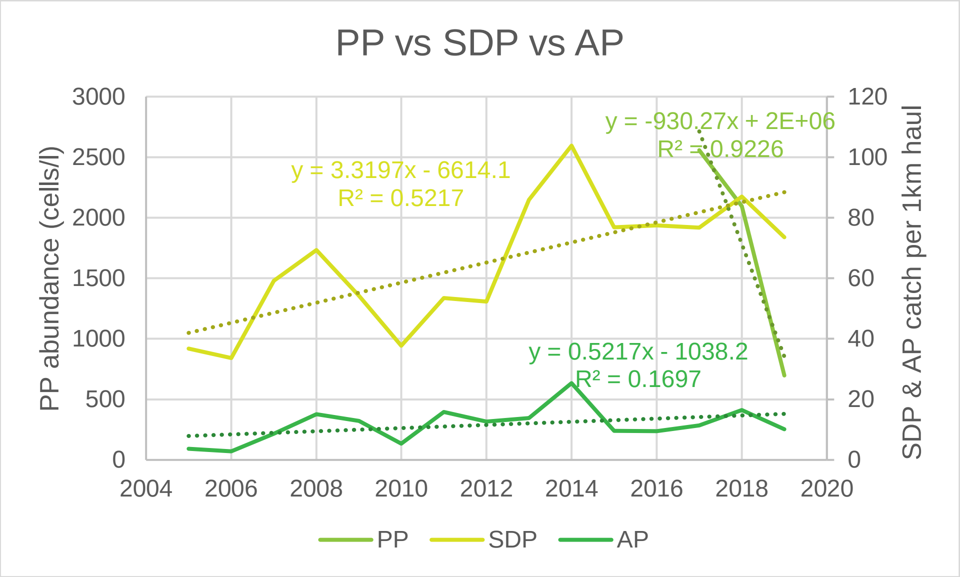

FIGURE 15: ABUNDANCE TRENDS BETWEEN TROPHIC GUILDS

2.6.1.3 Shortcomings & recommendations

Long-term data should be collected for phytoplankton in relation to this indicator. Thresholds for this indicator should be established through regional cooperation to enable quantitative assessment.

2.6.2 Marine Trophic Index

The marine trophic index (MTI) was assessed in accordance with D4C2 of the MSFD. The MTI is an indicator representative of the ecological state of the trophic guild. The index is a product of the TROPH of a group/species (i.e. the position of the organism in the food chain) and its abundance.[9] The TROPH represents the number of energy transfer steps to that level and ranges between 1 for primary producers and 5.5 for apex predators. Herbivores (i.e. primary consumers) have a TROPH of about 2, while carnivores range in TROPH between 3 and 5. For the purposes of this assessment, sub-apex demersal predators constitute all demersal consumers with a TROPH of 4 or

[9] UNEP (2004). *Indicators for Assessing Progress Towards the 2010 Target: Marine Trophic Index.* https://www.cbd.int/doc/meetings/sbstta/sbstta-10/information/sbstta-10-inf-18-en.pdf.

less.[10] This threshold is being drawn along arbitrary lines, taking into consideration the existing range of TROPHs for the Mediterranean Sea. Ideally, once data from other methodologies emerges (e.g. stable isotope analysis, fatty acid analysis), the recommended threshold should be reassessed for possible revision. These thresholds should also be discussed and agreed on a regional basis.

TROPHs are closely related to organism size, meaning changes in MTI mirror changes in food chain position and size composition. Since overfishing primarily targets large high-trophic level species, it leads to a deterioration in the ecosystem structure, reflected as a declining MTI.

D4C2 of the MSFD assesses the ecological status of food webs based on the relationship between the different trophic guilds. Considering the cascading nature of effects through trophic levels, issues in a particular guild may be visible in one/both other guilds. The MTI trends between the trophic guilds was compared on a qualitative basis.

2.6.2.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the MTI for all sub-apex demersal predators and apex predators in the catch over the time period. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 13.

Table 13: Data Queries for Marine Trophic Index Between Trophic Guilds

Year	Haul	Species
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All species with TROPH <4
		All species with TROPH ≥4

For each of the queried records, we calculated the total abundance of the species per swept area. We multiplied this value by the TROPH value for the particular species. We then calculated the MTI per year, which takes into consideration the abundances for all sub-apex demersal predators and apex predators, as follows:

[10] Essington, T., Beaudreau, A., & Wiedenmann, J. (2006). Fishing through marine food webs. *Proceedings of the National Academy of Sciences*, *103*(9), 3171-3175. https://doi.org/10.1073/pnas.0510964103.

$$\text{MTI} = \frac{\sum(\text{TROPH} \times \text{abundance})}{\sum(\text{abundance})}$$

2.6.2.2 Results & analysis

Figure 16 shows the MTI trend of the two trophic guilds, while Table 14 compares the values to GES. When comparing the patterns between MTI of sub-apex demersal predators and apex predators, the graphs indicate that the MTI for both groups fluctuated annually. The overall relationship between the two trophic guilds appears to be inversely proportional, with the MTI of sub-apex demersal predators increasing, and that of apex predators decreasing within the same time period. However, the overall variation is relatively minimal for both trophic guilds (<0.05), meaning the MTI of these trophic guilds can be considered as stable.

Interestingly, although the SDP and the AP trophic guilds demonstrate similarly-trending catch statistics, for the 2004-2020 period (Figure 15), the same trophic guilds exhibit opposing MTI trends (Figure 16). The MTI takes into consideration both the abundance and the trophic level of each species; the abundance indicators do not consider the trophic levels. With regards to AP, there was an opposing trend in abundance (increase) and MTI (decrease). This observation can be inferred to potentially represent a decrease in the TL of fished species, the so-called 'fishing down the food-web effect'.[11]

Considering that the 15-year MTI trend shows that the sub-apex predator and apex predator guilds are related and quite stable, this indicator has achieved GES.

TABLE 14: COMPARISON OF MTI BETWEEN TROPHIC GUILDS TO GES

STATISTIC	SDP	AP
Mean	3.64	4.17
Minimum	3.59	4.15
Maximum	3.72	4.19
GES	Stable directional trend between trophic guilds	
Assessed?	Yes	
Achieved GES?	Yes	

[11] Pauly, D., Watson, R., & Alder, J. (2005). Global trends in world fisheries: impacts on marine ecosystems and food security. *Philosophical Transactions Of The Royal Society B: Biological Sciences*, *360*(1453), 5-12. doi: 10.1098/rstb.2004.1574

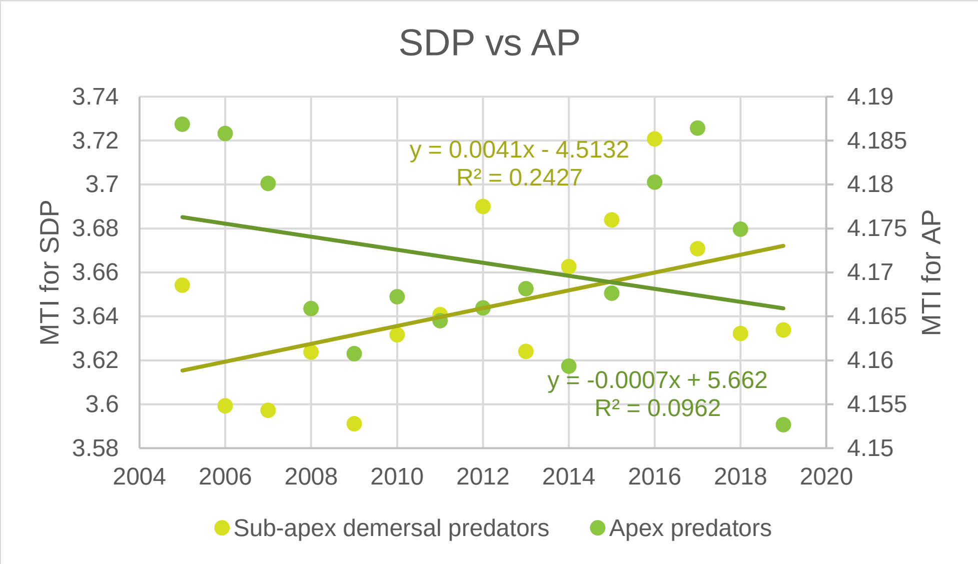

FIGURE 16: MARINE TROPHIC INDEX BETWEEN TROPHIC GUILDS

2.6.2.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.7 D4C3: SIZE DISTRIBUTION WITHIN TROPHIC GUILDS

2.7.1 Large Microphytoplankton vs Small Microphytoplankton

Large microphytoplankton and small microphytoplankton have been selected as constituent groups for the assessment of primary producers in accordance with D4C1 and D4C3 of the MSFD. The ratio between these taxonomic groups serves as a size-based indicator of the efficiency of energy flow to higher trophic levels.[12] Microphytoplankton are classified into two groups as follows:

- Large microphytoplankton, >20 µm cells (not colonies)
- Small microphytoplankton (picoplankton & nanoplankton), <20 µm cells (not colonies)

The size structure of phytoplankton affects the trophic organisation of the trophic level and food web as a whole. In communities dominated by small phytoplankton, the dominant trophic pathway is the microbial food web, where most of the primary production is consumed by dinoflagellates, ciliates and heterotrophic nanoflagellates.[13] Little transfer to large organisms such as mesozooplankton or fish occurs. Conversely, primary production produced by plankton communities dominated by large phytoplankton is available for higher trophic guilds such as mesozooplankton, a proportion of which is transported to deeper waters and higher

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[12] OSPAR (2018). *Common indicator: PH1/FW5 Plankton lifeforms.* https://www.ospar.org/documents?v=39001.

[13] Marañón, E. (2009). Phytoplankton Size Structure. *Encyclopedia Of Ocean Sciences*, 445-452. https://doi.org/10.1016/b978-012374473-9.00661-5.

trophic guilds.[6]

2.7.1.1 Methodology

Assessment for this indicator is not possible due to lack of available long-term data (refer to explanation of methodology in above sections).

2.7.1.2 Results & analysis

Assessment for this indicator is not possible due to lack of available long-term data.

2.7.1.3 Shortcomings & recommendations

Long-term data should be collected for this indicator. Thresholds for this indicator should be established through regional cooperation to enable quantitative assessment.

2.7.2 Large Fish Index of Sub-Apex Demersal Predators

The Large Fish Indicator (LFI) was assessed in accordance with D4C3 of the MSFD. The LFI is defined as the proportion by weight of large fish in the sample of a specified survey, irrespective of species.[14] Generally, the threshold between small and large fish (L_{th}) is determined on a regional basis, and is chosen to optimise responsiveness of the indicator to fishing pressure.[15] Considering that fishing is generally size-selective, larger individuals are targeted to a greater extent than smaller individuals, and therefore suffer higher rates of mortality.[16] The LFI is therefore sensitive to the fishing pressure. Furthermore, the proportions of the indicator are based on weight not by numbers, making it less likely to be affected by the tendency of smaller fish to be found in higher numbers than larger fish. This indicator is very useful for studying fish taxonomic groups and has been selected as a common foodweb indicator by HELCOM and OSPAR.[17]

2.7.2.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the LFI for all sub-apex demersal species in the catch over the time period. Since no regional length thresholds have been established,[18] the assessment made use of two cut-off points to distinguish large fish: 30cm and 40cm. These cut-off points are being drawn on an arbitrary basis, but would allow the assessment of this indicator on multiple levels. The principal pressure that affects this indicator is fishing, with declining values over

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[14] Greenstreet, S. P. R., Rogers, S. I., Rice, J. C., Piet, G. J., Guirey, E. J., Fraser, H. M. & Fryer, R. J. (2011). Development of the EcoQO for the North Sea fish community. *ICES Journal of Marine Science 68*, 1–11

[15] Shephard, S., Reid, D. G. & Greenstreet, S. P. R. (2011). Interpreting the large fish indicator for the Celtic Sea. *ICES Journal of Marine Science 68*, 1963–1972.

[16] Rogers, S., Casini, M., Cury, P., Heath, M., Irigoien, X., Kuosa, H., Scheidat, M., Skov, H., Stergiou, K., Trenkel, V., Wilkner, J. & Yunev, O. (2010). *Marine Strategy Framework Directive Task Group 4 Report: Food Webs.* doi: 10.2788/87659.

[17] ICES (2014). *Report of the Workshop to develop recommendations for potentially useful Food Web Indicators (WKFooWI)*, 31 March–3 April 2014, ICES Headquarters, Copenhagen, Denmark. ICES CM 2014\ACOM:48. 75 pp.

