



COMMISSION  
**OSPAR**

# Modifications du niveau trophique moyen des consommateurs marins

## Évaluation de l'Indicateur Commun



# OSPAR

## BILAN DE SANTÉ 2023

## 2023

# Modifications du niveau trophique moyen des consommateurs marins

## OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

## Convention OSPAR

La Convention pour la protection du milieu marin de l’Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d’Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l’Allemagne, la Belgique, le Danemark, l’Espagne, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume- Uni de Grande Bretagne et d’Irlande du Nord, la Suède, la Suisse et l’Union européenne

## Contributeurs

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## Message clé

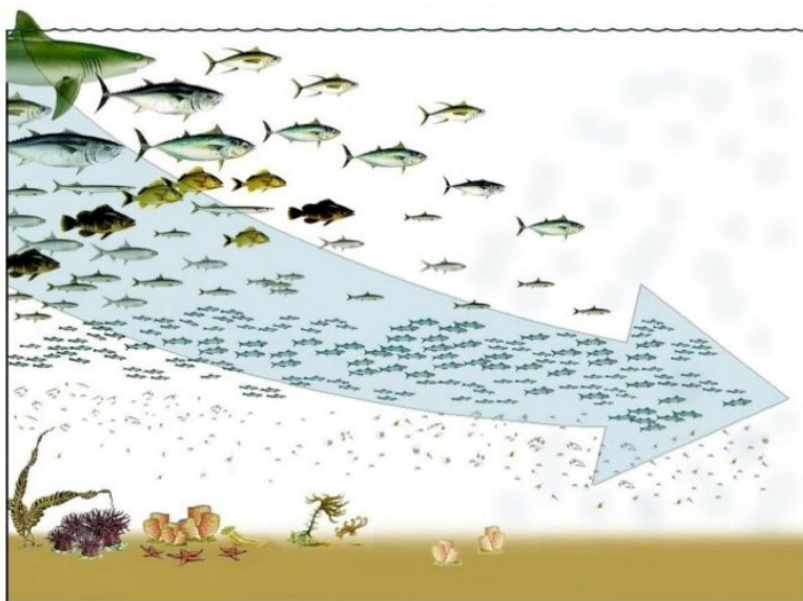
Le niveau trophique moyen (MTL) révèle des tendances contrastées dans les quatre subdivisions du Golfe de Gascogne et de la côte ibérique au cours des dernières décennies. Bien que des signes de récupération des prédateurs supérieurs et des mésoprédateurs soient observés dans la plupart des subdivisions, des tendances à la baisse sont constatées dans certaines zones locales.

## Contexte

Le MTL des organismes marins est un indicateur écologique qui reflète principalement les effets de la pression de la pêche sur la structure des réseaux trophiques. L'indicateur est basé sur les données sur la biomasse et le niveau trophique (TL) de l'espèce. Le TL, déterminé par les interactions prédateurs-proies, situe la position d'un organisme dans un réseau trophique. La valeur la plus basse du niveau trophique (TL = 1) est attribuée aux producteurs primaires à la base du réseau trophique, avec les herbivores au niveau suivant (TL = 2) et la valeur la plus élevée (TL ≥ 4) est attribuée aux prédateurs supérieurs. Ainsi, l'énergie est transférée des TL inférieurs vers les TL supérieurs en suivant les connexions consommateur-ressource des organismes du réseau trophique. Le TL peut être estimé à l'aide de données provenant d'analyses du contenu de l'estomac et/ou d'analyses d'isotopes stables.

La plupart des pêcheries ciblent des espèces à TL élevé (corrélé avec les plus grandes tailles) et entraînent ainsi une diminution de la disponibilité des prédateurs dans l'écosystème. Cette situation oblige à son tour les pêcheries à cibler des espèces dont le TL est de plus en plus faible, ce qui entraîne une baisse du MTL des débarquements des pêcheries. Hypothétiquement, dans les pêcheries ciblant les petits pélagiques, la diminution de la disponibilité de nourriture pour les niveaux trophiques supérieurs pourrait se refléter dans les tendances à la baisse de l'indicateur.

Par le passé, l'indicateur a été calculé en utilisant de longues séries de données historiques à grande échelle (échelle régionale). Cependant, des études récentes ont montré l'importance d'analyser l'indicateur au niveau local montrant des zones fortement impactées. Des relations négatives significatives entre le chalutage de fond et le MTL à une résolution spatiale à petite échelle ont été détectées au large de la côte ibérique nord (Preciado et al., 2019), malgré le rétablissement apparent des prédateurs supérieurs observé à l'échelle régionale (Arroyo et al., 2019). La forte influence locale de cette pression anthropique sur les réseaux trophiques benthodémersaux a montré la pertinence d'utiliser une résolution spatiale locale lors de l'étude des effets de pressions spatialement hétérogènes, telles que la pêche.



**Figure 1 : Diagramme montrant le raisonnement qui sous-tend l'indicateur MTL : si les niveaux trophiques (TL) diminuent, cela indique que les gros poissons ne sont plus disponibles parce que les pêcheries ont épuisé les stocks de prédateurs supérieurs.**

### **Contexte (version étendue)**

Marine ecosystem functioning strongly depends on its structure, diversity and integrity, which are subjected to many environmental and anthropogenic pressures that cause alterations on ecosystem components at high, intermediate and low trophic levels (Cury *et al.*, 2005; Bundy *et al.*, 2010; Link *et al.*, 2010; Heymans *et al.*, 2014; Coll *et al.*, 2016). Food webs, also called trophic networks, represent the most elemental structure of the ecosystem, illustrated by the consumer-resource interactions among organisms and evidencing the main pathways of energy flow through ecosystems, from primary producers to top predators. The knowledge of the functioning of these networks is key for understanding marine ecosystem functioning. Each life stage of an organism is associated with a particular trophic level and the energy is transferred from the lower trophic levels to the higher trophic levels following the interconnections between organisms within the food web.

The TL of a given species can be estimated using: i) dietary analysis from stomach contents, ii) stable isotopes analysis, and/or iii) modelling. Using stomach contents analyses, the TL of a species can be estimated by the TL of each prey category weighted by their relative abundance in its diet. Alternatively, stable isotope analyses rely on the ratio of  $^{15}\text{N}$  to  $^{14}\text{N}$  ( $\delta^{15}\text{N}$ ) in the organisms' tissues, as isotopic nitrogen increases regularly with each trophic step along the food webs.

The conceptual development of the MTL indicator, by Pauly *et al.*, (1998), is known as 'fishing down marine food webs'. This indicator proved that a decline in the MTL of the global fisheries catch during the 1990s revealed an erosion of the high trophic levels in the ecosystems worldwide, forcing fisheries to shift their pressure from the top predators to lower trophic levels, due to the decline in biomass of high trophic level species (**Figure 1**). Thus, this indicator aimed at highlighting the unsustainable fisheries practices of past

decades. The lack of trends in this indicator does not necessarily indicate no impact, as highly impacted ecosystems might become so resilient that no trend means resilience. The indicator was adopted by the Conference of the Parties to the Convention on Biological Diversity as one of eight indicators to monitor achievement of a significant reduction in the rate of biodiversity loss by 2010.

Since then, the use of MTL has been further explored and additional hypotheses have emerged to explain the patterns observed in the MTL. The 'fishing down food webs' concept as defined above was actually detected in the North Atlantic. Other scenarios were described in other parts of the world (Essington *et al.*, 2006; Morato *et al.*, 2006; Swartz *et al.*, 2010; Stergiou and Tsikliras, 2011; Shannon *et al.*, 2014) including for example the concept of fishing through the food webs (sequential addition of low trophic level species in fisheries); fisheries expansion (into deeper and further offshore waters with the inclusion of new high trophic level species); and fishing up the food webs (addition of new previously unfished high trophic level species).

Within the scientific community, it is considered that food web status should be based on ecosystem indicators which represent the ecosystem as whole, including as many species as possible and making sure different trophic levels are well represented. The Mean Trophic Level (MTL) indicator meets this requirement because it takes into account food web structure and uses a metric (the TL) that reflects energy transfer between predators and prey. MTL can be calculated using commercial landings or biomass estimates from scientific surveys, in combination with the estimated TL of the species. In this assessment, the indicator has been calculated taking into consideration as many taxonomic and functional groups of species as possible (benthic invertebrates, cephalopods, elasmobranchs, fish). Since groundfish trawl surveys target soft-bottom shelf habitats, the present assessment is primarily focused on benthic-demersal communities of the continental shelves of OSPAR Region IV and each sub-division. The methodological approach may however be transferred to other OSPAR Regions whenever adequate/appropriate data become available.

