Comment on « Long-term variability of Norway lobster (Nephrops norvegicus) landings in relation to a changing climate in the Northwestern Mediterranean Sea » by Mingote et al.

This study examines the causes of changes between 1970 and 2024, with a particular focus on the significant decline in Norway lobster catches in the northwestern Mediterranean since 2014. They inferred that this decline is not solely due to decreasing fishing pressure, but also results from climate change affecting the intermediate water layer (i.e. between depths of 200 and 600 metres). By analysing thermohaline and current velocity data from reanalysis, they revealed that widespread warming and salinification were affecting the availability of this resource. These environmental changes appear to be forcing the species to move to deeper waters, thereby reducing its accessibility to fishing fleets. The article concludes by emphasizing the need to incorporate oceanographic indicators into stock management in order to anticipate changes in marine resources more effectively.

This study presents an interesting analysis of the abundance and catchability of a species, clearly highlighting the link to environmental conditions derived from reanalyses. It is clearly presented and illustrated. This work deserves to be published because it provides solid results and useful information for resource management. However, I believe this work could and should be improved, particularly with regard to the analytical methods. The treatment of currents could be modified to make their interpretation easier and more robust. Some figures could be improved. Certain parts of the discussion could also be strengthened.

Introduction

Line 69. You could also refer to Vargas-Yáñez et al, 2017, Progress in Oceanography, doi: 10.1016/j.pocean.2017.09.004

Lines 90–95. It would be interesting to include a graph showing trends in the main fish species caught over the same period (1970–2024) as the Norway lobster, since this information is referenced in the discussion. This would also allow for an update to the current Figure 3, focusing on the same period as the physical reanalyses with which it is compared (1987–2024).

Lines 134–144 Could you provide more information about the characteristics of the Northern Current (such as its depth and seasonal variations)? This information will be useful for analysing its impact later in this article.

Material and Methods

Figure 2. This figure is very clear and important. However, I have some doubts about the position of the Northern Balearic Front. To my knowledge, it should extend eastward rather than northward (toward the Gulf of Lion shelf) (See the paper by Barral et al., 2021, Progress in Oceanography, doi: 10.1016/j.pocean.2021.102636).

Section 2.3. You applied an empirical orthogonal function (EOF) decomposition to oceanographic variables over a domain that extends well beyond the boundaries of the GS6 region. I wonder whether the modes obtained would be significantly different if you had applied this decomposition only to the GS6 region.

Lines 210-2011. Change ‘complete time series between 1987 and 2024’ by ‘complete monthly time series for the period from 1987 to 2024’

Lines 226,229. You use a local coordinate rotation to define along-slope and cross-slope velocity components from the horizontal currents (u, v). While this is a reasonable first-order approximation in areas with relatively straight bathymetry, it may not adequately capture the dynamics of the northern current and the Balearic current in the topographically complex NW Mediterranean. A bathymetry-based decomposition would provide a more physically consistent representation of the flow, because the along-slope direction is expected to follow the local contour lines of the continental slope rather than a fixed geographic axis.

Using a smoothed bathymetry field H (x, y), the local slope direction can be defined from the bathymetric gradient ∇H. The velocity components along and cross the isobaths are :

$$u_{along} = \frac{-u\,\partial H/\partial y + v\,\partial H/\partial x}{\sqrt{(\partial H/\partial x)^2 + (\partial H/\partial y)^2}}$$

$$u_{cross} = \frac{u\,\partial H/\partial x + v\,\partial H/\partial y}{\sqrt{(\partial H/\partial x)^2 + (\partial H/\partial y)^2}}$$

This formulation would better ensure that the along-slope component follows the shelf break, while the cross-slope component more directly represents exchanges between the shelf and the open ocean. The main along slope current will remains a continuous, coherent feature in the u_{along} variable, even as it curves around the Gulf of Lion and recirculates in the Balearic Sea.

Lines 416–419. Have you any references to support this finding linking the increase of temperature (and salinity) at 400 m with the decrease of the Northern Current at 200 m? Besides, the opposite behavior of the Balearic Current compared to the Northern Current is likely related to the choice of axis rotation. This will probably change using the new along- and cross-slope reference frame.

Results

Figure 3 It would be preferable for these time series to cover the same period as the environmental data (i.e., 1987–2024), in order to improve comparability and avoid any confusion arising from different time scales. The complete time series (1970–2024) should be presented in a separate figure in the introduction, alongside the landing data for the other relevant species mentioned in the state-of-the-art review.

Figure 5. Can you explain how the temperature anomaly is calculated? It would be interesting to add a plot of the average temperature to these graphs.

Line 323. Replace ‘The resulting cross-correlation matrix (Fig. 6)’ with ‘The resulting cross-correlation matrix for landings (Fig. 6)’ for clarity, since you describe the cross-correlation for LPUE later on.

Table 1. You sometimes use ‘Liguro-Provençal-Catalan Current’ and other times ‘Northern Current’ in the table and elsewhere in the text. You should standardize the terminology and, once the two terms have been introduced in section 2.1, use only one of them.

