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The Effect of Temperature on Sepia officinalis in the Mediterranean Sea and the Libyan Coastal Strip Using the RCP4.5 Climate Scenario

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ABSTRACT

A heterogeneous pattern of changes in the distribution, growth, survival, and abundance of many aquatic ecosystems has been brought about by climate change. The Mediterranean Sea, recognised as one of the most vulnerable regions, is anticipated to become warmer and drier, with an increase in interannual variability. The goal of this research is to analyse how anticipated climate change affects the cephalopod *Sepia officinalis*. The RCP4.5 warming scenario dataset was utilised to evaluate the ecological productivity of this species over the period 2006–2085. Upon analysing the data, it became clear that populations of *S. officinalis* are increasing in the central Mediterranean opposite Libya, while decreasing in other parts of the basin. From 2006 to 2023, the population was relatively large, reaching approximately 1.5 $\times 10^8$, as temperatures during this period were more stable, ranging from about 10–23°C. In contrast, during the period 2024–2085, temperatures increased significantly to around 12–24°C, which correlated with a notable decrease in population size, dropping to approximately 3.2 $\times$ 10^7.5. A strong inverse relationship was found between temperature and *S. officinalis* abundance in both the eastern and western Mediterranean, with Pearson correlation coefficients of -0.911 and -0.822, respectively. These findings highlight the significant impact of rising temperatures on the abundance of *S. officinalis*. To safeguard these valuable marine resources, it is essential to implement effective adaptation and mitigation strategies to reduce the effects of climate change on fisheries.

تأثير درجة الحرارة على سيبيا (Sepia officinalis) في البحر الابيض المتوسط والشريط الساحلي الليبي باستخدام سيناريو المناخ RCP4.5

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الكلمات المفتاحية:
تغير المناخ.
البحر الأبيض المتوسط.
سيبيا *S. officinalis* .
درجة الحرارة.
مسار التركيز التمثيلي (*RCP4.5*).

الملخص

أدى تغير المناخ إلى نمط غير متجانس من التغيرات في توزيع ونمو وبقاء ووفرة العديد من النظم البيئية المائية. ومن المتوقع أن يصبح البحر الأبيض المتوسط، الذي يُعتبر من أكثر المناطق عرضة للخطر، أكثر دفئًا وجفافًا مع زيادة التقلبات السنوية. يهدف هذا البحث إلى تحليل كيفية تأثير تغير المناخ المتوقع على رأسيات الأرجل *S. officinalis*. وقد استُخدمت مجموعة بيانات سيناريو الاحترار RCP4.5 لتقييم الإنتاجية البيئية لهذا النوع خلال الفترة 2006-2085. وعند تحليل البيانات، اتضح أن أعداد أفراد *S. officinalis* تتزايد في وسط البحر الأبيض المتوسط مقابل ليبيا، بينما تتناقص في بقية أجزائه. في الفترة من 2006-2023، كانت أعداد *S. officinalis* كبيرة، حيث وصلت إلى 15 E7، لأن درجات الحرارة في هذه الفترة تُعتبر أقل تقلبًا بحوالي 10-23 درجة مئوية مقارنة بالفترة 2024-2085، حيث كان الارتفاع ملحوظًا بحوالي 12-24 درجة مئوية، وبالتالي أثرت درجة الحرارة على أعداد *S. officinalis*، حيث انخفضت بحوالي 11 E7.5. في هذه الفترة

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نجد علاقة عكسية قوية في شرق وغرب البحر الأبيض المتوسط، مع العلم أن البحر يتميز بانخفاض درجات الحرارة في غربه عنها في شرقه، ومن هنا يتضح لنا أنه كلما ارتفعت درجة الحرارة، قل عدد *S. officinalis*، وكان معامل ارتباط بيرسون حوالي -0.911 و-0.822 في الشرق والغرب على التوالي. ولها تأثيرات واضحة على وفرة *S. officinalis*. وينبغي الحد من آثار تغير المناخ على موارد الصيد هذه قدر الإمكان من خلال تنفيذ استراتيجيات التكيف والتخفيف المناسبة.

1. Introduction

The distribution of marine fish and invertebrates shifts in response to ocean warming, typically moving towards deeper waters and higher latitudes [1]. Climate change (CC) can affect biological systems at multiple levels, including individual organisms, populations, and entire ecosystems. It particularly impacts species with limited dispersal abilities and may cause local extinctions, thereby further reducing biodiversity.

The Mediterranean Sea is considered one of the most vulnerable regions to global climate change, partly due to its geographic position between the arid zone of North Africa and the temperate climate of central Europe [1–3]. Extreme heat and drought events are expected to result in a warmer and drier Mediterranean climate, with greater interannual variability [3–5]. Although this warming trend likely affects the entire basin, most data available focuses on the north-western Mediterranean [6].