To compute the MTL indicator, landings have traditionally been the only source of biomass data, raising many concerns around their suitability for describing the ecosystem as a whole, due to the strong discrepancies between biomass caught and biomass landed among other shortcomings and uncertainties. For example, landings data are incomplete (i.e., they do not take into account illegal, unregulated and unreported species, or by-catch), and are subject to multiple biases induced by fisheries drivers (Branch *et al.*, 2010; Pauly *et al.*, 2013). In contrast, data from scientific surveys reflect actual changes in community composition because they are not influenced by market forces (i.e., selectively fishing for particular commercial species only) and include all species that fisheries by-catch and are commonly not reported with the landings. Although data coming from groundfish surveys have particular shortcomings (they are usually limited to a specific season, limited by the meshsize and underrepresenting the smallest species, and sometimes focus on commercial fish and cephalopods), the standardisation of IBT surveys together with the long-term series available online make scientific surveys the best data source to assess the MTL at the moment.

Estimates of the TL values of most demersal species are currently available in online databases and repositories (e.g., [www.fishbase.org](http://www.fishbase.org)). However, these values might refer to specific populations and sampling times or be calculated as worldwide averages based on TL data from different ecosystems. In many cases these values do not reflect the characteristics of a given region where trophic interactions between species can be region-specific. Environmental or human-induced pressures can trigger changes in prey availability and predator selectivity, in turn causing variability in the TL values for a given species in space and time or

even along ontogeny (Pinnegar *et al.*, 2002; Chassot *et al.*, 2008; Vinagre *et al.*, 2012). Therefore, TL values need to be region-specific in order to increase the accuracy of the analyses and better represent feeding interactions in the study region.

In the OSPAR Intermediate Assessment 2017, the assessment of this indicator was performed for OSPAR Region IV (French and North Iberian continental shelves) based on scientific surveys and landings, and including different scenarios: MTL2,0 (including all consumers), MTL3,25 (equal to the MTI defined by Pauly and Watson in 2005), MTL4,0 (focus on higher predators) (<https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/fish-and-food-webs/mtl-bay-biscay/>). The main results showed no apparent change in the overall food web structure for MTL2,0, whereas a subtle increase in MTL was detected when focusing on the predator community (MTL3,25 and MTL4,0) associated with signs of recovery in these ecosystems (Arroyo *et al.*, 2019).

The purpose of the present assessment, is to expand the analysis to other sub-divisions (Portuguese shelf and Gulf of Cadiz) and extend the historical series until 2021, as well as to analyse whether those regional-scale trends identified in 2017 can also be acknowledged at local level (haul/square). For that purpose, a spatio-temporal approach is performed, calculating the MTL in each haul by year and analysing the trend at the local scale. A case study in the North Iberian coast based on this approach has recently been published with promising results (Preciado *et al.*, 2019), despite using a shorter time series. In addition to the expansion of the analyses in space (other sub-divisions) and time (2000-2021), MTL trends are also calculated in different scenarios, in order to identify potential changes of the trends with depth (i.e., coastal, shelf and deep ecosystems).

## Méthode d'évaluation

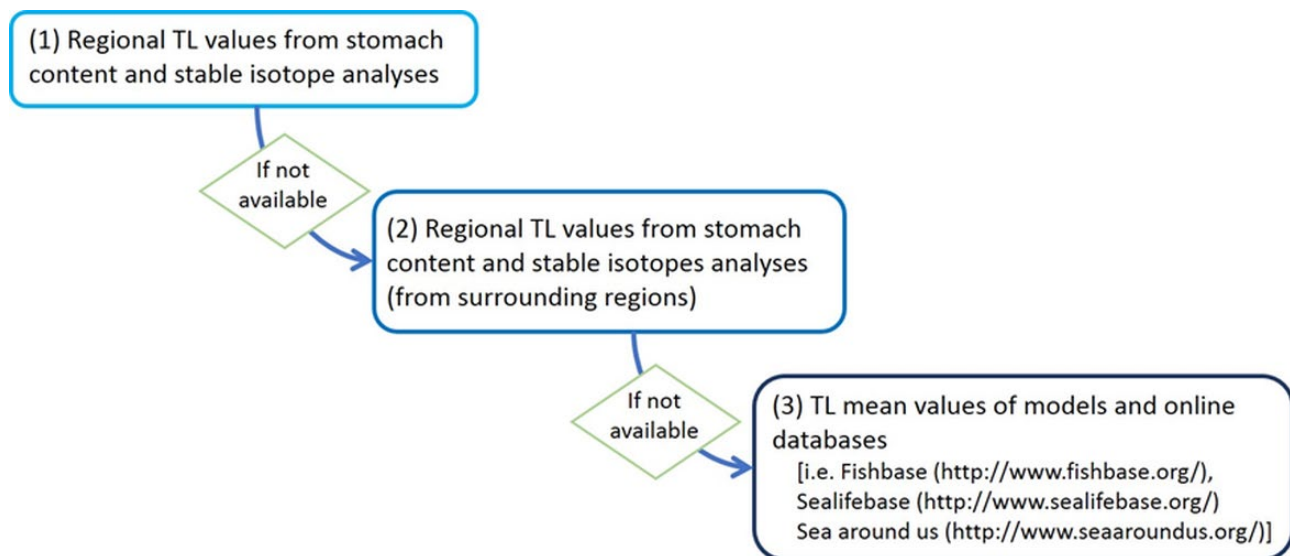
### Data sources

Biomass data of species can be downloaded directly from: DATRAS in exchange format [https://datras.ices.dk/Data\\_products/Download/Download\\_Data\\_public.aspx](https://datras.ices.dk/Data_products/Download/Download_Data_public.aspx). In the present assessment, the indicator has been calculated starting in 2000 and using only data from the fourth quarter of the year (Q4) in order to keep consistency across the four sub-divisions under study. The differences in the DATRAS database uploaded by each country should be taken into account when calculating the indicator, as they may prevent comparisons across regions. In Region IV this was not an issue since one survey is carried out per country in each sub-division. There is also agreement on the type of gear used. The set of species reported are also crucial for the comparability of the indicator among sub-divisions, as the inclusion of some species or others (commercial versus non-commercial fish and cephalopods, and/or benthic invertebrates) can lead to erroneous results of the indicator or even to not being able to calculate it.

The TL estimated from stomach content analysis, stable isotope analysis or models can be collected from the literature for regional and non-regional areas. Otherwise, TLs are available in online databases [i.e. Fishbase (<http://www.fishbase.org/>), Sealifebase (<http://www.sealifebase.org/>) and Sea Around Us (<http://www.seaaroundus.org/>)]. For this assessment, information on TLs per species have been estimated by sub-division using local stomach contents and stable isotopes (e.g. Chauvelon *et al.*, 2012; Lasalle *et al.*, 2011; Lasalle *et al.*, 2014; Le Loc'h *et al.*, 2008), except for Portuguese waters where TL coming from the North Iberian shelf has been applied in the calculations. The TL databases by sub-division were compiled into

a single database and populated by each country. This TL database for OSPAR Region IV is now available at the ODIMS repository ([https://odims.ospar.org/en/submissions/ospar\\_trophic\\_level\\_2021\\_05/](https://odims.ospar.org/en/submissions/ospar_trophic_level_2021_05/)).

During the 2017 assessment, a preliminary work was performed in to collate regional TL estimations per species for OSPAR Region IV. However, the use of TL databases by sub-division was recommended in order to capture local trophic interactions and regional differences in the structure of the trophic networks. TL estimates by sub-division are then more relevant to calculate the MTL of such particular sub-division. The TL was compiled in three different steps, prioritising in each case local estimates over TL estimated at larger scale, and making use of the latter only when the former were unavailable, as shown in the following scheme:



To do this, only taxons at high taxonomic resolution (species, genus or family) were considered, excluding taxa identified at low taxonomic resolution (i.e., phylum, sub-phylum, class, superorder, order, suborder and infraorder). Nevertheless, in terms of biomass, taxa identified with low taxonomic resolution were practically negligible.

Uncertainty exists for each TL value estimated by diet studies, which is related to the spatio-temporal variability of the diet and differences of diet throughout the ontogeny (Pinnegar *et al.*, 2002; Chassot *et al.*, 2008; Vinagre *et al.*, 2012). This uncertainty needs to be reported as a standard error for each TL value of a species.

### Ecological and geographical scenarios

Different scenarios were considered for the calculation of MTL and MTL changes across time. Firstly, the MTL of the four sub-divisions was calculated independently, using the same methodology (specified in the following section) but based on local TL and biomass data.

