Response to Referee #2 comments

We sincerely appreciate the reviewer's constructive comments and valuable suggestions, which have contributed to enhancing the clarity and robustness of our manuscript. In this document, the reviewer's comments are presented in black, while our associated responses are presented in blue. Additionally, we provide the revised version of the manuscript.

The paper titled "Micronekton Indicators Evolution Based on Biophysically Defined Provinces" by Albernhe et al. examines the evolution of micronekton indicators across biophysically defined provinces over a 25-year period, from 1998 to 2023.

This study offers a dynamic, long-term analysis of micronekton provinces, providing quantitative insights into surface area and latitude trends while presenting direct evidence of climate-driven shifts in marine ecosystems. It builds upon previous research by offering a more precise, time-resolved, and geographically validated understanding of micronekton variability.

By focusing on two key indicators—surface area trends and average latitude shifts—this study highlights metrics that could serve as future Ocean Monitoring Indicators. Its straightforward and impactful contribution makes it highly relevant for the OSR.

My primary concern is that this paper heavily relies on the work by Albernhe et al. (2024), which is still under review and not yet publicly available. Additionally, no reference to this paper is provided, leaving significant gaps in the current contribution. Without the publication of Albernhe et al. (2024), too many critical questions remain unanswered.

Therefore, unless Albernhe et al. (2024, under review) is officially published, I must recommend rejecting this submission. However, given the relatively long publication process for OSR9, this contribution could be accepted on the condition that the referenced paper is published before the final release of OSR9.

Furthermore, I suggest revisions, and the authors should provide a copy of Albernhe et al. (2024, under review) alongside their revisions to allow for a thorough evaluation of the current submission.

➔ Thank you for your thoughtful feedback. We appreciate your concern regarding the reference to the unpublished paper and the importance of providing sufficient context for our study. We are pleased to inform you that the referenced study, "Albernhe et al., 2024," has since been accepted and published. The full reference is as follows:

Albernhe, S., Gorgues, T., Lehodey, P., Menkes, C., Titaud, O., De La Giclais, S. M., & Conchon, A. (2024). Global characterization of modelled micronekton in biophysically defined provinces. Progress in Oceanography, 229, 103370.

We have updated the manuscript to reflect the status of this publication (i.e., Introduction l73, l93, Material and methods l100, l103, l116, etc.), and added the reference in the appropriate section.

However, we want this paper to be comprehensive on its own. The different steps of the methodology are detailed in Section 2.1., l102 : "*While the overall methodology is detailed in Albernhe et al. (2024), we outline the different steps of the method below to ensure this study is comprehensive and self-contained. […]*"

Major comments

1) It remains completely unclear how the 27 provinces are obtained. I suggest that authors will provide more information about the determination of 27 provinces in Materials and Methods section. Otherwise, the paper cannot be read as stand alone paper.

➔ We appreciate the reviewer's concern regarding the determination of the 27 provinces. We have ensured that this process is clearly explained in the Materials and Methods section. While we followed the methodology of Albernhe et al. (2024), we dedicated a specific section to detailing our approach (Section 2.1).

➔ First, we derived six biophysical biomes through the clustering of environmental variables (see Section 2.1 paragraphs 4 and 5, lines 121–133). Then, each biome was subdivided into provinces based on hemisphere and ocean basin, resulting in 27 provinces as subdivisions of biomes (see Section 2.1, lines 143): *"The six biophysical biomes obtained from the clustering of environmental data characterize homogeneous environmental regimes on a global scale. Since similar oceanographic regimes occur in multiple locations, biophysical biomes extend across various ocean basins. In this study, we also delineate "provinces" as subdivisions of biomes at the scale of ocean basins and hemispheres that have been shown to be characterized by stable biophysical drivers and potential taxonomic identity (Spalding et al., 2012; Sutton et al., 2017; Albernhe et al., 2024). This subdivision of each of the six biophysical biomes results in the definition of 27 provinces, establishing regional frameworks for studying micronekton."*

➔ To improve clarity, we have revised these paragraphs to better explain our methodology. We hope this addresses the reviewer's concern and enhances the manuscript's readability as a stand-alone paper.

2) The manuscript will benefit if more in-depth discussion in comparison to the works by (Reygondeau et al., 2012), (Sutton et al., 2017), (Costello et al., 2017), (Elizondo et al., 2021), (Proud et al., 2017), (Ariza et al., 2022) is provided.

➔ The Discussion section has been significantly improved, notably by deepening the comparison with several studies. Additionally, substantial work has been done to better contextualize the findings, expand the bibliography, and refine the interpretation of the results since the initial version.

Section 4, Discussion, paragraph 1, l329: *"In this study, we defined 27 biophysical provinces linked to micronekton, based on a methodology introduced in Albernhe et al. (2024). Our definition of the reference biophysical provinces (Figure 1) has been compared to other studies (e.g. Proud et al., 2017; Sutton et al., 2017, Ariza et al. 2022) employing comparable methodologies using environmental variables to derive biogeographic regions. Sutton et al. (2017) classified regions based on environmental drivers and expert knowledge, Proud et al. (2017) used clustering on environmental variables to model deep scattering layers characteristics, and Ariza et al. (2022) derived provinces by clustering acoustic data reconstructed from biophysical variables. Despite methodological differences among these three studies, the resulting biogeographical regions closely align with ours. Notably, beyond the evident latitudinal banding (in the austral Ocean for instance), more complex regional structures emerge in the North Atlantic, midlatitude frontal zones (except in the South Pacific), and upwelling regions (see Figure 4 in Sutton et al., 2017; Figure 3A in Proud et al., 2017; Figure 2a in Ariza et al., 2022; and our Figure 1). This similarity likely arises because all approaches rely on*

biophysical variables that capture key information on temperature, biological productivity, and water column mixing."

➔ Section 4, Discussion, line 410: *"In Ariza et al. (2022), the authors derive acoustic provinces from a clustering using acoustic data as a proxy of micronektonic biomasses, which they reconstructed from biophysical data (satellite-derived chlorophyll concentration, sea surface temperature and subsurface dissolved oxygen). In Albernhe et al. (2024), our biophysical provinces were compared to these acoustic provinces, revealing a strong overall agreement, particularly in terms of latitudinal patterns, dynamic regions, and upwelling areas. However, our clustering method did not capture oxygen-driven patterns. Ariza et al. (2022) also explored the spatio-temporal variability of provinces in future projections extending to 2100."*

Detailed comments

L172-174 The following statement is too general "Seasonal variability can be observed with the latitudinal shifts of the horizontal boundaries, as well as regional seasonal phenomena or isolated phenomena like ENSO events." Without any hints on what to look from the video, it requires detailed analysis of the video itself by readers.

➔ We agree with your comment, and we believe it's important to avoid misleading the reader about the study's focus which is on decadal to climatic trends rather than seasonality. Mentioning seasonal variability could create confusion. To maintain clarity and stay focused on the paper's central message, we have removed the sentence.

Section 3.4 More appropriate title is Sensitivity analysis instead of Uncertainty. Text of the section should be adjusted accordingly

➔ Section 3.4 has been titled accordingly.