[18] ICES (2014). EU request on proposal on indicators for MSFD Descriptor 4 (foodwebs).

the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 15.

Table 15: Data Queries for LFI of Sub-Apex Demersal Predators

Year	Haul	Species
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All fish species with TROPH <4

For each of the queried records, we extracted the total abundance. Using the individual length values, we split the data into fish larger or smaller than the 30cm cut-off point. We then calculated the total biomass for fish larger than 30cm and for all fish. The LFI per year was calculated as the proportion by biomass of large fish, as follows:

$$\mathrm{LFI}_{30} = \frac{\sum(\mathrm{biomass}_{\mathrm{large\ fish} \geq 30})}{\sum(\mathrm{biomass}_{\mathrm{all\ fish}})}$$

The process was repeated using the 40cm cut-off point as follows:

$$\mathrm{LFI}_{40} = \frac{\sum(\mathrm{biomass}_{\mathrm{large\ fish} \geq 40})}{\sum(\mathrm{biomass}_{\mathrm{all\ fish}})}$$

2.7.2.2 Results & analysis

Figure 17 shows the LFI_{30} and LFI_{40} trend for sub-apex demersal predators, which appear to be increasing over time, while Table 16 compares the values to GES. This pattern could be caused by:

- A decrease in fishing pressure on the large individuals of the trophic guild, allowing for more of the population to grow larger;
- An increase in prey availability due to reduced fishing pressure, causing the individuals to become larger; and/or
- A decrease in predation due to various possible impacts on apex predators, such as increased fishing pressure, habitat loss or alien species introduction.

Considering that the 15-year trend shows that both the LFI_{30} and LFI_{40} are increasing, these indicators have achieved GES.

Table 16: Comparison of SDP Large Fish Index to GES

Statistic	LFI of Fish ≥ 30	LFI of Fish ≥ 40
Mean	0.45	0.28

STATISTIC	LFI OF FISH ≥ 30	LFI OF FISH ≥ 40
Minimum	0.02	0.01
Maximum	0.68	0.45
GES	Stable/increasing directional trend	
Assessed?	Yes	
Achieved GES?	Yes	Yes

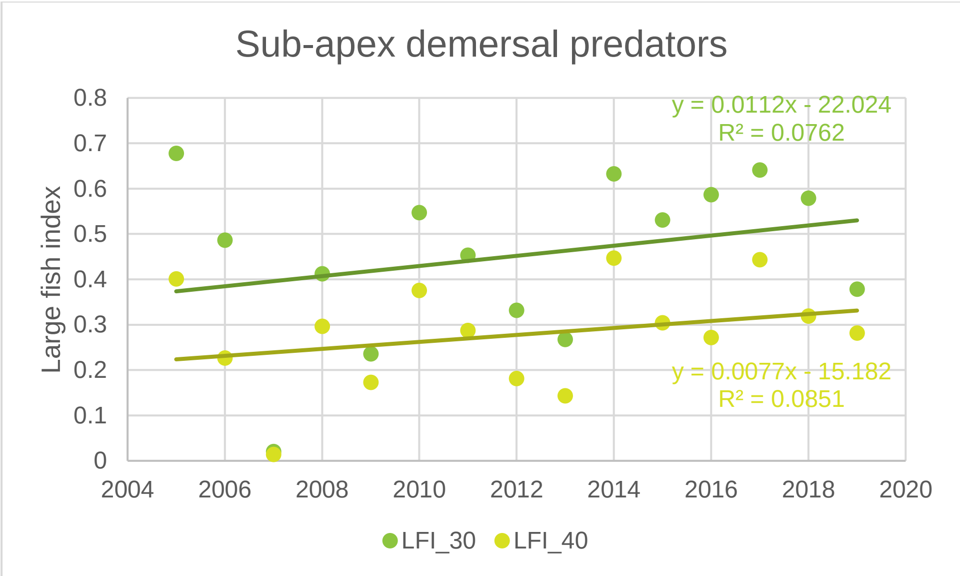

FIGURE 17: LARGE FISH INDEX TREND FOR ALL SUB-APEX DEMERSAL PREDATORS

2.7.2.3 Shortcomings & recommendations

Both the 30cm and 40cm cut-off marks are suitable for the assessment of Maltese MEDITS data. The threshold should however be agreed on a regional basis.

2.7.3 Large Fish Index of Apex Predators

The Large Fish Indicator (LFI) was assessed in accordance with D4C3 of the MSFD. The LFI is defined as the proportion by weight of large fish in the sample of a specified survey, irrespective of species.[14] Generally, the threshold between small and large fish (L_{th}) is determined on a regional basis, and is chosen to optimise responsiveness of the indicator to fishing pressure.[15] Considering that fishing is generally size-selective, larger individuals are targeted to a greater extent than smaller individuals, and therefore suffer higher rates of mortality.[16] The LFI is therefore sensitive to the fishing pressure. Furthermore, the proportions of the indicator are based on weight not by numbers, making it less likely to be affected by the tendency of smaller fish to be found in higher numbers than larger fish. This indicator is very useful for studying fish taxonomic groups and has been selected as a common foodweb indicator by HELCOM and OSPAR.[17]

2.7.3.1 Methodology

MEDITS data from all hauls in the FMZ and landings data was used to calculate the LFI for all apex species in the catch over the time period. Since no regional length thresholds have been established,[18] the assessment made use of two cut-off points to distinguish large fish: 30cm and 40cm. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 17.

Table 17: Data Queries for LFI of Apex Predators

Year	Haul	Species
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All fish species with TROPH ≥4

For each of the queried records, we extracted the total abundance. Considering that the lengths and weights of the individual fish was not available, we calculated the average lengths and weights per species per haul per year. We then calculated the LFI per year, which takes into account all apex fish species larger than 30cm and 40cm, as follows:

$$LFI_{30} = \frac{\sum(\text{biomass}_{\text{large fish} \geq 30})}{\sum(\text{biomass}_{\text{all fish}})}$$

$$LFI_{40} = \frac{\sum(\text{biomass}_{\text{large fish} \geq 40})}{\sum(\text{biomass}_{\text{all fish}})}$$

2.7.3.2 Results & analysis

Figure 18 shows the LFI30 and LFI40 trend for apex predators, which appear to be increasing over time, while Table 18 compares the values to GES. This pattern could be caused by:

- A decrease in fishing pressure on the large individuals of the trophic guild, allowing for more of the population to grow larger; and/or
- An increase in prey availability due to reduced fishing pressure, causing the individuals to become larger.

Considering that the 15-year trend shows that both the LFI30 and LFI4 are increasing, these indicators have achieved GES.

Table 18: Comparison of AP Large Fish Index to GES

Statistic	Biomass ≥ 30	Biomass ≥ 40
Mean	0.36	0.23
Minimum	0.18	0.07
Maximum	0.57	0.38
GES	Stable/increasing directional trend	
Assessed?	Yes	
Achieved GES?	Yes	Yes

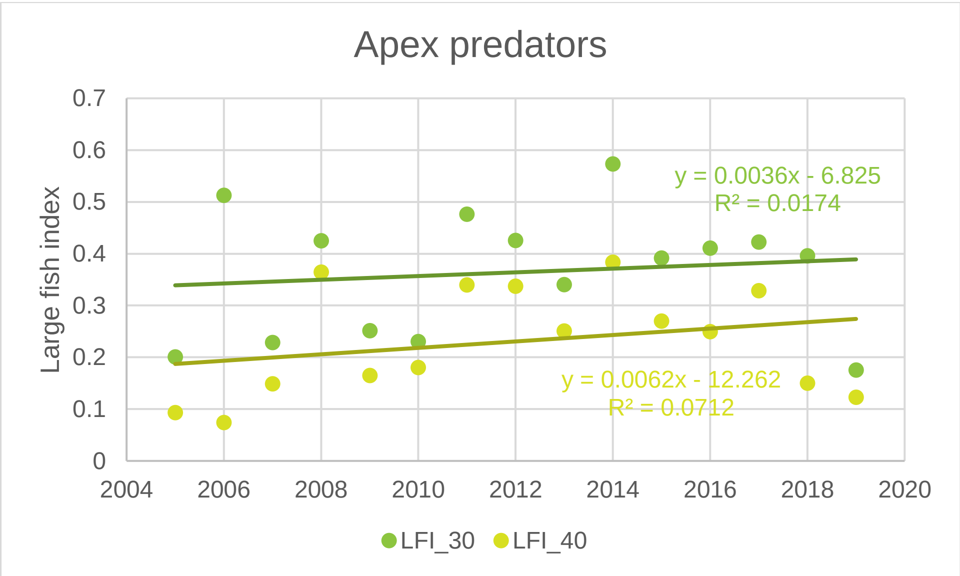

Figure 18: Large Fish Index Trend for all Apex Predators

2.7.3.3 Shortcomings & recommendations

Both the 30cm and 40cm cut-off marks are suitable for the assessment of Maltese MEDITS data. The variation in LFI over the study time period was larger for individuals larger than 40cm, making this more sensitive to change and therefore preferred as a cut-off mark. Nevertheless, the threshold should be agreed on a regional basis.

2.7.4 Weights-at-Age of Sub-Apex Demersal Predators

The mean weights-at-age of predatory fish was assessed in accordance with D4C3 of the MSFD. As outlined above, fishing pressure is higher on large individuals than smaller ones. Consequently, the mean weights-at-age indicator serves to provide the average "weight anomaly" for the fish community in a particular year, i.e. the deviation around an observed long-term mean.[17] The youngest and oldest groups of fish are excluded to avoid sampling bias, and the weights of the remaining fish are averaged for all ages of each stock to obtain a mean annual anomaly for that stock. Stock anomalies are then averaged by year to obtain the stock average weight for the whole predatory fish community, where indicator values fluctuate around this norm. This indicator can be applied to different species or whole communities.

2.7.4.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the mean weights-at-age for all sub-apex demersal fish species in the catch over the time period. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 19.

TABLE 19: DATA QUERIES FOR WEIGHTS-AT-AGE OF SUB-APEX DEMERSAL PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All fish species with TROPH <4 and maturity 2/3

For each of the queried records, we extracted the total weight of each fraction per haul. Considering that the weights of the individual fish were not available, we calculated the average weights per species per haul per year. These were calculated by dividing the total weights of the species per haul per year by the number of individuals of the same species within the particular haul. We then calculated the mean weight at age per year, which takes into account all sub-apex demersal predator fish at maturity level 2/3.

2.7.4.2 Results & analysis

Figure 19 shows the mean weights-at-age trend for sub-apex demersal predators, which appears to be increasing over time, while Table 20 compares the values to GES. This pattern could be caused by:

- A decrease in fishing pressure on the large individuals of the trophic guild, allowing for more of the population to grow larger;
- An increase in prey availability due to reduced fishing pressure, causing the individuals to become larger; and/or
- A decrease in predation due to various possible impacts on apex predators, such as increased fishing pressure, habitat loss or alien species introduction.

Considering that the 15-year trend shows that the mean weights-at age is increasing, this indicator has achieved GES.

TABLE 20: COMPARISON OF SDP WEIGHTS-AT-AGE TO GES

STATISTIC	WEIGHTS-AT-AGE
Mean	543.47
Minimum	152.87
Maximum	1095.17
GES	Stable/increasing directional trend
Assessed?	Yes
Achieved GES?	Yes

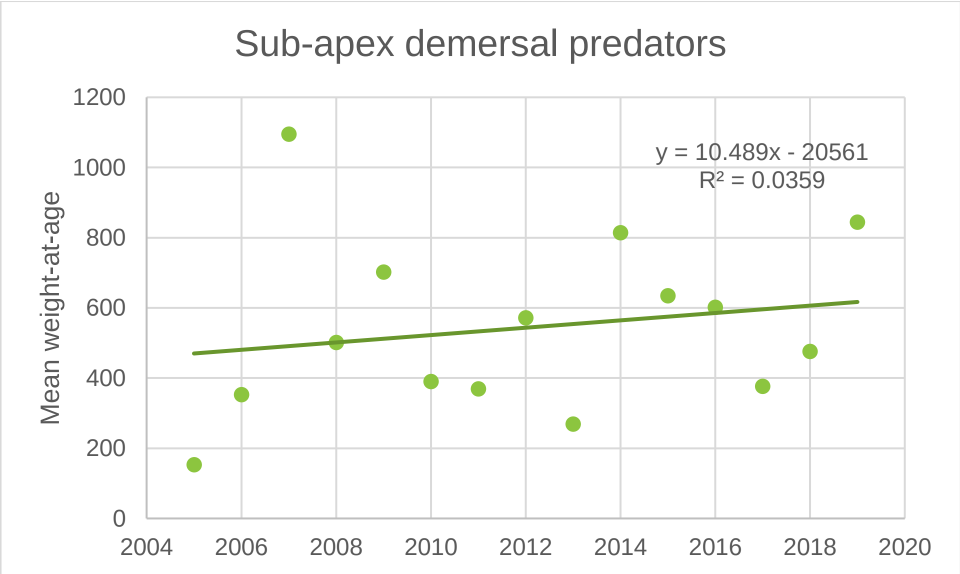

FIGURE 19: MEAN WEIGHT-AT-AGE TREND FOR ALL SUB-APEX DEMERSAL PREDATORS

2.7.4.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.7.5 Weights-at-Age of Apex Predators

The mean weights-at-age of predatory fish was assessed in accordance with D4C3 of the MSFD. As outlined above, fishing pressure is higher on large individuals than smaller ones. Consequently, the mean weights-at-age indicator serves to provide the average "weight anomaly" for the fish community in a particular year, i.e. the deviation around an observed long-term mean.[17] The youngest and oldest groups of fish are excluded to avoid sampling bias, and the weights of the remaining fish are averaged for all ages of each stock to obtain a mean annual anomaly for that stock. Stock anomalies are then averaged by year to obtain the stock average weight for the whole predatory fish community, where indicator values fluctuate around this norm. This indicator can be applied to different species or whole communities.