For each of the sub-divisions, three different bathymetric ranges were considered, assessing independently MTL at the coastal (<30 m depth), continental shelf (30-200 m depth) and continental slope (>200 m depth). These bathymetric ranges reflect the fact that communities on regional seas are commonly structured along the depth gradient, and the community inhabiting the coastal area is fundamentally different from that inhabiting the deeper area, although both can be summarised into an MTL value. Thus, the bathymetric

segregation allowed us to explore temporal changes in these communities independently, with the potential to identify divergent trends along the depth gradient. The coastal area (<30 m) did not have a sufficient sampling coverage in the North-western Iberian and Portuguese regional seas to be included in this assessment, so in these two sub-divisions only the continental shelf and slope were assessed.

Furthermore, for each sub-division and depth range three ecological cut-offs in the trophic structure of the community were considered. MTL2 included all species in the community except for primary producers. MTL3,25 included only those species with TL $\geq$ 3,25, which are essentially secondary consumers and top predators, here called meso + top predators. Lastly, MTL4 included only species in the top of the food web, here called top predators (**Figure a**). Differentiating the ecological community in these thresholds makes it possible to identify patterns affecting only top predators (as might be the case of the “fishing down” hypothesis) which might be obscured by the high biomass of low trophic level species otherwise.

Finally, considering the fact that bottom trawl surveys do not specifically target pelagic species but are designed to capture and evaluate benthic-demersal species and that the biomass of pelagic species dominates the community showing very high variability, the bathymetric range and MTL cut-offs, including and excluding pelagic species, were considered in each sub-division. The combination of this geographic and ecological constraints resulted in 18 scenarios which are summarised in **Table a**.

<b>Table a: Summary of 18 scenarios by sub-division depending on the TL cut-off, depth strata, including/excluding pelagic species.</b>				
		<b>Top predators (MTL_4,0)</b>	<b>Meso + top predators (MTL_3,25)</b>	<b>All community (MTL_2,0)</b>
<b>Coastal (depth &lt;30 m)</b>	with pelagics	top predators	mesopredators + top predators	all consumers
	without pelagics	top predators (excluding pelagic species)	Mesopredators + Top predators (excluding pelagic species)	all consumers (excluding pelagic species)
<b>Shelf (depth 30- 200 m)</b>	with pelagics	top predators	mesopredators + top predators	all consumers
	without pelagics	top predators (excluding pelagic species)	Mesopredators + Top predators (excluding pelagic species)	all consumers (excluding pelagic species)
<b>Deep (depth &gt;200 m)</b>	with pelagics	top predators	mesopredators + top predators	all consumers

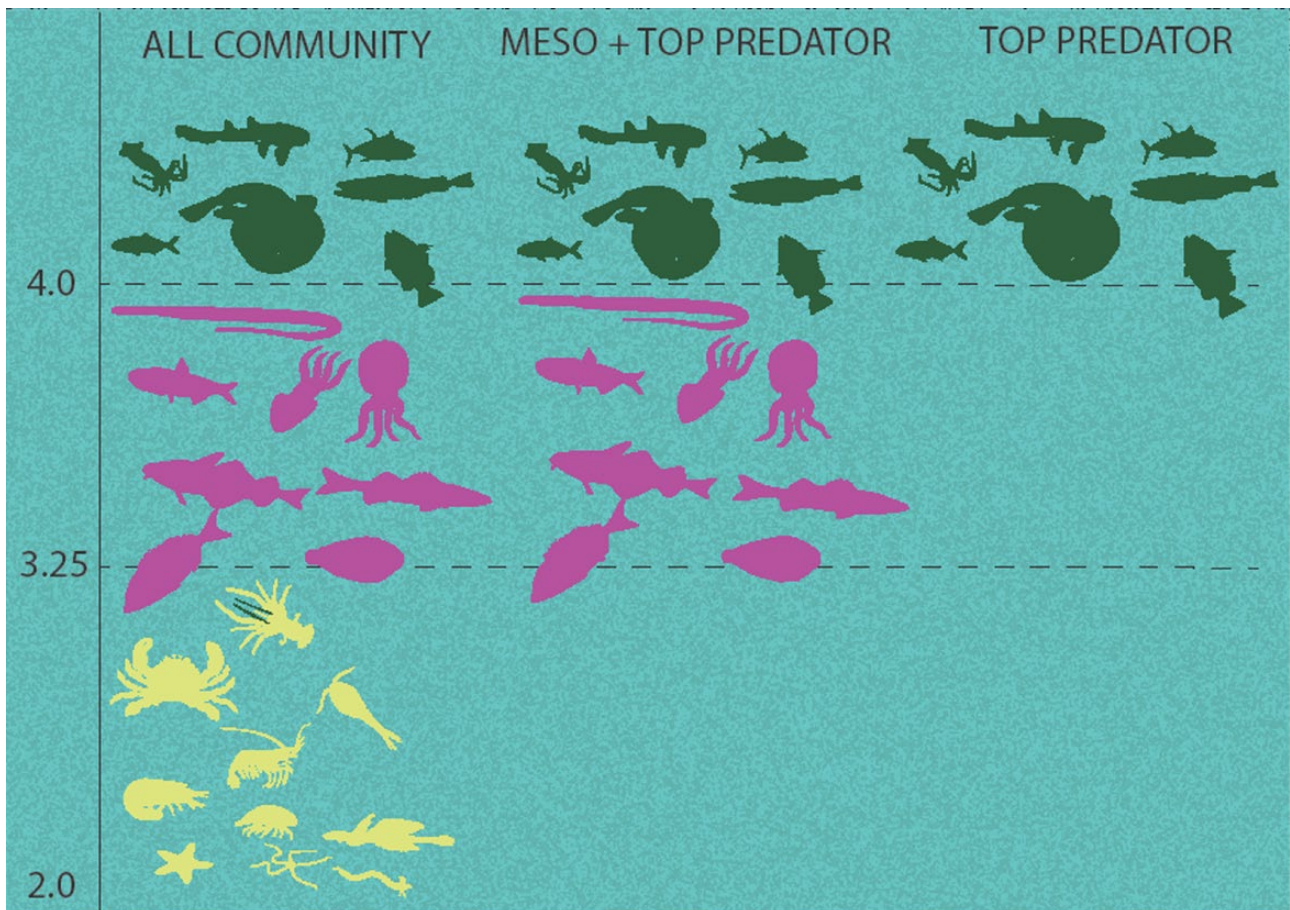
Table a: Summary of 18 scenarios by sub-division depending on the TL cut-off, depth strata, including/excluding pelagic species.				
		Top predators (MTL_4,0)	Meso + top predators (MTL_3,25)	All community (MTL_2,0)
	without pelagics	top predators (excluding pelagic species)	Mesopredators + Top predators (excluding pelagic species)	all consumers (excluding pelagic species)

### Calculation of the Mean Trophic Level

Before performing the calculations and in order to select a set of species that have been consistently well sampled through the historical series, cumulative curves were applied to the biomass database to make a selection of species. Filter criteria should be agreed among scientists so that the assessment is consistent across regions. The following criteria were finally decided, based on the inflection points of species frequency of occurrence by space and time, and their abundance distribution:

- species that appeared at least in 50% of the years
- species that appeared at least in 10% of the hauls each year
- species that displayed an abundance above the quantile 10

The TL value and biomass of each species in each haul were used to calculate the MTL per haul. The indicator is then calculated for the whole community (all community, MTL<sub>2,0</sub>), including only species with TL higher than 3,25 (meso + top predators, MTL<sub>3,25</sub>) and including only species with TL higher than 4 (top predators, MTL<sub>4,0</sub>) (**Figure a**).



**Figure a:** Schematic diagram showing the composition of species/taxa included in each TL cut-off: i) all community (MTL\_2,0), ii) mesopredators and top predators (MTL\_3,25), iii) top predators (MTL\_4,0).

The Mean Trophic Level indicator for each haul  $h$  can be calculated using the biomass and TL of species with the following formula:

$$MTL_h = \sum_i (TL_i) * (Y_{ih}) / \sum_i (Y_{ih})$$

$MTL_h$  refers to the MTL indicator by haul  
 $TL_i$  refers to the trophic level estimation of species (group)  $i$   
 $Y_{ih}$  refers to the biomass ( $Y$ ) of species (group)  $i$  in each haul  $h$ .

The resulting MTL values were explored to identify changes along the historical series in the different scenarios, by modelling the MTL as a function of year using Linear Models (LM) and/or Generalised Additive Models (GAM). All statistical analyses were performed using R software (R Core Team, 2022).

For the spatio-temporal approach, the calculation process follows the next steps for each of the scenarios (**Figure b**):

- Step 1. Calculate the mean MTL on a 0.2 x 0.2 degree grid over the whole time series.
- Step 2. For those grid cells having a sufficient number of data ( $n > 10$ ) assess any linear trend in MTL by year, reporting the slope of the linear model and its p-value.
- Step 3. Plot these results spatially, with MTL and the slope of MTL represented by a colour scale, and any significant trend represented by the cell of interest framed in bold.