Line 369. Rather than writing ‘changes in the mean climate’ which suggests that you are also taking the long-term trend into account, I suggest to write ‘fluctuations of the mean climate’ to make it clear that these are deviations from that long-term trend

Lines 397–399. Regarding the modes associated with currents, please refer to my previous comment on the use of bathymetry-based decomposition

Discussion

Section 4.2. Although there is a strong correlation between global warming and a decrease in LPUE, as well as an increase in the depth at which LPUE is at its maximum, I believe the authors should also highlight the rise in salinity and the decline in oxygen concentration (not documented here but a real phenomenon), whose current levels are approaching the tolerance thresholds of the Norway lobster. The average salinity of the intermediate water layer increased from 38.5 to 38.65 between 2010 and 2025 and is now approaching the 38.8 threshold, while oxygen levels decreased from 6.1 to 5.1 mg/L over the same period and are now below the 5.9 threshold. These two factors, whether considered separately or together, may be just as important – or even more so – than temperature, whose current values fall in the middle of the tolerance range.

Section 4.3. The time series you are analysing represents deviations from the long-term thermohaline trends that you have subtracted from your data. However, these trends are truely significant and have resulted in increases over three decades of approximately 1 °C in temperature and 0.15 g/kg in salinity. In your analysis, the mode 1 of temperature and salinity for the core of the intermediate waters (typically between 400 and 600 m depth) shows that this trend has been accelerating since 2014. I think you should also place greater emphasis in your analysis on the impact of long-term changes in environmental conditions. You briefly mention this in Section 4.6, where you note that climate projections predict an additional 1.5 °C increase in temperature between 2030 and 2052. How are these temperature trends, as well as those related to salinity and oxygen levels, likely to affect the dynamics of this species and others? In other word, I am trying to understand why the dynamics of this species, as observed through catches and landings, would be more sensitive to decadal fluctuations in environmental conditions, particularly temperature and salinity as noted in your work, than to long-term increases, which are even more pronounced.

Line 483. You can also refer to Houpert et al., 2016, Journal of Geophysical Research, doi: 1002/2016 JC011857

Lines 490–491. You hypothesize that increased stratification and reduced winter convection lead to a decrease in the flux of organic matter to deeper layers. I agree with this idea, but do you have any references to support it.

Lines 499–500. You are assuming that a slowdown in the slope current would result in less transport toward the seafloor. This argument remains vague. Could you elaborate on it?

Lines 516–524. This paragraph partly repeats arguments already presented in the previous section (the potential role of warming and the decrease in winter convection) and does not provide any further evidence. To strengthen these hypotheses, it would be interesting to present long-term time series covering the same period as the landings (i.e., between 1970 and 2024) showing the evolution of temperature and salinity in the intermediate waters, as well as the variability of winter convection (see, for example, the article by Somot et al., 2016, Climate Dynamics, doi: 10.1007/s00382-016-3295-0

Line 534–540. Once again, it may be necessary here as well to consider the effects of salinity and oxygen concentration, which might be more limiting for the ecological niche of the Norwegian lobster.

Line 546. You may refer to the work by Fos et al., 2025, *Ocean Science*, doi: 10.5194/os-21-2169-2025, which demonstrates that the reanalysis successfully reproduces observed intense dense shelf water cascading events in the Gulf of Lion. It might be worth applying an archetypal analysis – Cutler & Breiman, 1994, Technometrics, doi: 10.2307/1,269,949 – to your dataset.

Lines 543–548. The use of Empirical Orthogonal Functions – EOFs – on de-trended oceanographical variables is a robust choice for identifying dominant modes of natural variability, but authors themselves correctly note that the resulting modes ‘may not always be meaningful from a mechanistic point of view’. To further strengthen the interpretation of the oceanographic regimes affecting the Norway lobster, I suggest the authors consider, or at least discuss, the potential of Archetypal Analysis – AA – – Cutler & Breiman, 1994, Technometrics, doi: 10.2307/1,269,949 – .

AA could offer several advantages over the current EOF framework:

- Unlike EOFs, which represent statistical axes of variance that can be abstract, AA identifies archetypes which are extreme and representative states of the system located at the boundary of the data cloud. In this study, AA could define physical regimes such as a ‘convective/intensified current/colder state’ versus a ‘stratified/weaker current/warmer/saltier state’. This would align more closely with the two contrasting scenarios propose by the authors in Figure 9.

- Besides, EOFs force modes to be independent – orthogonal – . However, in the Mediterranean, changes in temperature, salinity, and current intensity are often coupled and non-linear. AA does not impose orthogonality, allowing it to better capture the actual co-variability of the environmental ‘envelope’.
- The study highlights a dramatic shift in landings and centroid depth since 2014. AA is particularly suitable to see how a system migrates between archetypal profiles over time. This might provide a clearer visualization of how the GSA 6 region has drifted away from the optimal conditions observed in the early 2010s.

Lines 585–586. Rather than speaking of ‘widespread warming and salinization at depth’ I would say that this is a ‘widespread acceleration of warming and salinization at depth,’ as this pattern is in addition to the long-term upward trend.