2.7.5.1 Methodology

MEDITS data from all hauls in the FMZ and landings data was used to calculate the mean weights-at-age for all apex fish species in the catch over the time period. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 21.

Table 21: Data Queries for Weights-at-Age of Apex Predators

Year	Haul	Species
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All fish species with TROPH ≥4 and maturity 2/3

For each of the queried records, we extracted the total weight of each fraction per haul. Considering that the weights of the individual fish were not available, we calculated the average weights per species per haul per year. These were calculated by dividing the total weights of the species per haul per year by the number of individuals of the same species within the particular haul. We then calculated the mean weight at age per year, which takes into account all apex predator fish at maturity level 2/3.

2.7.5.2 Results & analysis

Figure 20 shows the mean weights-at-age trend for apex predators, which appears to be decreasing over time, while Table 22 compares the values to GES. This pattern could be caused by:

- An increase in fishing pressure on the large individuals of the trophic guild, allowing for fewer of the population to grow larger; and/or
- A decrease in prey availability due to reduced fishing pressure, causing the individuals to remain small.

Considering that the 15-year trend shows that the mean weights-at age is decreasing, this indicator has failed to achieve GES.

Table 22: Comparison of AP Weights-At-Age to GES

Statistic	Weights-At-Age
Mean	474.16
Minimum	281.52
Maximum	991.14

STATISTIC	WEIGHTS-AT-AGE
GES	Stable/increasing directional trend
Assessed?	Yes
Achieved GES?	No

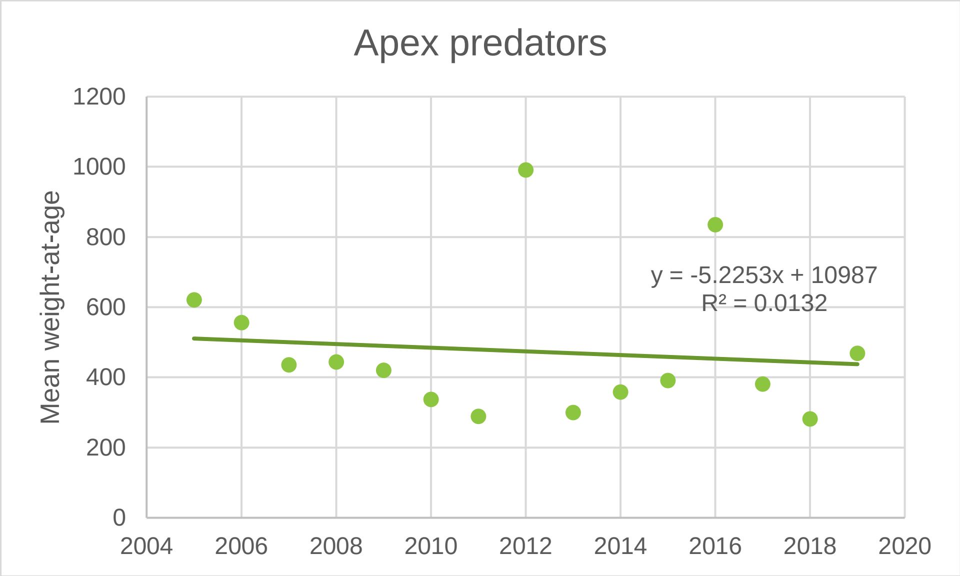

FIGURE 20: MEAN WEIGHT-AT-AGE TREND FOR ALL APEX PREDATORS

2.7.5.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.7.6 Mean Length of Sub-Apex Demersal Predators

The mean length (ML) of the surveyed community was assessed in accordance with D4C3 of the MSFD. This indicator again takes into consideration the fishing pressure which is higher on larger individuals. ML of all species caught in a survey (ML) can be a useful and simple indicator to study the overall effects of fishing on an ecosystem.[17] This indicator quantifies relative abundances of large and small individuals, thereby describing the size distribution of the community.[19] Although this is a useful indicator, the direction of the response to fishing pressures could be an indication of increasing/decreasing large fish or decreasing/increasing small fish.

2.7.6.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the ML for all sub-apex demersal species in the catch over the time period. The assessment was also carried out for sub-apex demersal fish and cephalopods separately, to assess the contributions of each of the taxonomic groups towards any patterns observed in the

[19] Shin, Y. J., Rochet, M. J., Jennings, S., Field, J. G., & Gislason, H. (2005). Using size-based indicators to evaluate the ecosystem effects of fishing. *ICES Journal of Marine Science: Journal du Conseil, 62*(3), 384–396.

ML. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 23.

TABLE 23: DATA QUERIES FOR MEAN LENGTH OF SUB-APEX DEMERSAL PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All species with TROPH <4 *Illex coindetii, Octopus vulgaris, Mullus barbatus, Trachurus trachurus*

For each of the queried records, we calculated the mean length per year. We performed this analysis for both the full trophic guild (species with TROPH <4) and for each of the representative species.

2.7.6.2 Results & analysis

Figure 21 to Figure 25 shows the mean length trend for sub-apex demersal predators, which appears to be increasing over time, while Table 24 compares the values to GES. *Illex coindetii* appears to be increasing in length over time, which could be caused by:

- A decrease in fishing pressure, allowing for more of the population to grow larger;
- An increase in prey availability due to reduced fishing pressure, causing the individuals to become larger; and/or
- A decrease in predation due to various possible impacts on apex predators, such as increased fishing pressure, habitat loss or alien species introduction.

Conversely, the full SDP group and *Octopus vulgaris*, *Mullus barbatus* and *Trachurus trachurus* all appear to be decreasing in length over time, which could be caused by:

- An increase in fishing pressure, allowing for more of the population to remain small;
- A decrease in prey availability due to reduced fishing pressure, causing the individuals to remain small; and/or
- An increase in predation due to reduced impacts on apex predators.

Four of these indicators show decreasing trends with time, meaning they have failed to achieve GES. One indicator shows an increasing trend with time, meaning it has achieved GES.

TABLE 24: COMPARISON OF SDP MEAN LENGTH TO GES

STATISTIC	ALL SDP	*I. COINDETII*	*O. VULGARIS*	*M. BARBATUS*	*T. TRACHURUS*
Mean	267.06	118.86	87.56	156.69	143.72
Minimum	242.99	80.00	63.00	126.50	116.00
Maximum	298.09	168.46	110.00	174.00	171.56
GES	Stable/increasing directional trend				
Assessed?	Yes				
Achieved GES?	No	Yes	No	No	No