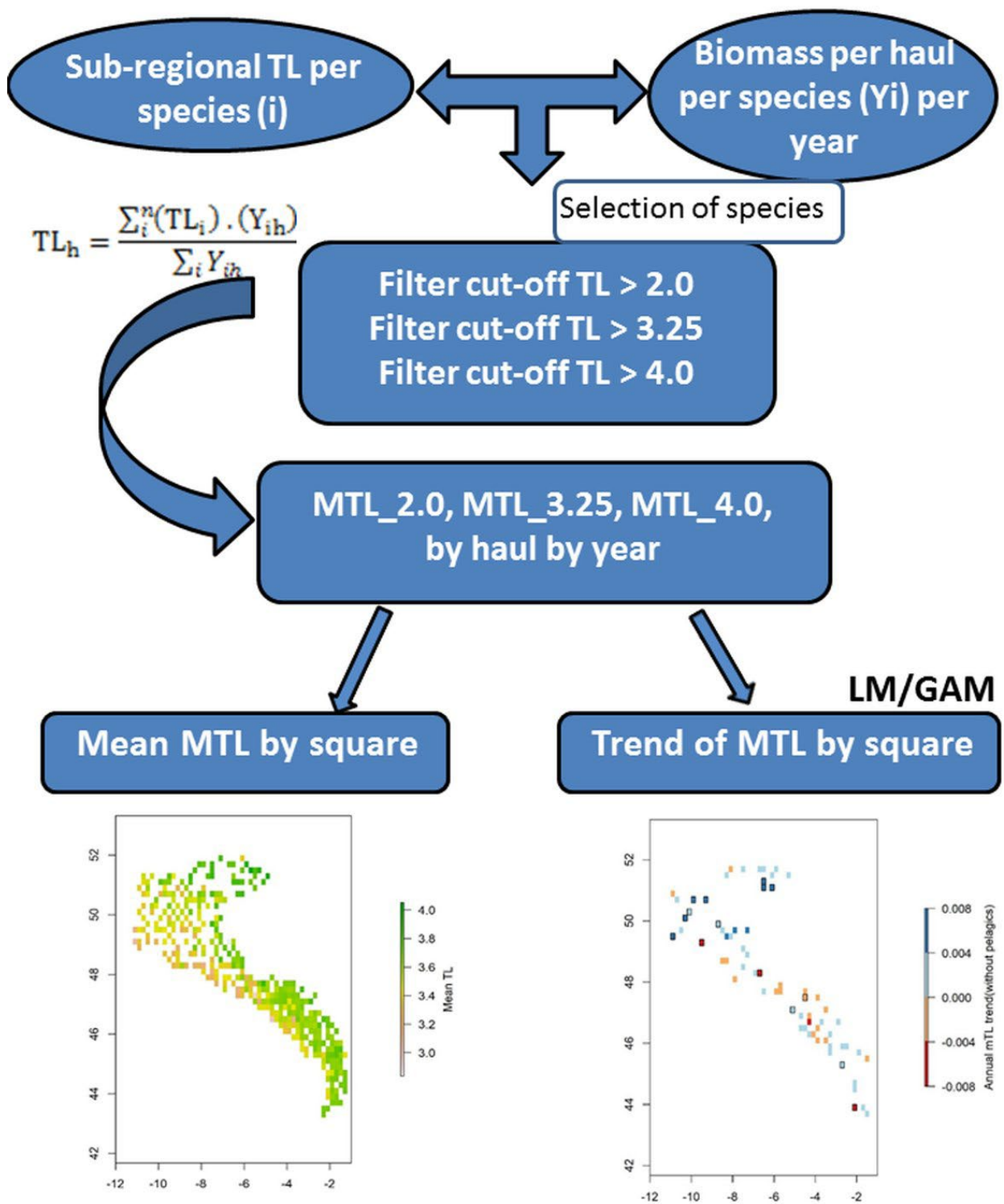
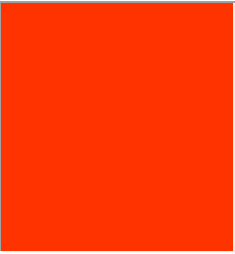

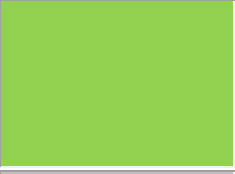



Figure b: Testing framework for the calculation of the spatio-temporal approach: MTL by haul and by year

## Assessment criteria

The assessment of the MTL is based on its trend analysis. To summarise the results of different scenarios and show a comprehensive message to the scientific and non-scientific community, the results of the trend analyses were binned into categories after McQuatters-Gollop *et al.*, 2022. Colours are the result of the linear models showing increase/no-trend/decrease of the indicator. Trends were considered to be increasing or decreasing only when linear models were significant (\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ). The resulting categories are shown in **Table b**. Please note that the present assessment shows changes in the indicator starting in 2000 when the benthic-demersal ecosystems were already overexploited, so the values at the start of the series do not represent ecological target values. Any positive trend in MTL is therefore considered as a sign of recovery, while a non-significant trend can be considered as a sign of the high resilience characterising systems enduring high and sustained impacts.

Table b: Biodiversity status categories and colours used for the interpretation of the results. Trend analysis (linear model and significant tests) and expert judgement are used to set colours based on the categories proposed by McQuatters-Gollop *et al.*, 2022.

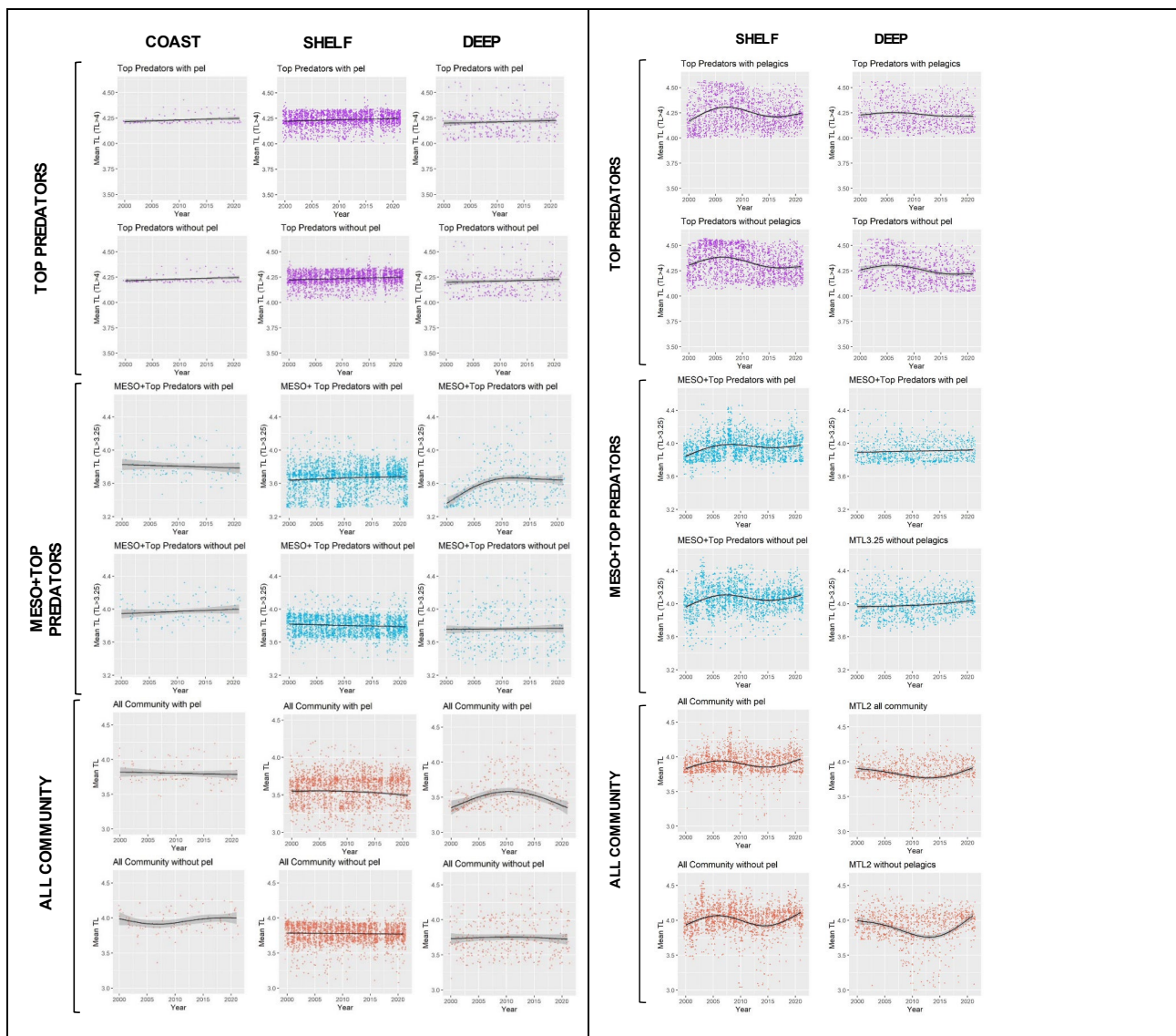
Biodiversity status categories	
	Indicator value is below assessment threshold, or change in indicator represents a declining state, or indicator change is linked to increasing impact of anthropogenic pressures (including climate change), or indicator shows no change but state is considered unsatisfactory
	No assessment threshold and/or unclear if change represents declining or improving state, or indicator shows no change but uncertain if state represented is satisfactory
	Indicator value is above assessment threshold, or indicator represents improving state, or indicator shows no change but state is satisfactory
	Indicator was not assessed in a region due to lack of data, lack of expert resource, or lack of policy support.