Notable mass mortality events involving sponges, gorgonians, bryozoans, and molluscs were recorded during temperature anomalies in the summers of 1999 and 2003 [7–9]. Without effective management plans, the declining state of Mediterranean fisheries is projected to deteriorate further, especially under the pressures of climate change [4].

The catch composition of crustacean fisheries in the region includes deep-water rose shrimp, giant red shrimp, blue crab, caramote prawn, Norway lobster, blue and red shrimp, and mantis shrimp. Cephalopod fisheries include common octopus, common squid, common cuttlefish, and *Eledone* spp. [10]. However, the dataset titled *"Fish abundance and catch data for the Northwest European Shelf and Mediterranean Sea from 2006 to 2098 derived from climate projections"* in the Copernicus EU database does not contain any of the listed crustacean species [11].

A recent study examined the effects of climate change represented by increased Sea Surface Temperature (SST) on the abundance and fisheries catch of marine invertebrates. This study was motivated by satellite data showing a steady rise in Mediterranean SST over recent decades and an increase in reports of mass mortalities among benthic marine invertebrates during the same period [12].

Libya, a nation bordering the Mediterranean Sea, will be affected by these changes. Its marine fisheries are especially vulnerable due to the combined impact of climate change and illegal practices such as overfishing and overexploitation. The main objective of this research is to evaluate the projected effects of climate change on the abundance and catch of the common cuttlefish (*Sepia officinalis*), a key marine invertebrate.

The common cuttlefish is a nektobenthic species inhabiting shallow coastal waters up to 200 metres deep. Its natural range spans the northeast Atlantic (from the Baltic Sea to the Mediterranean and south to the Mauritania Senegal boundary) [13]. Statistically, it is one of the most heavily fished cephalopods. Libya, with its 2,000 km coastline along the Mediterranean, has a comparatively large and socioeconomically important fishing sector that provides employment in many coastal communities. The most significant segments of Libyan fisheries are marine and coastal fisheries, categorised into professional artisanal and industrial operations. Libyan waters are home to many of the Mediterranean's commonly targeted marine resources.

2. Area of Study

The study area is the Mediterranean Sea, located between latitudes 30° and 45.5°N, and longitudes -5° to 36°E, as shown in Figure 1.

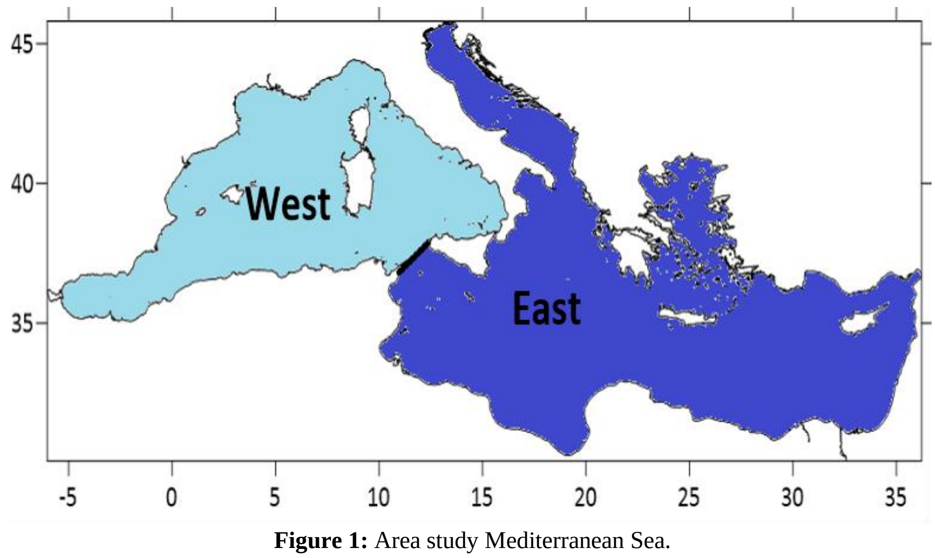

Figure 1: Area study Mediterranean Sea.

3. Data Source

The study used annual average for number of *S. officinalis* is and take annual average for temperature (C°) using climate scenario RCP4.5 (Representative Concentration Pathway) has been defined RCP4.5 is described by the IPCC as an intermediate scenario between RCP2.6 and RCP8.5 [5], for period 2006-2085. The data were obtained via the Climate Data Store – Copernicus (www.cds.climate.copernicus.eu).