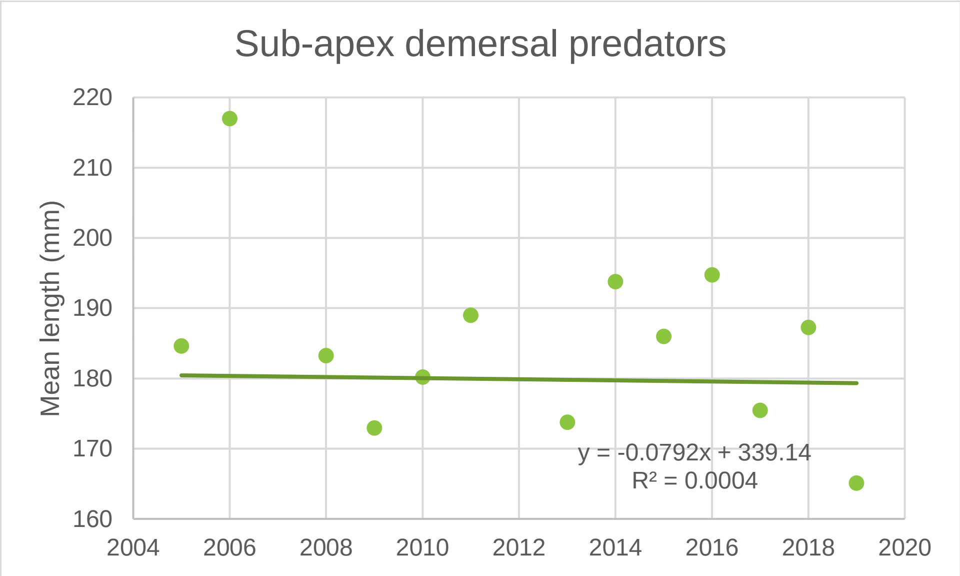

FIGURE 21: MEAN LENGTH TREND FOR ALL SUB-APEX DEMERSAL PREDATORS

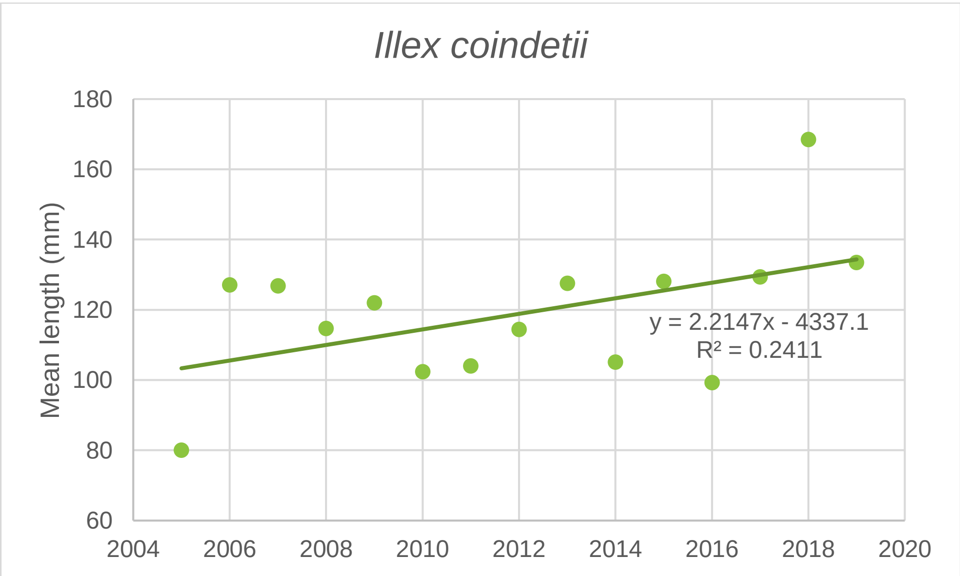

FIGURE 22: MEAN LENGTH TREND FOR *ILLEX COINDETII*

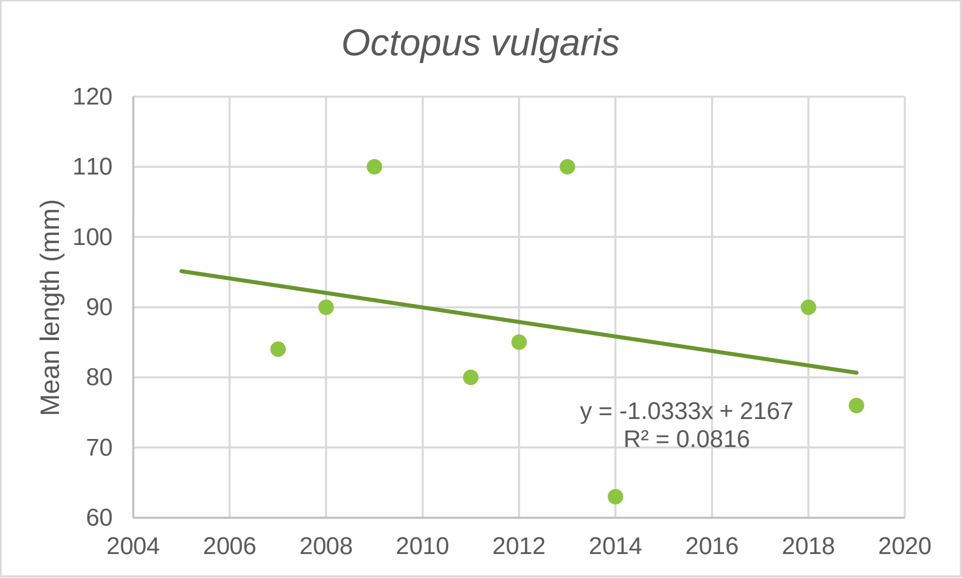

FIGURE 23: MEAN LENGTH TREND FOR *OCTOPUS VULGARIS*

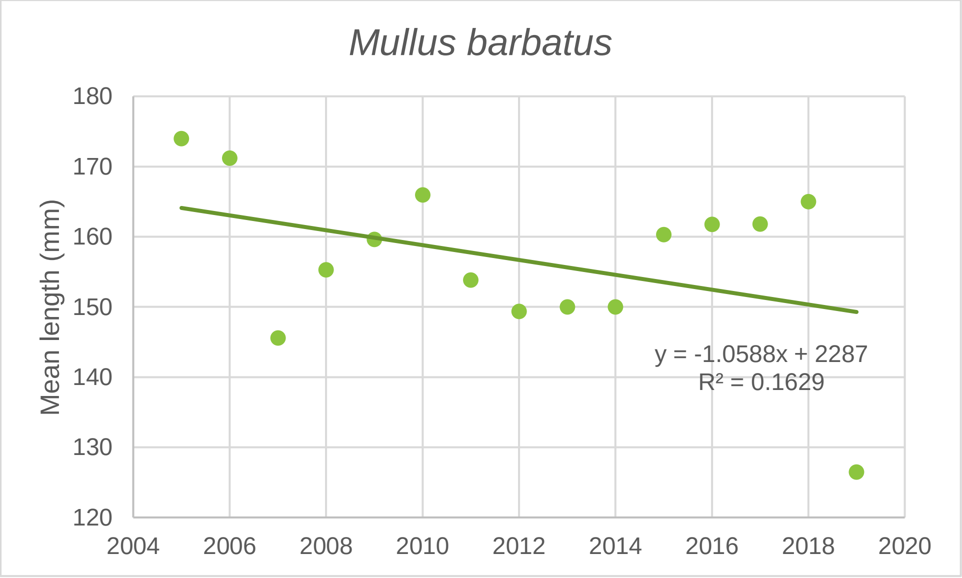

FIGURE 24: MEAN LENGTH TREND FOR *MULLUS BARBATUS*

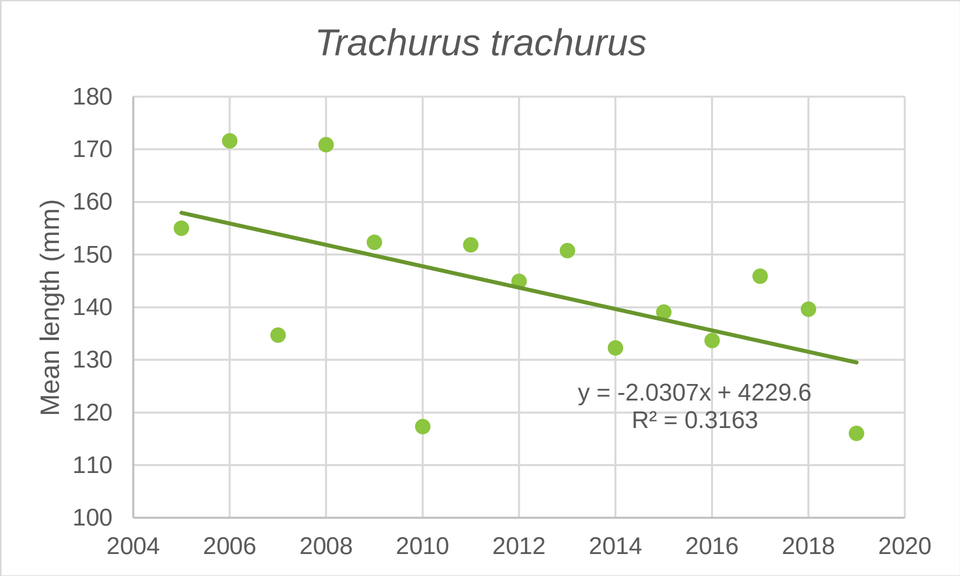

FIGURE 25: MEAN LENGTH TREND FOR *TRACHURUS TRACHURUS*

2.7.6.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.7.7 Mean Length of Apex Predators

The mean length (ML) of the surveyed community was assessed in accordance with D4C3 of the MSFD. This indicator again takes into consideration the fishing pressure which is higher on larger individuals. ML of all species caught in a survey can be a useful and simple indicator to study the overall effects of fishing on an ecosystem.[17] This indicator quantifies relative abundances of large and small individuals, thereby describing the size distribution of the community.[19] Although this is a useful indicator, the direction of the response to fishing pressures could be an indication of increasing/decreasing large fish or decreasing/increasing small fish.

2.7.7.1 Methodology

MEDITS data from all hauls in the FMZ and landings data was used to calculate the ML for all apex species in the catch over the time period. The assessment was carried out for apex fish, to assess the contributions of each of the taxonomic groups towards any patterns observed in the ML. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 25.

TABLE 25: DATA QUERIES FOR MEAN LENGTH OF APEX PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All species with TROPH ≥4 *Squalus blainville, Heptranchias perlo, Lophius piscatorius*

For each of the queried records, we calculated the mean length per year. We performed this analysis for both the full trophic guild (species with TROPH ≥4) and for each of the representative species.

2.7.7.2 Results & analysis

Figure 26 to Figure 30 shows the mean length trend for apex predators, which appears to be increasing over time, while Table 26 compares the values to GES. The full AP group, *Heptranchias perlo*, *Lophius piscatorius* and *Coryphaena hippurus* appear to be increasing in length over time, which could be caused by:

- A decrease in fishing pressure, allowing for more of the population to grow larger; and/or
- An increase in prey availability due to reduced fishing pressure, causing the individuals to become larger.

Conversely, *Squalus blainville* appears to be decreasing in length over time, which could be caused by:

- An increase in fishing pressure, allowing for more of the population to remain small; and/or
- A decrease in prey availability due to reduced fishing pressure, causing the individuals to remain small.

Four of these indicators show increasing trends with time, meaning they have achieved GES. One indicator shows a decreasing trend with time, meaning it has failed to achieve GES.

TABLE 26: COMPARISON OF AP MEAN LENGTH TO GES

STATISTIC	ALL AP	*S. BLAINVILLE*	*H. PERLO*	*L. PISCATORIUS*	*C. HIPPURUS*
Mean	305.41	466.34	863.54	326.38	60.04
Minimum	211.11	351.06	625.00	65.00	33.23
Maximum	372.25	549.00	1400.00	940.00	100.76
GES	Stable/increasing directional trend				
Assessed?	Yes				

STATISTIC	ALL AP	*S. BLAINVILLE*	*H. PERLO*	*L. PISCATORIUS*	*C. HIPPURUS*
Achieved GES?	Yes	No	Yes	Yes	Yes