## Résultats

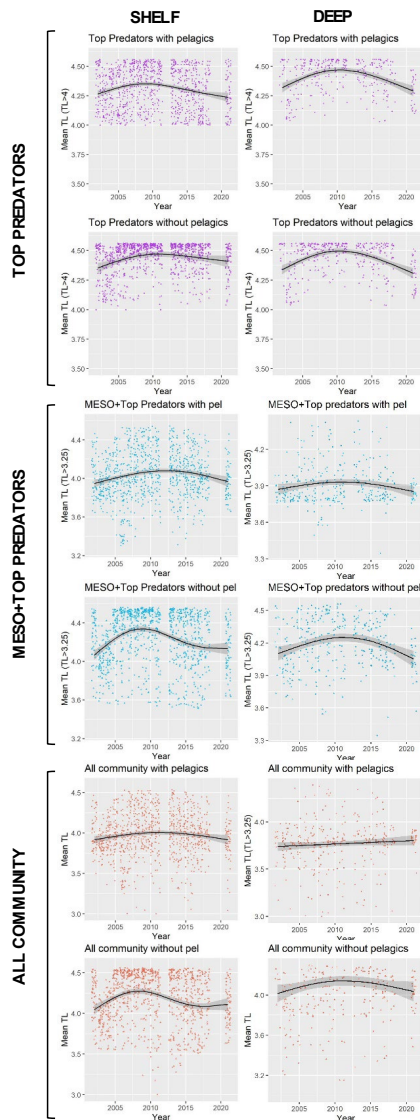
L'indicateur du niveau trophique moyen (MTL) a été évalué sur une période de 19 à 22 ans selon la subdivision (Région OSPAR IV) : plateau français (22 ans), plateau ibérique nord (22 ans), plateau portugais (19 ans) et plateau du golfe de Cadix (21 ans) (**Figures 2 à 8**) à l'aide de données d'enquête sur la biomasse et de valeurs de TL spécifiques à chaque subdivision. Au-dessus d'un TL de 4,0 (prédateurs supérieurs), on inclut les prédateurs de niveau supérieur des communautés benthico-démersales ; au-dessus d'un TL de 3,25

(prédateurs méso- et supérieurs), on inclut les poissons de niveau trophique moyen et supérieur, les éla-smobranches et les céphalopodes ; et au-dessus d'un TL de 2,0 (toute la communauté), on inclut tous les consommateurs.

Les résultats de l'approche temporelle révèlent des tendances différentes dans les quatre subdivisions (**Figures 2 à 5 ; Tableau 1**). Les résultats observés sur le plateau continental français indiquent une augmentation globale des prédateurs supérieurs dans l'écosystème côtier et du plateau et aucun changement dans les zones plus profondes. Des tendances générales à la hausse ont également été détectées lors de l'analyse des prédateurs méso- et supérieurs. Sur la côte nord-ibérique, des résultats contrastés ont été détectés avec une diminution du MTL des prédateurs supérieurs et une augmentation significative des prédateurs méso- supérieurs dans tous les scénarios. Dans les eaux portugaises, une diminution significative des prédateurs supérieurs dans les écosystèmes du plateau continental était apparente en incluant les pélagiques. Dans le Golfe de Cadix, les écosystèmes côtiers montrent des tendances à la baisse lorsque l'on considère toutes les communautés et les prédateurs méso et supérieurs. En revanche, les écosystèmes du plateau et les écosystèmes profonds montrent des signes de récupération à tous les niveaux trophiques.

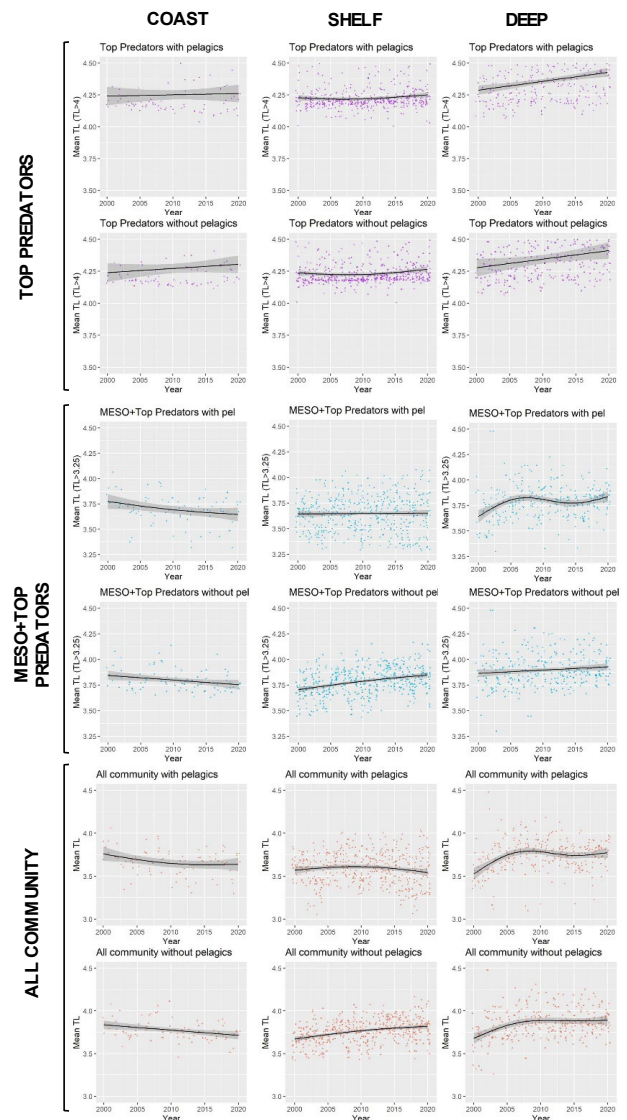


**Figure 2 : Plateau continental français, analyse des données de l'enquête sur les poissons de fond. Tendances de l'indicateur MTL avec 18 scénarios différents : seuils TL (prédateurs supérieurs, méso + prédateurs supérieurs, toute la communauté), plages de profondeur (côte, plateau, profond), avec/sans espèces pélagiques.**



**Figure 4 : Plateau continental portugais, analyse des données de l'enquête sur les poissons de fond. Tendances de l'indicateur MTL avec 12 scénarios différents : seuils TL (prédateurs supérieurs, méso**

**Figure 3 : Côte nord ibérique, analyse des données de l'enquête sur les poissons de fond. Tendances de l'indicateur MTL avec 12 scénarios différents : seuils TL (prédateurs supérieurs, méso + prédateurs supérieurs, toute la communauté), plages de profondeur (plateau, profond), avec/sans espèces pélagiques**



**Figure 5 : Plateau continental du Golfe de Cadix, analyse des données de l'enquête sur les poissons de fond. Tendances de l'indicateur MTL avec 18 scénarios différents : seuils TL (prédateurs**

<p>+ prédateurs supérieurs, toute la communauté, plages de profondeur (plateau, profond), avec/sans espèces pélagiques.</p>	<p>supérieurs, méso + prédateurs supérieurs, toute la communauté, plages de profondeur (côte, plateau, profonde), avec/sans espèces pélagiques.</p>
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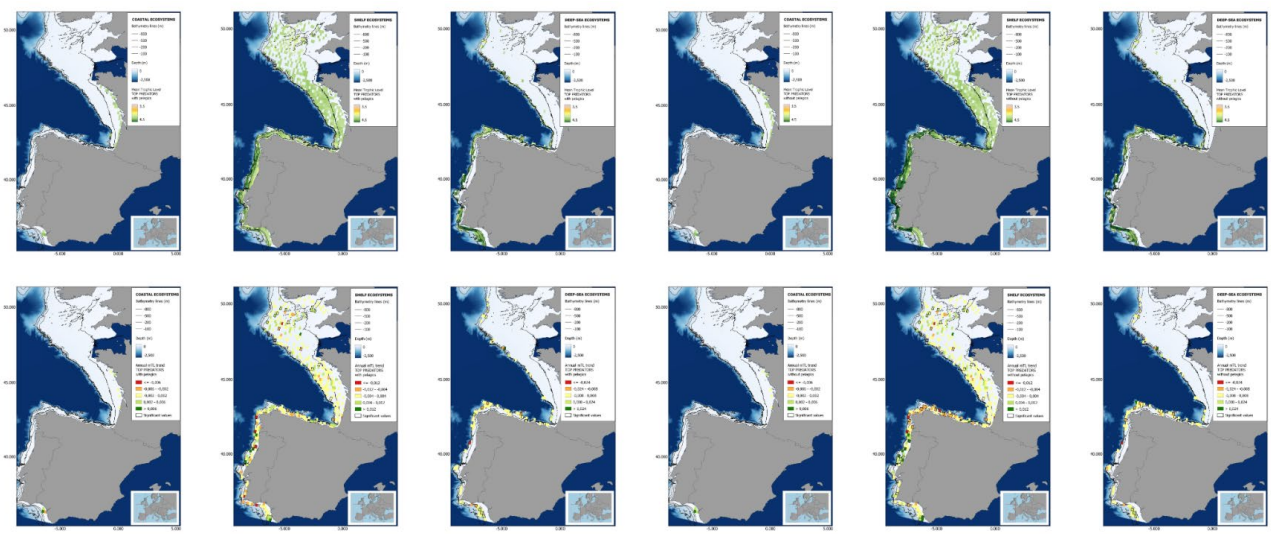


Figure 6 : Cartes montrant les résultats de l'approche spatio-temporelle des prédateurs supérieurs : les 6 cartes du haut montrent le niveau trophique moyen par carré, les 6 cartes du bas montrent la tendance du niveau trophique moyen par carré. Vert = tendance à la hausse, orange-jaune = pas de tendance, rouge = tendance à la baisse. Les tendances significatives sont encadrées en gras.

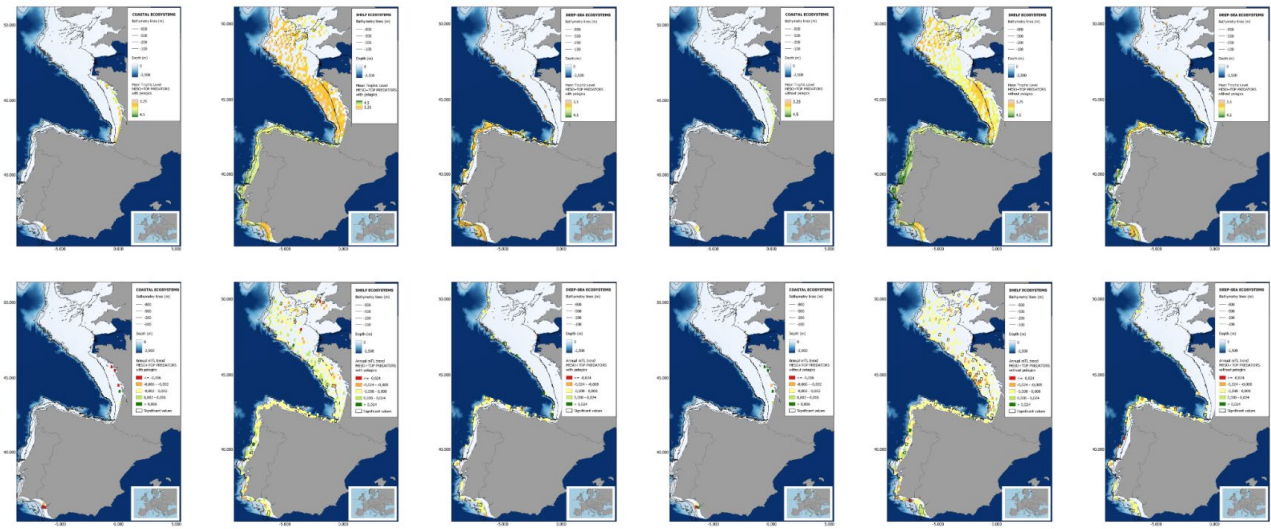
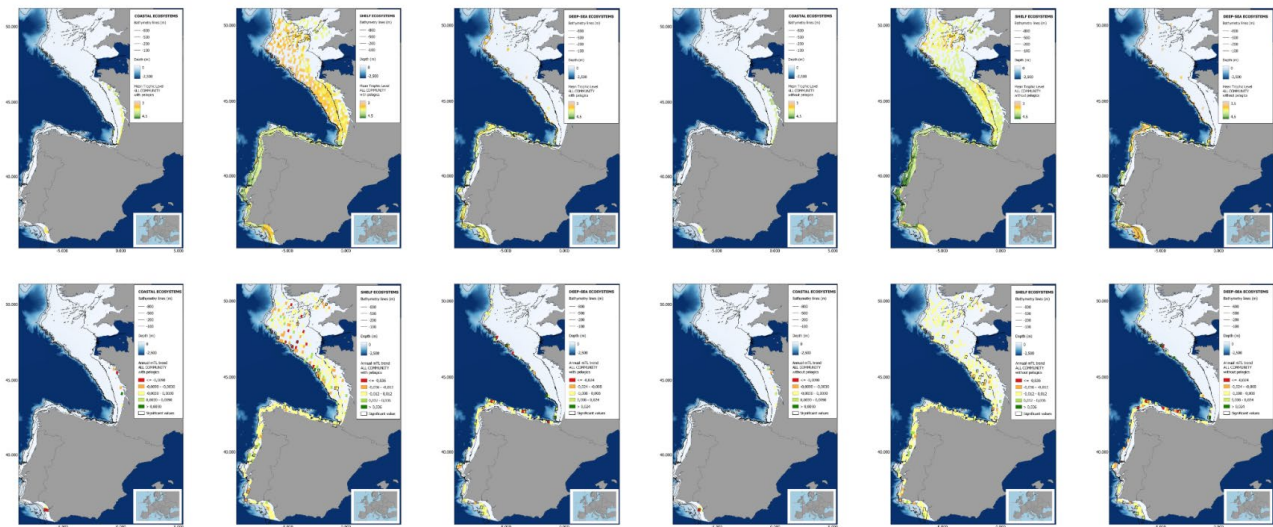


Figure 7 : Cartes montrant les résultats de l'approche spatio-temporelle des méso + prédateurs supérieurs : les 6 cartes du haut montrent le niveau trophique moyen par carré, les 6 cartes du bas montrent la tendance du niveau trophique moyen par carré. Vert = tendance à la hausse, orange-jaune = pas de tendance, rouge = tendance à la baisse. Les tendances significatives sont encadrées en gras.



**Figure 8 : Cartes montrant les résultats de l'approche spatio-temporelle de toute la communauté : les 6 cartes du haut montrent le niveau trophique moyen par carré, les 6 cartes du bas montrent la tendance du niveau trophique moyen par carré. Vert = tendance à la hausse, orange-jaune = pas de tendance, rouge = tendance à la baisse. Les tendances significatives sont encadrées en gras.**

Les résultats de la cartographie de l'indicateur montrent des valeurs de MTL plus faibles dans les zones septentrionales contrastant avec des MTL plus élevés dans l'écosystème du plateau portugais. En traçant les tendances par carré, des changements temporels à petite échelle qui étaient masqués lorsque l'indicateur était calculé par subdivision sont apparus. En ce qui concerne les résultats des prédateurs supérieurs, la zone nord du plateau français et portugais a montré une distribution inégale de tendances positives, tandis qu'une concentration de tendances décroissantes peut être observée dans le nord-ouest de la péninsule ibérique (écosystèmes du plateau et des profondeurs). La tendance à la baisse des prédateurs méso et supérieurs observée dans l'approche temporelle sur le plateau français semble être liée à la forte concentration de tendances négatives dans la zone la plus méridionale. Les changements temporels et positifs des prédateurs méso-+supérieurs sur le plateau ibérique sont observés uniquement dans quelques zones dispersées. L'indicateur incluant toutes les communautés a montré une forte concentration de valeurs décroissantes dans la partie la plus septentrionale du plateau français et du talus ibérique Nord, tout en montrant des tendances générales à la hausse dans le plateau et le talus portugais Nord.