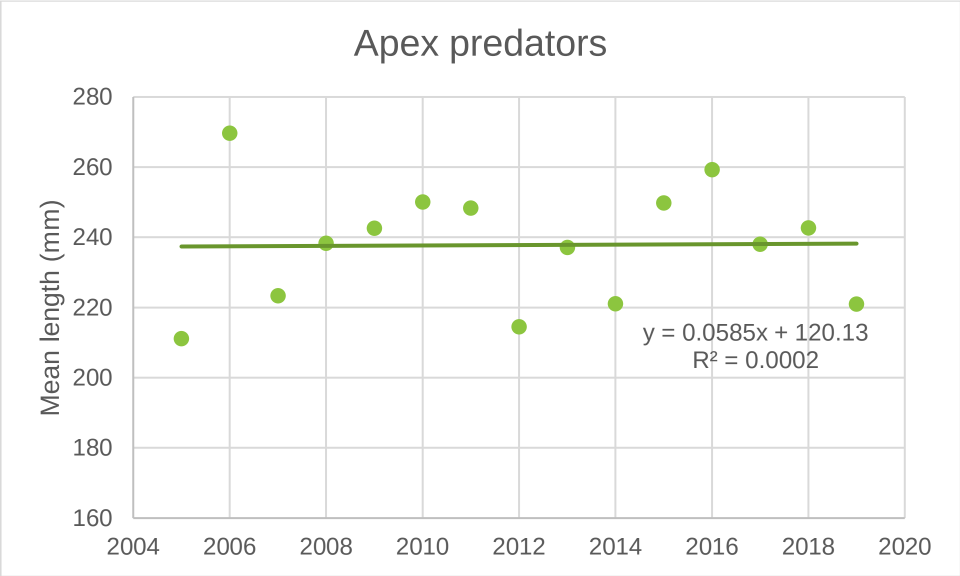

FIGURE 26: MEAN LENGTH TREND FOR ALL APEX PREDATORS

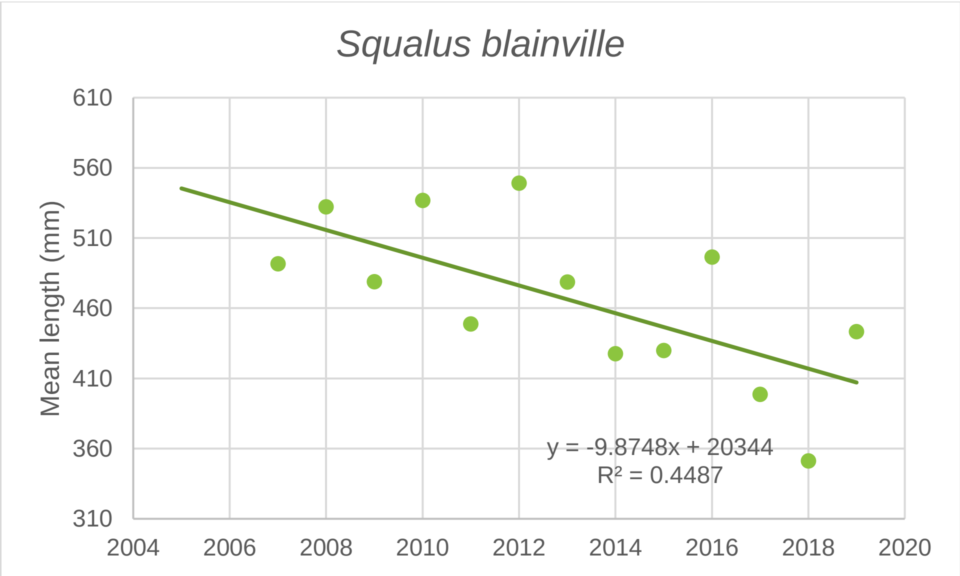

FIGURE 27: MEAN LENGTH TREND FOR *SQUALUS BLAINVILLE*

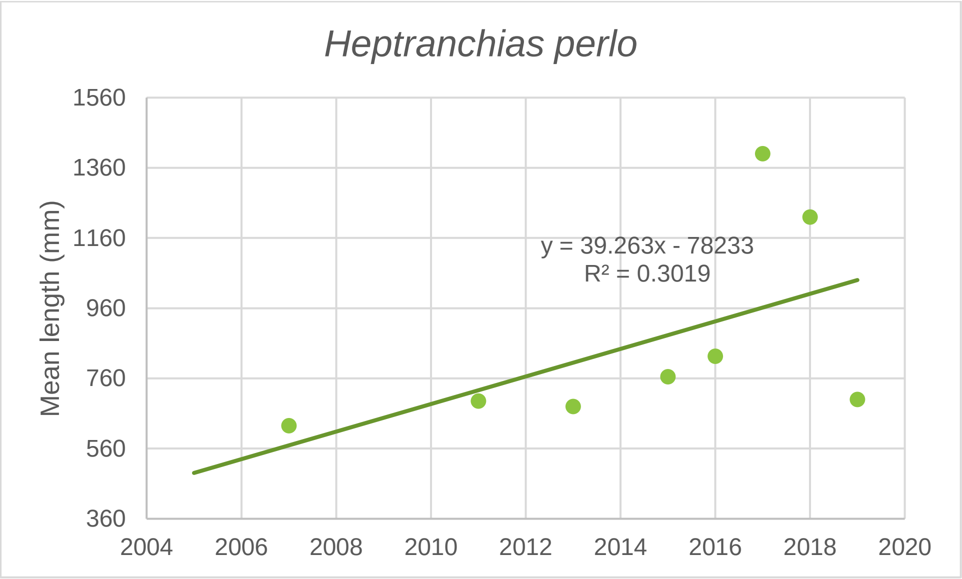

FIGURE 28: MEAN LENGTH TREND FOR *HEPTRANCHIAS PERLO*

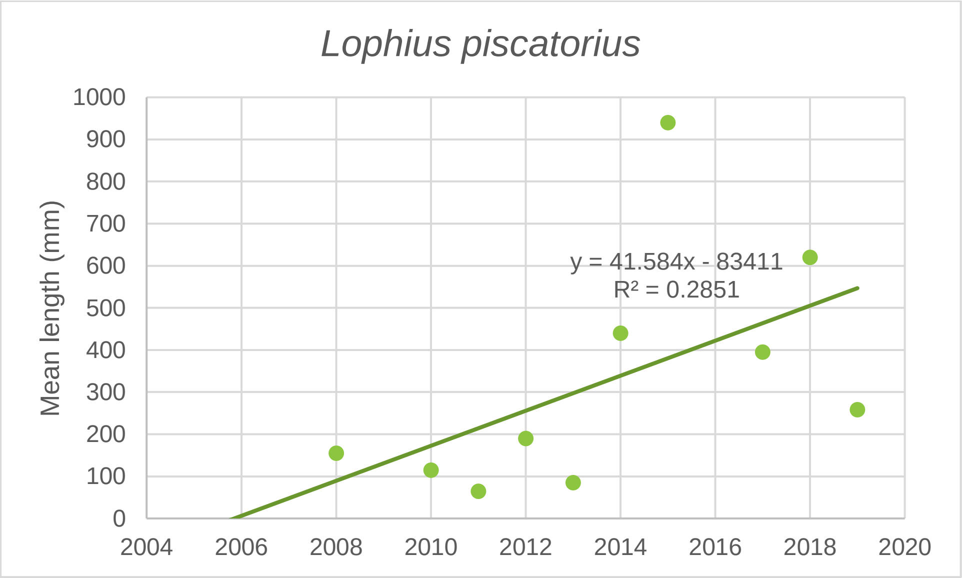

FIGURE 29: MEAN LENGTH TREND FOR *LOPHIUS PISCATORIUS*

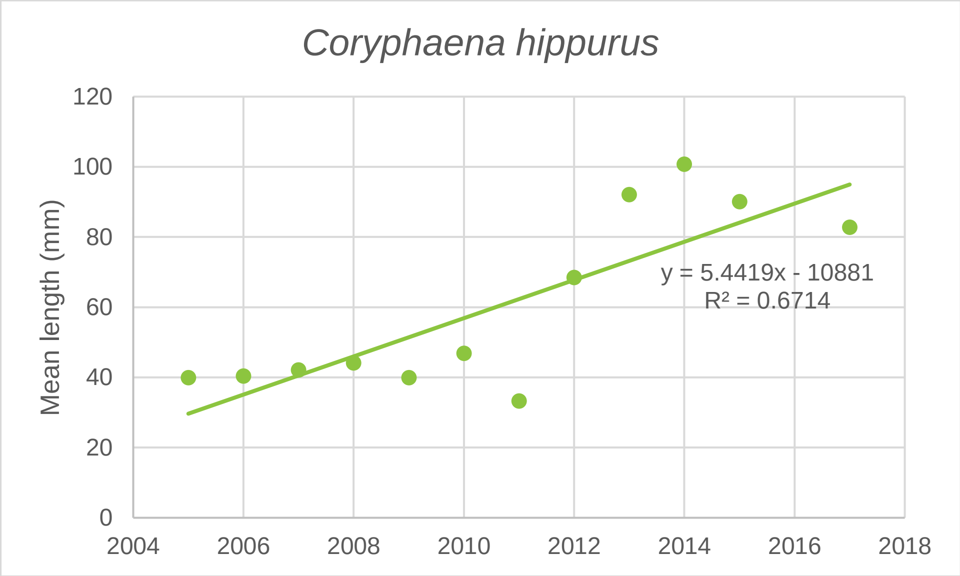

FIGURE 30: MEAN LENGTH TREND FOR *CORYPHAENA HIPPURUS*

2.7.7.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.8 D4C4: PRODUCTIVITY OF THE TROPHIC GUILD

2.8.1 90th Percentile Chlorophyll-a

Primary production in the pelagic region was assessed in accordance with D4C4 of the MSFD. Primary production refers to the biomass generated by primary producers, in this case phytoplankton. Primary production depends on availability of light, water, carbon dioxide and chemical nutrients such as nitrogen, phosphorus, etc.). Primary production transfers energy up the food chain through consumption from primary producers, and therefore represents the basis of the marine ecosystem (i.e. trophic level 1). Chlorophyll-a was used as a proxy index to estimate primary production. This indicator is directly and closely related to the biomass and therefore productivity of the phytoplankton trophic guild.[20]

2.8.1.1 Methodology

Phytoplankton data from inshore, territorial and offshore waters was used to calculate the 90th percentile chlorophyll-a concentration for each station. The principal pressure that affects this indicator is nutrient and organic matter enrichment, with eutrophic conditions indicating that the ecosystem is in bad ecological status in terms of Descriptor 4. Low primary production is also an indicator of bad ecological status, since little biomass is available for transfer to higher trophic levels. Consequently, the stability of this indicator (indicating good status) was qualitatively studied through trend analysis. Thresholds for this indicator should be

[20] Hinder, S., Hays, G., Edwards, M., Roberts, E., Walne, A., & Gravenor, M. (2012). *Changes in marine dinoflagellate and diatom abundance under climate change. Nature Climate Change, 4*(2), 271-275. https://doi.org/10.1038/nclimate1388.

established through regional cooperation to enable quantitative assessment.

2.8.1.2 Results & analysis

Table 27 and Figure 31 provide a summary of the 90th percentile chlorophyll-a results. No GES threshold is available for this indicator in relation to Descriptor 4. This indicator fluctuates naturally on a seasonal basis. Considering that existing data is limited to 2 years, assessing the variation of this indicator with time to determine stability of this indicator is not possible at this stage.

TABLE 27: COMPARISON OF CHLOROPHYLL-A RESULTS TO GES

STATISTIC	INSHORE	TERRITORIAL	OFFSHORE
Mean	0.14	0.08	0.06
Minimum	0.00	0.00	0.00
Maximum	1.60	0.41	0.11
GES	Not established		
Assessed?	No (missing long-term data)		
Achieved GES?	N/A	N/A	N/A

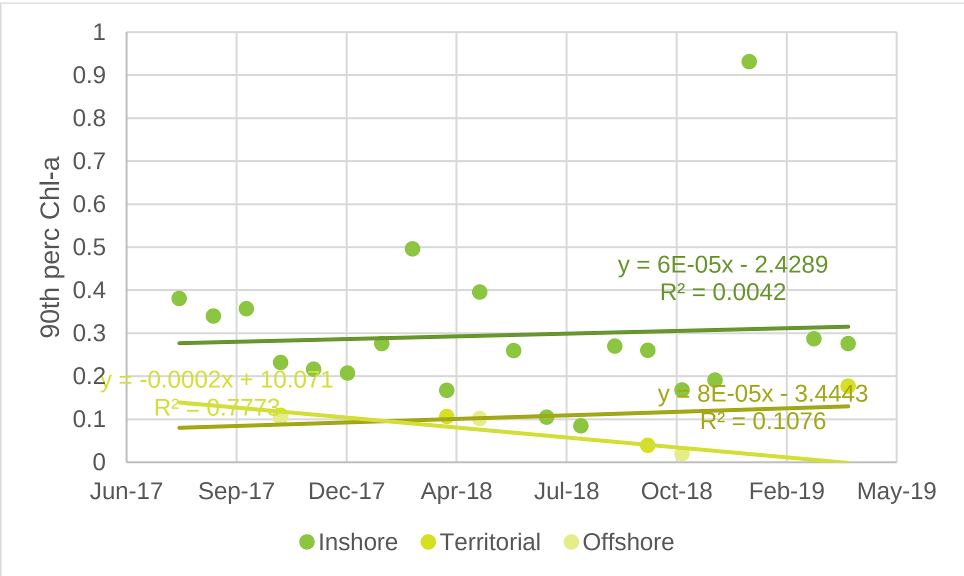

FIGURE 31: 90TH PERCENTILE CHLOROPHYLL-A TREND FOR PRIMARY PRODUCERS

2.8.1.3 Shortcomings & recommendations

Long-term data should be collected for this indicator. Thresholds for this indicator should be established through regional cooperation to enable quantitative assessment.

2.8.2 Biomass of Sub-Apex Demersal Predators

The biomass was assessed in accordance with D4C4 of the MSFD. One of the primary pressures which give rise to cascading changes in food webs, visible throughout the trophic guilds, is fishing. The removal of commercial species from the food web would directly reduce the biomass of the respective trophic level, and indirectly affect the biomasses of higher and lower trophic levels. This anthropogenic pressure directly affects target species, while indirectly affecting non-target components of food webs. Prey of exploited species tend to increase in biomass, while predators tend to decrease.

Exploited populations would therefore show decreasing trends in biomass than healthy populations. Consequently, trends in biomass are good measures of ecosystem structure, particularly at trophic levels which are targeted by commercial fishing.[17] The pressure of fishing on non-target species can also be investigated through the assessment of trends in biomass.

2.8.2.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the biomass of all representative sub-apex demersal predator species over the study time period. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 28.

TABLE 28: DATA QUERIES FOR BIOMASS OF SUB-APEX DEMERSAL PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All species with TROPH <4 *Illex coindetii, Octopus vulgaris, Mullus barbatus, Trachurus trachurus*

For each of the queried records, we extracted the mean biomass of each species per year. We performed this analysis for both the full trophic guild (species with TROPH <4) and for each of the representative species.

2.8.2.2 Results & analysis

Figure 32 to Figure 36 shows the mean biomass trend for sub-apex demersal predators, which appears to be increasing over time, while Table 29 compares the values to GES. *Illex coindetii* appears to be increasing in biomass over time, which could be caused by:

- A decrease in fishing pressure, allowing for more of the population to grow larger;
- An increase in prey availability due to reduced fishing pressure,; and/or
- A decrease in predation due to various possible impacts on apex predators,

such as increased fishing pressure, habitat loss or alien species introduction.

Conversely, the full SDP group and *Octopus vulgaris*, *Mullus barbatus* and *Trachurus trachurus* all appear to be decreasing in biomass over time, which could be caused by:

- An increase in fishing pressure, allowing for more of the population to remain small;
- A decrease in prey availability due to reduced fishing pressure,; and/or
- An increase in predation due to reduced impacts on apex predators.

Four of these indicators show decreasing trends with time, meaning they have failed to achieve GES. One indicator shows an increasing trend with time, meaning it has achieved GES.