**Tableau 1 : Résumé de l'évaluation des différents scénarios dans les quatre sous-divisions OSPAR, en tenant compte des seuils TL, des strates de profondeur et en incluant/excluant les espèces pélagiques. Les valeurs positives indiquent une tendance à la hausse ; les valeurs négatives indiquent une tendance à la baisse. Les couleurs et les catégories sont expliquées dans le tableau 2. Le nombre dans chaque cellule représente le taux de changement du MTL sur l'ensemble de la série historique, calculé en multipliant la pente de la courbe linéaire par le nombre total d'années de la série temporelle**

	Prédateurs supérieurs			Mésos + prédateurs supérieurs			Toute la communauté		
	côte	plateau	profond	côte	plateau	profond	côte	plateau	profond
<b>France</b>									
Avec espèces pélagiques	0.03*	0.03***	0.03	0.03	0.05***	0.02***	-0.04	-0.06**	-0.01
Sans espèces pélagiques	0.03*	0.03***	0.03	-0.04	-0.03***	0.01	0.07	-0.01	-0.01
<b>Côte nord ibérique</b>									
Avec espèces pélagiques		-0.03*	-0.04**		0.06***	0.03*		0.01	-0.05
Sans espèces pélagiques		-0.10***	-0.10***		0.04**	0.07***		-0.01	-0.06
<b>Portugal</b>									
Avec espèces pélagiques		-0.05**	-0.04		0.06	-0.01		0.02*	0.07
Sans espèces pélagiques		0.05	-0.04		-0.06	-0.03		-0.09	0.02
<b>Golfe de Cadix</b>									
Avec espèces pélagiques	0.02	0.03	0.15***	-0.13*	0.01	0.08*	-0.12*	-0.03	0.13***
Sans espèces pélagiques	0.07	0.03*	0.14*	-0.10*	0.15***	0.07*	-0.13**	0.16***	0.16***

Valeur p pour le test statistique de signification (modèle linéaire), \*:  $p < 0.05$ , \*\*:  $p < 0.01$  \*\*\*:  $p < 0.001$ .

## Résultats (version étendue)

In the present assessment the indicator MTL has been tested in the four sub-divisions within OSPAR Region IV: French, North Iberian, Portuguese and Gulf of Cadiz shelves. The compilation of TL values by sub-division for calculating MTL was possible for the main representative species in three out of four sub-divisions: French, North Iberian and Gulf of Cádiz continental shelves. The use of regional TLs is expected to improve the robustness of the indicator and reduce the uncertainty around the calculations.

### French sub-division

Considering top predators alone (MTL4), the MTL indicator shows significant linear increasing trends in coastal and shelf areas, but no change in deeper waters. Similar responses are observed with and without pelagic species (**Figure 2, Table 1**). Considering meso + top predators (MTL3.25), the MTL indicator displayed

contrasting responses: no significant trend was identified in coastal areas, but an increasing trend was displayed in continental shelf and slope which disappeared when the pelagic species were excluded from the community (**Figure 2**). No changes are observed when considering the whole community (MTL2) except for shelf ecosystems with pelagic, where a decreasing trend was detected.

Attending to the results of the spatio-temporal approach, the MTL of top predators (MTL4) showed no spatial differences with and without pelagic species (**Figure 6**). However, patchily distributed increasing trends were observed in the northernmost areas of the shelf ecosystem, around an area of lower mean MTL4 values in the Celtic Sea. The spatio-temporal analyses of meso + top predators MTL (MTL3.25), showed generally higher values on the shelf than on the slope (**Figure 7**). It's noteworthy the decrease in MTL3.25 in these bathymetric ranges when excluding the pelagic species from the analyses, which is also associated to a change from mostly increasing trends to mostly decreasing trends in the annual values. (**Figure 7**). Regardless of the pelagic species, negative trends prevailed in the Southern Irish Sea (**Figure 7**). Attending to the whole community (MTL2), this change from mostly positive trends to mostly negative trends when excluding the pelagic species was also apparent (**Figure 8**) suggesting that the pelagic and demersal domains of the community are experiencing contrasting evolutions. When looking at the trends, no significant changes were observed in coastal areas at any of the MTL cut-offs (**Figure 6**, **Figure 7** and **Figure 8**), but there was a clearly higher mean values in the northern area (Brittany and Pays de la Loire) than in the southern one (Nouvelle-Aquitaine) (**Figure 6**, **Figure 7** and **Figure 8**). Overall, trends appeared heterogeneously and patchily distributed in all scenarios.

#### **North Iberian sub-division**

The indicator MTL4 (including top predators) showed moderate to strong decreasing trends in all scenarios: both depth strata (shelf and deep ecosystems), including and excluding pelagic species (**Figure 3**, **Table 1**). However, when including mesopredators, analysis revealed a significant positive trend in all scenarios. These contrasting trends could be detecting a signal of decline in biomass of top predators (some important commercial species) while an apparent improvement of mid trophic level consumers (mainly fish, elasmobranchs and cephalopods) in the last two decades. No changes have been observed when considering all community.

In the north Iberian sub-division, the MTL4 indicator (only top predators) showed higher values in the western part of the area in comparison to the inner Bay of Biscay (**Figure 6**), with almost no apparent differences including and excluding pelagic species. When looking at the trends of top predators, significant decreasing trends were observed in the westernmost area, more pronounced in shelf than in deep ecosystems (**Figure 6**), and also more pronounced when pelagic species were excluded from the analysis (**Figure 6**). Spatial differences in mean values and temporal changes were less evident when including mesopredators, although these contrasting trends (mostly negative at MTL4 and mostly positive at MTL3.25) were also observed at small scale. (**Figure 6** and **Figure 7**). Taking into account all species in the community (MTL2) slope ecosystems displayed mostly decreasing trends in the indicator both including and excluding pelagic species, while shelf ecosystems showed mostly increasing trends in the indicator, regardless of the pelagic species (**Figure 8**).

#### **Portuguese sub-division**

In Portuguese waters, a moderate decline in MTL4 (top predators including pelagics) was observed in shelf ecosystems (**Figure 4, Table 1**). However, no changes are observed in the rest of scenarios, with the exception of a slight increase in the indicator including all community (MTL2 with pelagic) in shelf ecosystems (**Table 1**).

Higher values of MTL in Portuguese waters in comparison with other sub-divisions were evident when looking at the maps (**Figure 6, Figure 7 and Figure 8**). These results are consistently pronounced in almost all scenarios, and particularly evident in the central part of the Portuguese shelf and deep ecosystems. This sub-division showed little evidence of MTL changes at the local scale in any of the scenarios, with very few cells showing significant trends being scattered across the area (**Figure 6, Figure 7 and Figure 8**). These results at the local scale mostly agree with the temporal trends obtained when analysing the sub-division as a whole (**Figure 4, Table 1**), highlighting the greater stability/resilience of the Portuguese sub-division, in relation to the adjacent areas.

### **Gulf of Cadiz sub-division**

Increasing trends in all scenarios excluding pelagic species were observed except for coastal areas (**Figure 5 and Table 1**) where a decline was evident when considering all community (MTL2) and meso + top predators (MTL3.25), but not for top predators only (MTL4). However, the results from coastal areas should be taken with caution due to the low number of hauls in comparison with shelf and deep ecosystems. It should be noted that the rate of change in MTL across the time series in many of the scenarios was one order of magnitude higher compared to other sub-divisions (**Table 1**).

Despite the low number of hauls analysed in coastal areas, the decreasing trends detected in the temporal approach can also be observed when mapping the indicator at small scale (**Figure 6, Figure 7 and Figure 8**). For top predators (MTL4) significant positive trends were detected in the southernmost part of the sub-division in shelf ecosystems, and generally over the continental slope (**Figure 6**). When mesopredators are included (MTL3.25), positive trends emerge in the southern part of the sub-division persist on the shelf, while areas with positive values on the slope have a scattered distribution (**Figure 7**). A few cells showed increasing trends when including all community (MTL2) in the scenarios where pelagic species were excluded (**Figure 8**).

In summary, analyses of groundfish data show an apparent improvement in top predators in the French continental shelf, in contrast to the decrease generally observed in North Iberian and Portuguese waters. In the Gulf of Cadiz however, there were signs of recovery in shelf and deep-sea ecosystems. When including mesopredators in the calculations, increasing trends were observed in most of the sub-divisions. The state of the marine food web displayed no apparent changes when analysing the entire community, with the exception of the Gulf of Cadiz, where contrasting trends were observed in the MTL depending on the depth strata considered (decrease versus increase in coastal and slope areas, respectively). These contrasting trends highlight the importance of focusing the assessment by sub-division, and also, the need to consider different bathymetric and ecological scenarios. Nevertheless, these findings need to be taken with caution as they are highly dependent on the length and source of the time series considered.