TABLE 29: COMPARISON OF SDP BIOMASS TO GES

STATISTIC	ALL SDP	*I. COINDETII*	*O. VULGARIS*	*M. BARBATUS*	*T. TRACHURUS*
Mean	324.79	172.01	633.25	148.84	324.58
Minimum	200.90	47.43	231.13	48.40	18.85
Maximum	685.13	294.41	1405.00	278.85	1493.52
GES	Stable/increasing directional trend				
Assessed?	Yes				
Achieved GES?	No	Yes	No	No	No

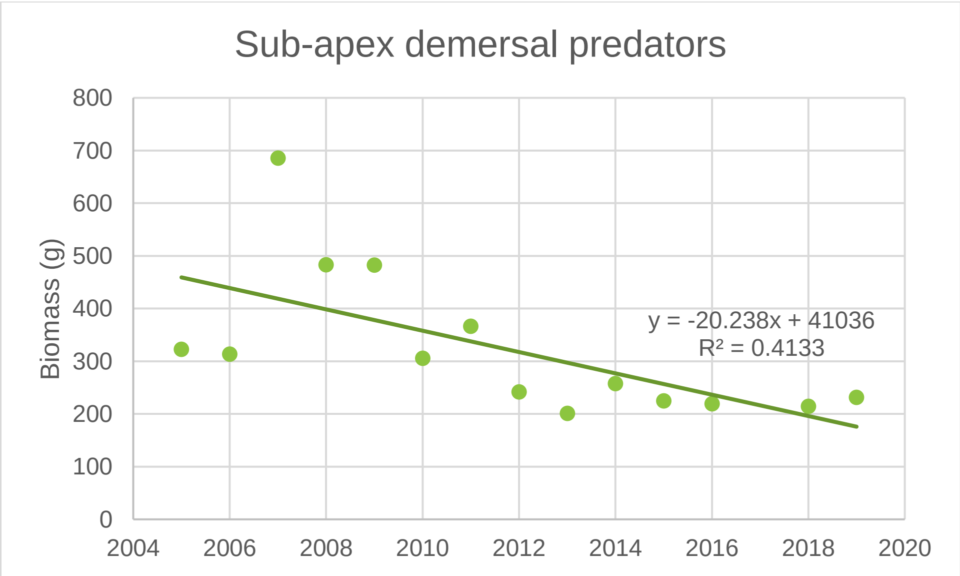

FIGURE 32: BIOMASS TREND FOR ALL SUB-APEX DEMERSAL PREDATORS

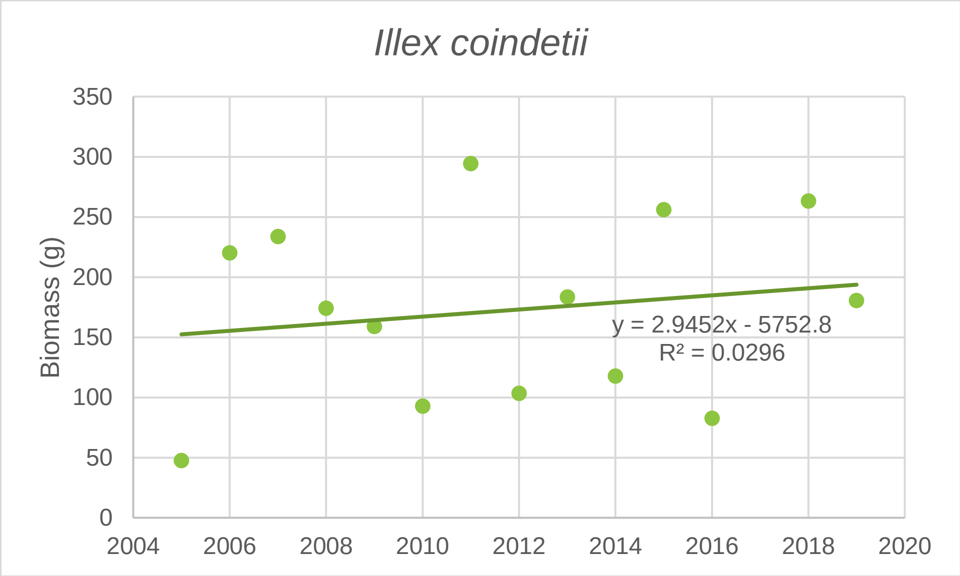

FIGURE 33: BIOMASS TREND FOR *ILLEX COINDETII*

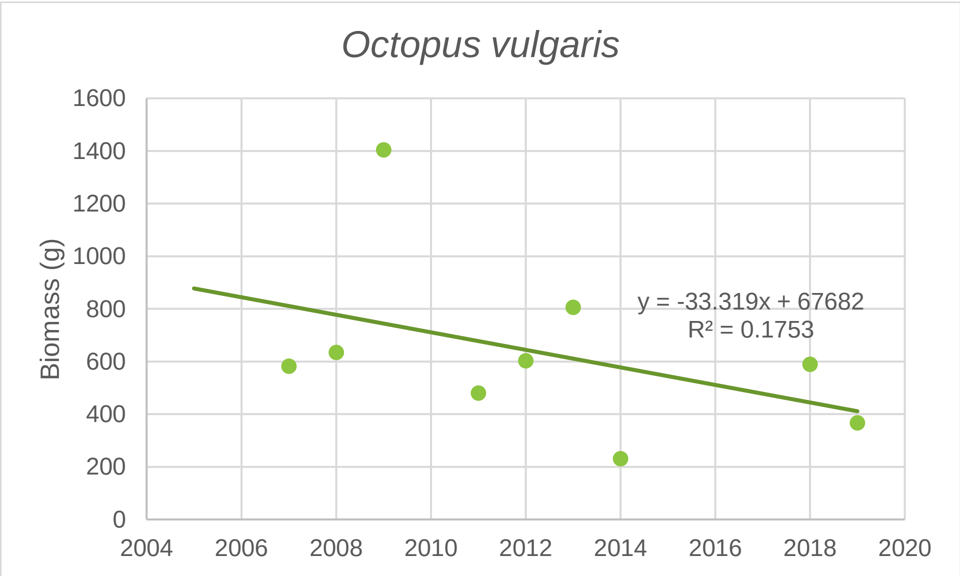

FIGURE 34: BIOMASS TREND FOR *OCTOPUS VULGARIS*

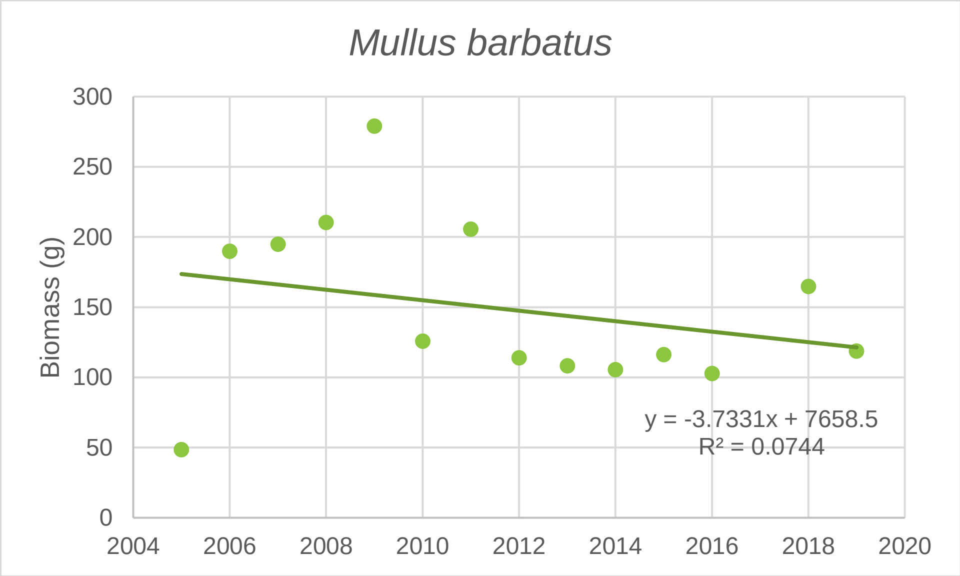

FIGURE 35: BIOMASS TREND FOR *MULLUS BARBATUS*

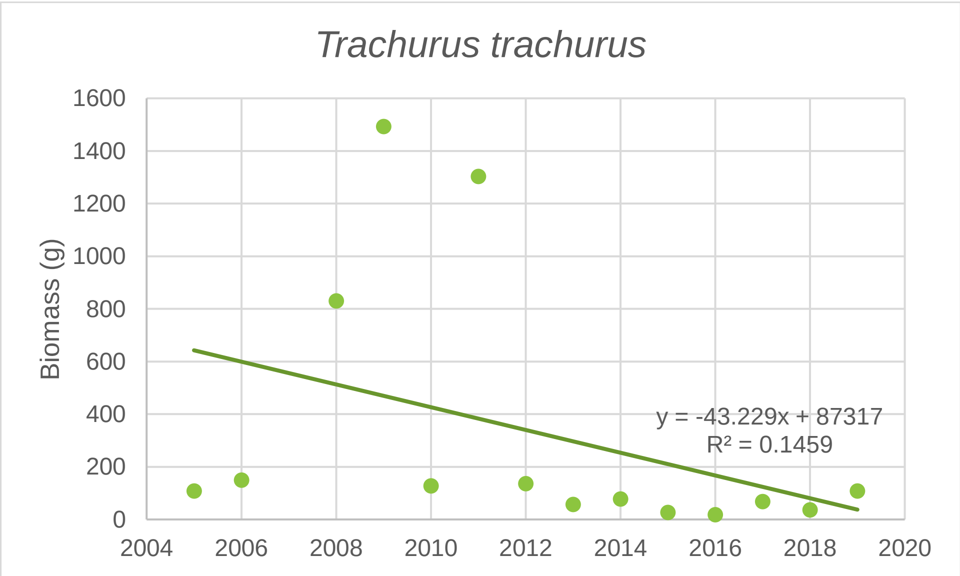

FIGURE 36: BIOMASS TREND FOR *TRACHURUS TRACHURUS*

2.8.2.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

2.8.3 Biomass of Apex Predators

The biomass was assessed in accordance with D4C4 of the MSFD. One of the primary pressures which give rise to cascading changes in food webs, visible throughout the trophic guilds, is fishing. The removal of commercial species from the food web would directly reduce the biomass of the respective trophic level, and indirectly affect the biomasses of higher and lower trophic levels. This anthropogenic pressure directly affects target species, while indirectly affecting non-target components of food webs. Prey of exploited species tend to increase in biomass, while predators tend to decrease.

Exploited populations would therefore show decreasing trends in biomass than healthy populations. Consequently, trends in biomass are good measures of ecosystem structure, particularly at trophic levels which are targeted by commercial fishing.[17] The pressure of fishing on non-target species can also be investigated through the assessment of trends in biomass.

2.8.3.1 Methodology

MEDITS data from all hauls in the FMZ was used to calculate the biomasses of *Squalus blainville*, *Heptranchias perlo*, and *Lophius piscatorius* individuals over the study time period. The available landings data could not be used to attempt application of this indicator to *Coryphaena hippurus* over the study time period. The principal pressure that affects this indicator is fishing, with declining values over the time period indicating that the stations are in bad ecological status in terms of Descriptor 4. Considering that this assessment was undertaken in relation to time, no thresholds are applicable. Instead, the variation of this indicator over time was used to assess the environmental status of Maltese waters.

The MEDITS data was queried as outlined in Table 28.

TABLE 30: DATA QUERIES FOR BIOMASS OF SUB-APEX DEMERSAL PREDATORS

YEAR	HAUL	SPECIES
2005-2019	5, 7, 8, 10, 49, 54, 55, 70, 74, 76, 79	All species with TROPH ≥4 *Squalus blainville*, *Heptranchias perlo*, and *Lophius piscatorius*

For each of the queried records, we extracted the mean biomass of each species per year. We performed this analysis for both the full trophic guild (species with TROPH ≥4) and for each of the representative species.

2.8.3.2 Results & analysis

Figure 26 to Figure 30 shows the mean biomass trend for apex predators, which appears to be increasing over time, while Table 31 compares the values to GES. *Heptranchias perlo* and *Lophius piscatorius* appear to be increasing in biomass over time, which could be caused by:

- A decrease in fishing pressure, allowing for more of the population to grow larger; and/or
- An increase in prey availability due to reduced fishing pressure,.

Conversely, the full AP group and *Squalus blainville* appear to be decreasing in biomass over time, which could be caused by:

- An increase in fishing pressure, allowing for more of the population to remain

small; and/or
- A decrease in prey availability due to reduced fishing pressure, causing the individuals to remain small.

Two of these indicators show increasing trends with time, meaning they have achieved GES. Two indicators show a decreasing trend with time, meaning they have failed to achieve GES.