## **Conclusion**

Le niveau trophique moyen (MTL) dans la Région IV d'OSPAR a montré des tendances contrastées dans la structure globale du réseau trophique, selon la subdivision et la partie de l'écosystème étudiée. Dans les zones septentrionales (plateau français) et méridionales (plateau du golfe de Cadix), on observe des signes d'amélioration dans les niveaux trophiques supérieurs, ce qui contraste avec le déclin observé chez les prédateurs supérieurs dans le plateau ibérique nord et portugais. Cependant, si l'on se concentre sur les prédateurs méso et supérieurs, la récupération est une caractéristique commune à la plupart des scénarios dans les quatre subdivisions. En prenant en compte l'ensemble de la communauté, aucun changement n'a été observé dans la plupart des scénarios, à l'exception du Golfe de Cadix. L'absence de variations dans ce scénario pourrait être due à l'effet de masquage de l'inclusion de nombreuses espèces ayant des comportements alimentaires différents (poissons, céphalopodes et invertébrés benthiques). Une résilience globale du réseau trophique due à une pression persistante dans le temps pourrait également expliquer les tendances stables observées au cours des deux dernières décennies.

L'utilisation des valeurs des niveaux trophiques par subdivision permet d'avoir une meilleure vision de la structure des communautés au sein de la région étudiée et renforce la précision et la robustesse de cette évaluation. De plus, en analysant l'indicateur avec une approche spatio-temporelle, l'évaluation fournit des informations complémentaires de l'évolution de l'indicateur à différentes échelles, renforçant les effets locaux sur la structure du réseau trophique. Dans l'ensemble, l'examen de la communauté dans son ensemble (avec et sans les espèces pélagiques) ainsi que la focalisation sur différents niveaux trophiques (prédateurs supérieurs et mésoprédateurs) permettent de révéler des changements dans la structure du réseau alimentaire qui resteraient cachés autrement.

## **Conclusion (version étendue)**

The Mean Trophic Level (MTL) in OSPAR Region IV showed an apparent sign of recovery when focusing on top predators (MTL4) in the northern and southernmost areas of the region (French continental and Gulf of Cadiz shelves). Nevertheless, when including mesopredators in the indicator (MTL3.25) an overall improvement was observed across sub-divisions. An increasing trend in the MTL indicator is considered to reflect decreasing impacts of fisheries on food webs, while a stable or declining trend needs to be further investigated in order to determine whether it can be attributed to resilience of the system or other possible causes. However, the contrasting trends observed in the different scenarios and sub-divisions support the idea that MTL should be assessed at sub-division level. Knowledge of the fisheries history in the region also helps to interpret these trends: the implementation of fisheries regulations may have decreased fishing pressure on top predators. Implementing fishing pressure data on the models will greatly help to investigate the direct response of the indicator. Additional information about the communities inhabiting the area and the environmental variability may be necessary to confirm the findings of this assessment. Furthermore, linking the MTL indicator to other biodiversity and food webs indicators (e.g., Feeding guilds) would also allow a more detailed examination of the impact of fisheries on the ecosystem.

Further work should be undertaken to improve the assessment of the state of the food web. Particularly important is the analysis of the interannual variability of TLs of species, which has been overlooked in the present assessment due to lack of appropriate data. Predator-prey interactions change over time, and therefore including these variations in the TL estimates will greatly improve the robustness of the models. In addition, as most species increase their trophic level along their ontogeny, mostly due to their larger size

gape and increased motility, it would be more appropriate to estimate MTLs in the community based on both species and size distributions within the species. However, information of changes in TL with size are still unavailable for most of the species at the moment. Besides, incorporating additional datasets of other biological compartments (e.g., benthos, mammals, or birds) and / or from other sources (e.g., pelagic survey data) into the MTL indicator will enable a more holistic assessment of the area. Data on invertebrates (including cephalopods), which represent an important component of the biomass and play a key role as prey items with a fundamental role in the food web, should also be included in all sub-divisions.

An important effort has been made in the present assessment by performing the spatio-temporal approach, applying the indicator to finer geographic scales, identifying particularly impacted areas within those under high fishing pressure. However, it would be beneficial to further develop this indicator if more variables are included in the models (e.g., fishing pressure and climate variables), in order to explore the influence of anthropogenic pressure on MTL indicator trends, and how they affect the overall assessment.

Another issue is the difficulty of establishing reference conditions and assessment values. Indeed, the scientific survey time series used here started after the expansion of the fishing industry in this region and a period of high fishing pressure. The criteria used in the present assessment follow McQuatters-Gollop (2022), applying a combination of linear models and expert knowledge.

## **Lacunes dans les connaissances**

Grâce à la présente approche méthodologique, il est actuellement possible d'appliquer l'indicateur MTL dans d'autres régions, dès lors que des données solides sur la biomasse et les TL des espèces sont disponibles. Le manque de données sur la biomasse du benthos et des invertébrés constitue une limite au calcul de l'indicateur pour l'ensemble de la communauté. En outre, des informations détaillées sur les interactions alimentaires sont fortement nécessaires. Des études alimentaires répétées et des analyses d'isotopes stables mises en œuvre à l'échelle (sous-)régionale, ainsi que le calcul des valeurs de TL, contribueraient à combler cette lacune dans les connaissances.

Pour améliorer l'évaluation de l'état du réseau trophique, les travaux futurs sur l'indicateur MTL comprennent : i) l'intégration de la variabilité interannuelle du niveau trophique des espèces, ii) l'intégration des variations du niveau trophique des espèces en fonction de la taille, iii) l'étude de l'influence de diverses pressions anthropiques sur l'indicateur, iv) l'amélioration des critères d'évaluation en définissant des seuils à l'aide de courbes pression-état.

## **Lacunes dans les connaissances (version étendue)**

In order to establish trophic relationships more accurately so that TL values can be determined, data are required on species feeding habits and their variations with ontogeny. Large-scale groundfish surveys (such as the Data Collection Framework, DCF) and pelagic surveys should aim at systematically collecting: i) as many species as possible in the food web; and ii) data for dietary analyses using stomach content and / or stable isotope analyses for the different size classes of a given species (in order to account for the ontogeny effect on species TL values). Comprehensive datasets on the feeding ecology of many of the key species in marine food webs are currently insufficient for the purposes of conducting this type of assessment, and this is especially the case for species at lower trophic levels.

The first step in filling these gaps in knowledge of food web structure and connectivity is to extend data collection on feeding ecology by sub-division (Carafa *et al.*, 2007; Moloney *et al.*, 2010; Rossberg *et al.*, 2011). Analyses of stomach contents can provide accurate information on the species consumed as well as serving as a sampler of the smaller invertebrates and other benthic components not retained by the sampling gear. Stable isotope analyses indicate trophic level based on a longer feeding signature, and so provide a broader view of feeding strategy of a given species. Both approaches provide complementary information about food web functioning. Repeat dietary analyses also provide information on spatial and temporal variability in the trophic relationships of the species present in a given ecosystem and thus, of their TL values. Such data would be useful not only for strengthening the MTL indicator, but also for all trophic-level and food-web based indicators as well as for models.

## Métadonnées d'évaluation

Champ	Type de données	
Type d'évaluation	Liste	Évaluation de l'indicateur
Résumé des résultats	URL	<a href="https://odims.ospar.org/en/submissions/ospar_change_mtl_consumer_msfd_2022_06/">https://odims.ospar.org/en/submissions/ospar_change_mtl_consumer_msfd_2022_06/</a>
Indicateur ODD	Liste	14.2 D'ici à 2020, gérer et protéger durablement les écosystèmes marins et côtiers, notamment en renforçant leur résilience, afin d'éviter les graves conséquences de leur dégradation et prendre des mesures en faveur de leur restauration pour rétablir la santé la productivité des océans
Activité thématique	Liste	Diversité biologique et écosystèmes
Documentation OSPAR pertinente	Texte	OSPAR Agreement 2018-08 CEMP Guidelines: Common Indicator in Region IV: Change in average trophic level of marine predators (FW4)
Lien	URL	<a href="https://www.ospar.org/documents?v=39002">https://www.ospar.org/documents?v=39002</a>
Date de publication	Date	2022-06-30
Conditions d'accès et d'utilisation	URL	<a href="https://oap.ospar.org/fr/politique-de-donnees/">https://oap.ospar.org/fr/politique-de-donnees/</a>
Instantané de données	URL	<a href="https://odims.ospar.org/en/submissions/ospar_change_mtl_consumer_snapsh_2022_06/">https://odims.ospar.org/en/submissions/ospar_change_mtl_consumer_snapsh_2022_06/</a>

Champ	Type de données	
<b>Résultats des données</b>	Fichier Zip	<a href="https://odims.ospar.org/en/submissions/ospar_change_mtl_consumers_result_2022_06/">https://odims.ospar.org/en/submissions/ospar_change_mtl_consumers_result_2022_06/</a>



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**Notre vision est celle d'un océan Atlantique Nord-Est propre, sain et biologiquement diversifié, qui soit productif, utilisé de manière durable et résilient au changement climatique et à l'acidification des océans.**

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