Table 31: Comparison of AP Biomass to GES

Statistic	All AP	*S. blainville*	*H. perlo*	*L. piscatorius*
Mean	444.02	1096.21	1590.17	1943.88
Minimum	313.93	486.64	735.00	10.00
Maximum	618.72	2384.50	3233.00	13000.00
GES	Stable/increasing directional trend			
Assessed?	Yes			
Achieved GES?	No	No	Yes	Yes

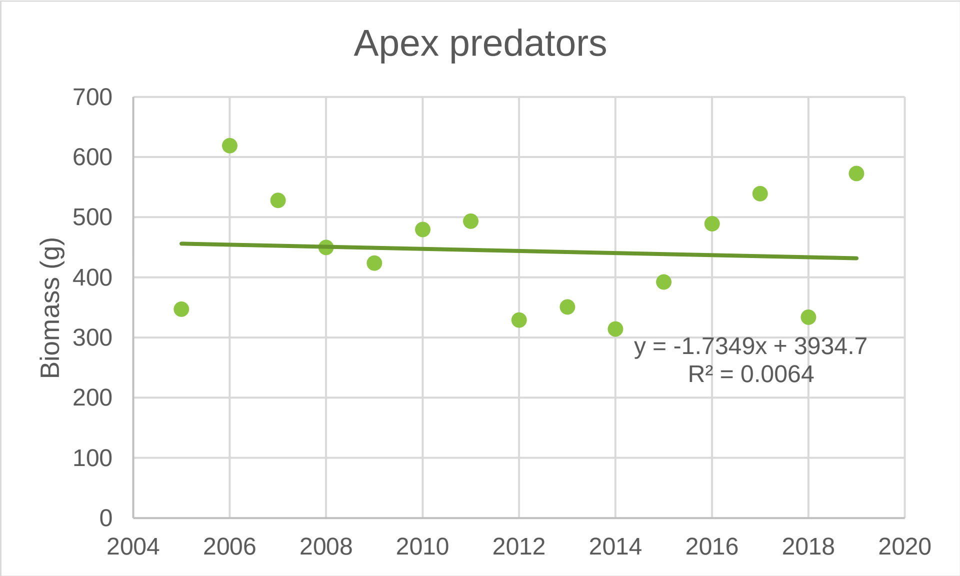

Figure 37: Biomass Trend for All Apex Predators

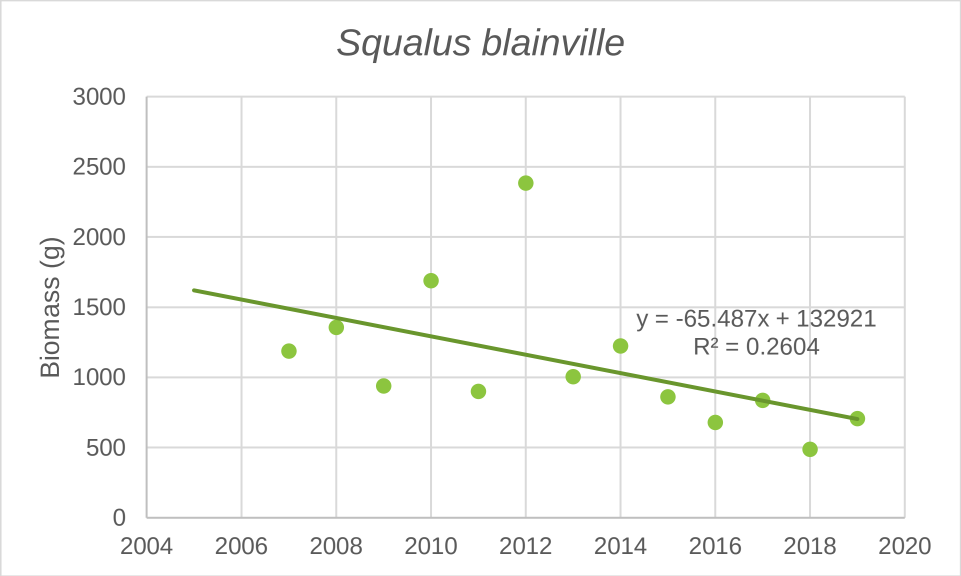

FIGURE 38: BIOMASS TREND FOR *SQUALUS BLAINVILLE*

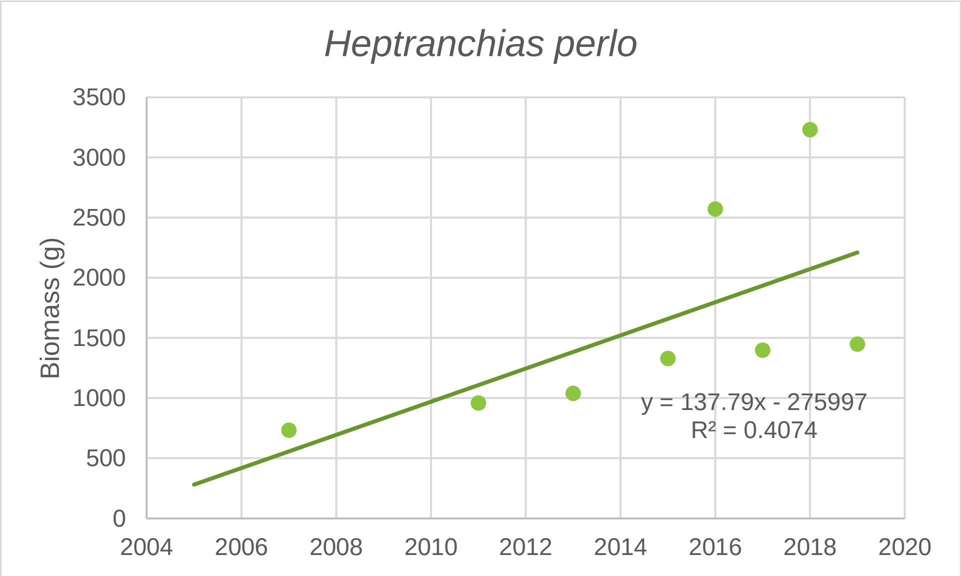

FIGURE 39: BIOMASS TREND FOR *HEPTRANCHIAS PERLO*

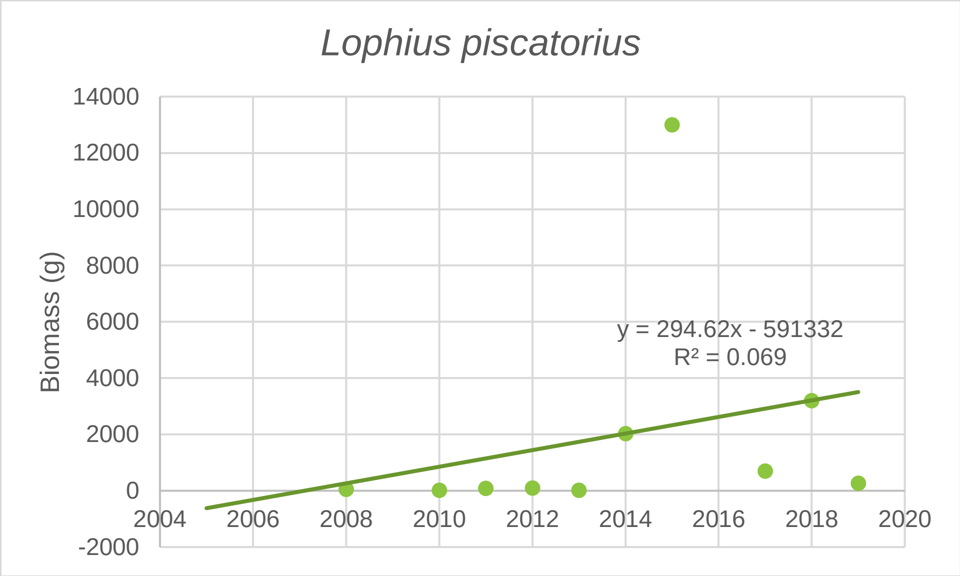

FIGURE 40: BIOMASS TREND FOR *LOPHIUS PISCATORIUS*

2.8.3.3 Shortcomings & recommendations

Thresholds should be established on a regional basis.

3 SUMMARY OF STATUS ASSESSMENT

The assessment was done, as far as possible, in accordance with Annex III of the MSFD and with the criteria and methodological standards by the European Commission.[1,24] The method which was used to assess the status of Maltese waters in line with Descriptor 4 (food webs) is outlined in Section Error! Reference source not found.. Steps 1 to 5 have already been completed as part of Deliverable 1 and 2 of SPD8/2021/016. Steps 6 and 7 was performed as part of this project on a pilot basis.

The first step of the assessment exercise involved the computation of the indicators, as outlined in Section 2.4 and shown in Figure 2. The mean, minimum and maximum values for each indicator from all stations associated to each MRU was then extracted. These values were aggregated to MRU-level, as outlined in Section Error! Reference source not found.. Results from individual stations were aggregated by calculating the mean value, or the percentage of areas achieving good status (computed as the proportion of monitoring stations which achieve good status). This step produced an MRU-level assessment for each indicator. In line with the draft ICES guidance for assessment of MSFD D3 and D4, each trophic guild was assessed separately, and integration of the MRU-level assessments for each indicator was not carried out.[25]

In line with MSFD Guidance Document 14, the assessment of Maltese waters in line with MSFD Descriptor 4 included the comparison to pressures.[24] The draft ICES guidance for assessment of MSFD D4 states that "*link to direct human pressure and hence direct management actions can be difficult to identify*." Links to suspected pressures was discussed wherever possible. The predominant pressure on phytoplankton is nutrient and organic matter enrichment. The indicators for the assessment of primary producers in line with Descriptor 4 was compared to thresholds which reflect this pressure-impact relationship.

Conversely, the predominant pressure on higher marine trophic guilds is fishing. The indicators for sub-apex demersal predators and apex predators were compared across the data time period to observe variation in the pelagic and demersal communities with time. An indicator which is stable or improving over time constituted GES for that particular indicator. Of particular note is the use of the Marine Trophic Index, for which numerous papers note its suitability and reliability for such assessments.[26]

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[24] European Commission (2018). *Reporting on the 2018 update of articles 8, 9 & 10 for the Marine Strategy Framework Directive.* DG Environment, Brussels. pp 72 (MSFD Guidance Document 14).

[25] ICES (2021). *EU request for a Technical Service on MSFD Article 8 guidance on undertaking assessments for Descriptor 3 (commercially exploited fish and shellfish) and Descriptor 4 (marine foodwebs).* [DRAFT Provided to AIS Environment by the ERA].

[26] Coll, M., Shannon, L., Kleisner, K., Juan-Jordá, M., Bundy, A., & Akoglu, A. et al. (2016). Ecological indicators to capture the effects of fishing on biodiversity and conservation status of marine ecosystems. *Ecological Indicators*, *60*, 947-962. doi: 10.1016/j.ecolind.2015.08.048.

The summary of the assessment results, implemented on a pilot basis, is provided in Table 32. Further detail is provided in the Excel sheet, enclosed as Appendix II.

TABLE 32: STATUS ASSESSMENT SUMMARY FOR DESCRIPTOR 4

INDICATOR	TROPHIC GUILD	TAXONOMIC GROUP	ASSESSED?	ACHIEVED GES?
D4C1: Diversity within trophic guilds				
Dia/Dino index	PP	Diatoms, dinoflagellates	No (lack of long-term data)	N/A
Large microphytoplankton vs small microphytoplankton	PP	Large/small microphytoplankton	No (lack of data)	N/A
Abundance	SDP	*Illex coindetii*	Yes	No
Abundance	SDP	*Octopus vulgaris*	Yes	Yes
Abundance	SDP	*Mullus barbatus*	Yes	No
Abundance	SDP	*Trachurus trachurus*	Yes	Yes
Abundance	AP	*Squalus blainville*	Yes	Yes
Abundance	AP	*Heptranchias perlo*	Yes	Yes
Abundance	AP	*Lophius piscatorius*	Yes	Yes
Abundance	AP	*Coryphaena hippurus*	No (lack of data)	N/A
Marine Trophic Index (MTI)	SDP	All species with TROPH <4	Yes	Yes
Marine Trophic Index (MTI)	AP	All species with TROPH ≥4	Yes	Yes
D4C2: Total abundance between trophic guilds[27]				
Relative abundance	PP, SDP, AP	All phytoplankton, All species with TROPH <4, All species with TROPH ≥4	Partly (lack of long-term PP data)	SDP & AP: Yes
Marine Trophic Index (MTI)	SDP, AP	All species with TROPH <4, All species with TROPH ≥4	Yes	Yes

[27] Comparison between the trophic guilds will be done on a qualitative basis.

INDICATOR	TROPHIC GUILD	TAXONOMIC GROUP	ASSESSED?	ACHIEVED GES?
D4C3: Size distribution within trophic guilds				
Large microphytoplankton vs small microphytoplankton	PP	Large/small microphytoplankton	No (lack of data)	N/A
Large fish indicator (LFI) 30	SDP	All fish species with TROPH <4	Yes	Yes
Large fish indicator (LFI) 40	SDP	All fish species with TROPH <4	Yes	Yes
Large fish indicator (LFI) 30	AP	All fish species with TROPH ≥4	Yes	Yes
Large fish indicator (LFI) 40	AP	All fish species with TROPH ≥4	Yes	Yes
Mean weights-at-age	SDP	All fish species with TROPH <4 and maturity 2/3	Yes	Yes
Mean weights-at-age	AP	All fish species with TROPH ≥4 and maturity 2/3	Yes	No
Mean length	SDP	All species with TROPH <4	Yes	No
Mean length	SDP	*Illex coindetii*	Yes	Yes
Mean length	SDP	*Octopus vulgaris*	Yes	No
Mean length	SDP	*Mullus barbatus*	Yes	No
Mean length	SDP	*Trachurus trachurus*	Yes	No
Mean length	AP	All species with TROPH ≥4	Yes	Yes
Mean length	AP	*Squalus blainville*	Yes	No
Mean length	AP	*Heptranchias perlo*	Yes	Yes
Mean length	AP	*Lophius piscatorius*	Yes	Yes
Mean length	AP	*Coryphaena hippurus*	Yes	Yes
D4C4: Productivity within trophic guilds				
90^{th} percentile chlorophyll-a	PP	All phytoplankton	No (lack of long-term data)	N/A

INDICATOR	TROPHIC GUILD	TAXONOMIC GROUP	ASSESSED?	ACHIEVED GES?
Biomass	SDP	All species with TROPH <4	Yes	No
Biomass	SDP	*Illex coindetii*	Yes	Yes
Biomass	SDP	*Octopus vulgaris*	Yes	No
Biomass	SDP	*Mullus barbatus*	Yes	No
Biomass	SDP	*Trachurus trachurus*	Yes	No
Biomass	AP	All species with TROPH ≥4	Yes	No
Biomass	AP	*Squalus blainville*	Yes	No
Biomass	AP	*Heptranchias perlo*	Yes	Yes
Biomass	AP	*Lophius piscatorius*	Yes	Yes
Biomass	AP	*Coryphaena hippurus*	No (lack of data)	N/A

3.1 DATA GAPS & LIMITATIONS

The assessment of Maltese waters in line with MSFD Descriptor 4 has been successfully completed for 36 indicators, as summarized in Table 33. A total of 20 indicators were used on sub-apex demersal predators and 18 indicators were used on apex predators. Both trophic guilds are therefore amply represented by the existing monitoring programme and the proposed assessment methodology. Conversely, no indicators were successfully used in the assessment of primary producers trophic guilds, due to a lack of long-term data.

TABLE 33: NUMBER OF INDICATORS USED IN ASSESSMENT OF DESCRIPTOR 4 CRITERIA

CRITERION	NUMBER OF INDICATORS USED IN D4 ASSESSMENT			
	PP	SDP	AP	TOTAL
D4C1	0	5	4	9
D4C2	0	2		2
D4C3	0	8	8	16
D4C4	0	5	4	9
TOTAL	0	20	18	36

The assessment made use of data which was collected from existing national monitoring programmes. Gaps and limitations encountered during the data collection processes produced data gaps and limitations in the MSFD Descriptor 4 assessment covered by SPD8/2021/016, as outlined below.

Missing long-term data: Information on the primary producers trophic guild is limited, with no data encountered for some indicators, whilst other indicators are supplemented by limited two-year datasets only. Long-term data is crucial to assess trophic guilds in line with the MSFD, especially considering the current methodology made use of trend analysis rather than thresholds between good/not good status.

Thresholds: Most indicators have been assessed using trend analysis, since thresholds between good/not good status are unavailable for Descriptor 4 indicators. In line with guidance documents, these thresholds should be agreed with countries falling in the relevant region to ensure that the assessment methodologies align with those performed in other Mediterranean Member States.

Relationship to pressures: The majority of the indicators have been qualitatively assessed in terms of their relationship to anthropogenic pressures. Knowledge on the effects of existing and historic pressures on these indicators is somewhat limited, making quantitative comparison to pressures impossible at this stage. Of particular note is the large:small microphytoplankton ratio, which is a state indicator with no apparent relationship to pressures. Further research should be carried out in this regard to determine its usability for MSFD Descriptor 4 assessment.

Local trophic relationships: There is limited knowledge on the existing Maltese food webs and trophic relationships between different species in local waters. TROPH values for the species were obtained from online databases (FishBase and SeaLifeBase),[28,29] and not from local studies. Furthermore, the cut-off point between sub-apex and apex predators has been arbitrarily assigned on the basis of existing literature.[30] Considering that the trophic levels of different species vary depending on the location, local studies should ideally be carried out to identify locally-valid TROPH values and threshold between sub-apex and apex predators. Such studies could take the form of stable isotope analysis and/or fatty acid analysis. These thresholds should also be discussed and agreed on a regional basis.

Fish length cut-off point: To determine the Large Fish Index (LFI), the methodology requires the assessor to draw a line between large and small fish. Considering that there is currently no regionally-determined length cut-off point, two have been arbitrarily assigned for the purposes of this assessment. Such cut-off points should also be discussed and agreed on a regional basis, and one common cut-off point

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[28] Froese, R. and D. Pauly. Editors. 2022. FishBase. World Wide Web electronic publication. www.fishbase.org, version (02/2022).

[29] Palomares, M.L.D. and D. Pauly. Editors. 2022. SeaLifeBase. World Wide Web electronic publication. www.sealifebase.org, version (04/2022).

[30] Essington, T., Beaudreau, A., & Wiedenmann, J. (2006). Fishing through marine food webs. *Proceedings of the National Academy of Sciences*, *103*(9), 3171-3175. https://doi.org/10.1073/pnas.0510964103.

should ideally be selected.

Individual biomass data: The existing MEDITS national monitoring programme collects biological data from annual trawling hauls. Such data does not include biomass data for each individual sampled fish. Consequently, the assessors estimated the individual biomass data by dividing the total species weight per haul by the number of individuals from that species within the haul. While such estimates are considered sufficient for the assessment of trophic guilds in line with Descriptor 4, using real individual biomass data would make the assessment more robust and should be considered for inclusion in the MEDITS protocol.

Landings coordinates: The assessors have made use of landings data provided by the Department of Fisheries & Aquaculture to evaluate the pelagic *Coryphaena hippurus* as a representative species of the apex predators trophic guild. We successfully used this dataset to compute one of the indicators (mean length). However, the data was not considered sufficient to compute the abundance and biomass indicators for this representative species. Representation of demersal predators by only one indicator constitutes a limitation to the existing assessment methodology, which should be addressed through the collection of long-term individual data for this species.

APPENDIX I: TROPH VALUES FOR MEDITS SPECIES

FAUNISTIC CATEGORY	MEDITS CODES		SPECIES	TROPH
	GENUS	SPECIES		
B	ARIS	FOL	*Aristaeomorpha foliacea*	3.31
B	ARIT	ANT	*Aristeus antennatus*	3.3
Ao	ASPI	CUC	*Aspitrigla cuculus*	3.8
Ao	BOOP	BOO	*Boops boops*	2.92
Ae	CENT	GRA	*Centrophorus granulosus*	4.1
Ae	CHIM	MON	*Chimaera monstrosa*	3.8
Ao	CITH	MAC	*Citharus linguatula*	4
Ao	CONG	CON	*Conger conger*	4.3
Ae	DASI	PAS	*Dasyatis pastinaca*	4.1
C	ELED	CIR	*Eledone cirrhosa*	3.7
C	ELED	MOS	*Eledone moschata*	4
Ae	ENGR	ENC	*Engraulis encrasicolus*	3.1
Ae	ETMO	SPI	*Etmopterus spinax*	4.1
Ao	EUTR	GUR	*Eutrigla gurnardus*	3.9
Ae	GALU	ATL	*Galeus atlanticus*	4
Ae	GALU	MEL	*Galeus melastomus*	3.97
Ae	HELI	DAC	*Helicolenus dactylopterus*	3.9
Ae	HEPT	PER	*Heptranchias perlo*	4.2
Ae	HEXA	GRI	*Hexanchus griseus*	4.5
C	ILLE	COI	*Illex coindetii*	3.94
Ao	LEPI	CAU	*Lepidopus caudatus*	3.8
Ao	LEPM	BOS	*Lepidorhombus boscii*	3.7
Ao	LEPM	WHS	*Lepidorhombus whiffiagonis*	4.3
C	LOLI	VUL	*Loligo vulgaris*	3.8
Ao	LOPH	BUD	*Lophius budegassa*	4.4
Ao	LOPH	PIS	*Lophius piscatorius*	4.3
Ao	MERL	MER	*Merluccius merluccius*	4.17
Ao	MICM	POU	*Micromesistius poutassou*	4.1

FAUNISTIC CATEGORY	MEDITS CODES		SPECIES	TROPH
	GENUS	SPECIES		
Ao	MULL	BAR	*Mullus barbatus*	3.1
Ao	MULL	SUR	*Mullus surmuletus*	3.5
Ae	MUST	AST	*Mustelus asterias*	3.6
Ae	MUST	MUS	*Mustelus mustelus*	4.3
Ae	MYLI	AQU	*Myliobatis aquila*	3.6
B	NEPR	NOR	*Nephrops norvegicus*	3.67
C	OCTO	VUL	*Octopus vulgaris*	3.74
Ae	OXYN	CEN	*Oxynotus centrina*	3.1
Ao	PAGE	ACA	*Pagellus acarne*	3.5
Ao	PAGE	BOG	*Pagellus bogaraveo*	4.2
Ao	PAGE	ERY	*Pagellus erythrinus*	3.5
B	PALI	ELE	*Palinurus elephas*	3.7
B	PAPE	LON	*Parapenaeus longirostris*	3.68
Ao	PHYI	BLE	*Phycis blennoides*	3.7
Ae	RAJA	ALB	*Rostroraja alba*	4.4
Ae	RAJA	AST	*Raja asterias*	3.8
Ae	RAJA	BRA	*Raja brachyura*	3.8
Ae	RAJA	CIR	*Leucoraja circularis*	3.5
Ae	RAJA	CLA	*Raja clavata*	3.8
Ae	RAJA	FUL	*Raja fullonica*	3.5
Ae	RAJA	MEL	*Leucoraja melitensis*	3.3
Ae	RAJA	MIR	*Raja miraletus*	3.7
Ae	RAJA	MON	*Raja montagui*	3.9
Ae	RAJA	OXY	*Dipturus oxyrinchus*	3.5
Ae	RAJA	POL	*Raja polistigma*	3.3
Ao	SARD	PIL	*Sardina pilchardus*	3.1
Ao	SARI	AUR	*Sardinella aurita*	3.4
Ao	SCOM	PNE	*Scomber (Pneumatophorus) japonicus*	3.4
Ao	SCOM	SCO	*Scomber scombrus*	3.6

FAUNISTIC CATEGORY	MEDITS CODES		SPECIES	TROPH
	GENUS	SPECIES		
Ao	SCOR	ELO	*Scorpaena elongata*	3.9
Ao	SCOR	SCO	*Scorpaena scrofa*	4.3
Ae	SCYM	LIC	*Dalatias licha*	4.2
Ae	SCYO	CAN	*Scyliorhinus canicula*	3.8
Ae	SCYO	STE	*Scyliorhinus stellaris*	4
C	SEPI	OFF	*Sepia officinalis*	4.27
Ao	SERA	CAB	*Serranus cabrilla*	3.3
Ao	SERA	HEP	*Serranus hepatus*	3.5
Ao	SPAR	PAG	*Pagrus pagrus*	3.9
Ao	SPIC	FLE	*Spicara flexuosa*	3.5
Ao	SPIC	MAE	*Spicara maena*	4.2
Ao	SPIC	SMA	*Spicara smaris*	3
Ae	SQUA	ACA	*Squalus acanthias*	4.4
Ae	SQUA	BLA	*Squalus blainvillei*	4.17
Ae	SQUT	ACU	*Squatina aculeata*	4
Ae	SQUT	OCL	*Squatina oculata*	4
Ae	SQUT	SQU	*Squatina squatina*	4.1
C	TODA	SAG	*Todarodes sagittatus*	4.19
Ae	TORP	MAR	*Torpedo marmorata*	4.6
Ae	TORP	NOB	*Torpedo nobiliana*	4.5
Ao	TRAC	MED	*Trachurus mediterraneus*	3.8
Ao	TRAC	TRA	*Trachurus trachurus*	3.7
Ao	TRIG	LUC	*Trigla lucerna*	4
Ao	TRIG	LYR	*Trigla lyra*	3.8
Ao	TRIP	LAS	*Trigloporus lastoviza*	3.5
Ao	TRIS	CAP	*Trisopterus minutus capelanus*	3.7
Ao	ZEUS	FAB	*Zeus faber*	4.47

APPENDIX II: FULL ASSESSMENT OF DESCRIPTOR 4