4. Data Analysis for Distributions of S. Officinalis on the Space and Time

Climate change has become evident in the oceans, centered on biological changes in the Mediterranean Sea in terms of rising temperatures and increasing amounts of carbon dioxide, which will cause ocean acidification in the future [14]. When analyzing one species of *S. officinalis* in the Mediterranean Sea with temperatures using the RCP4.5 scenario for the period 2006-2085, and dividing the period into two periods 2006-2023 and 2024-2085, we notice that in the first period the temperatures in the western Mediterranean region are colder than the eastern Mediterranean, as It is a well-known [15], shown in Figure (2, c), which shows the average annual temperature. The increase in the eastern Mediterranean reached 23 C° and in the western Mediterranean it reached about 10 C°, during the period 2006-2023, while during the period 2024-2085, it was found that there was a clear increase in temperature, reaching between 12-24 C°, as shown in Figure (2, d). In contrast, the annual average number of *S. officinal*is was analyzed, and it became clear that there are large numbers of them concentrated in the central Mediterranean, reaching 15. E7 versus the Libyan beaches , as shown in Figure (2, a), but in smaller numbers in various parts of the Mediterranean Sea during the period 2006-2023, and this decrease appeared to coincide with the rise in temperatures and was evident during the period 2024-2085, where its highest value reached 11.5 E7 See Figure (2, b).

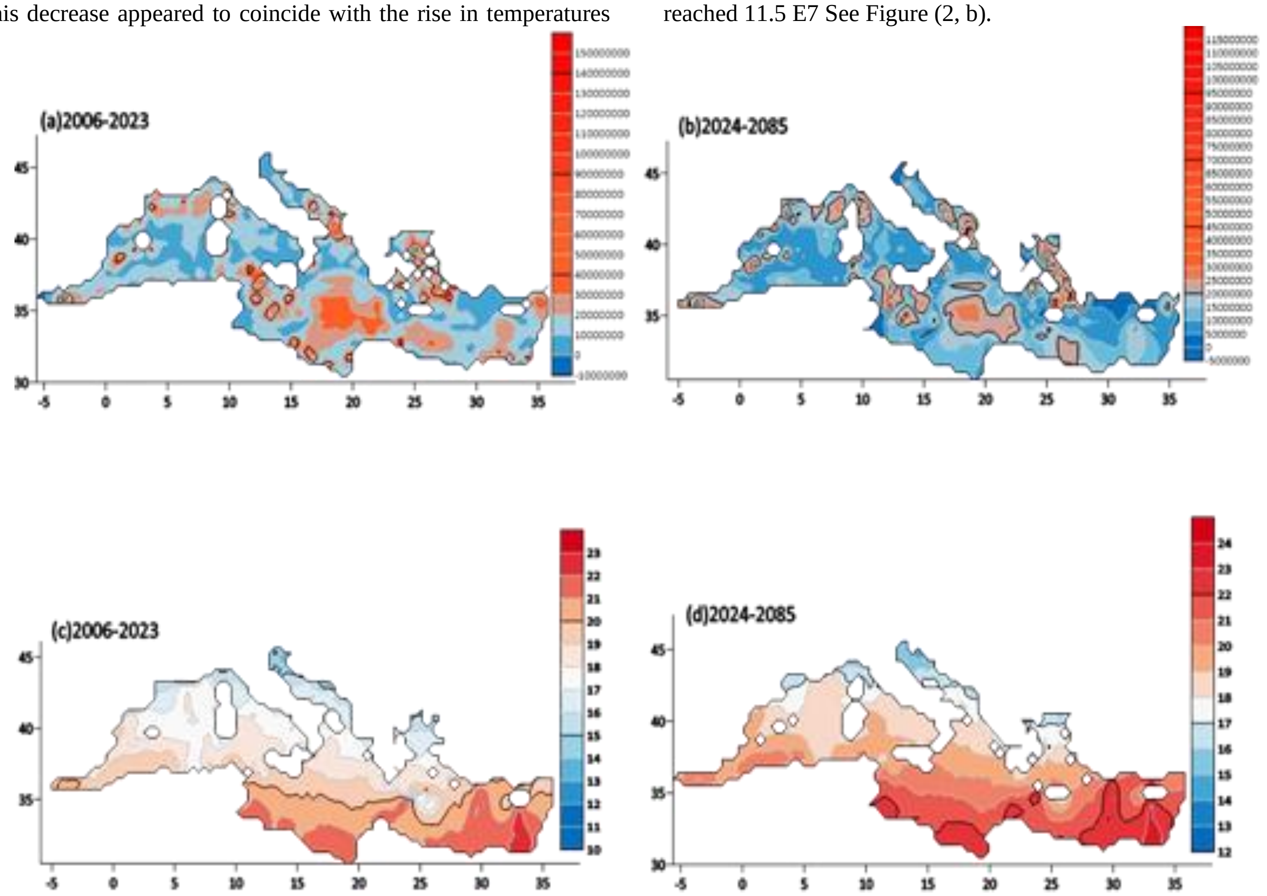

Figure 2: Effects of the temperatures on distributions of species *S. officinalis* (a,b) and Average annual of temperature (C°) (c,d) for the periods 2006-2023 and 2024-2085 - scenario RCP4.5.

The statistical methods show us a strong inverse relationship in the eastern and western Mediterranean. Figure .3 show time series, (a) average annual of the temperature (C°), while (b) average annual of the number of *S. officinalis*, for the period 2006-2085 - scenario RCP4.5.

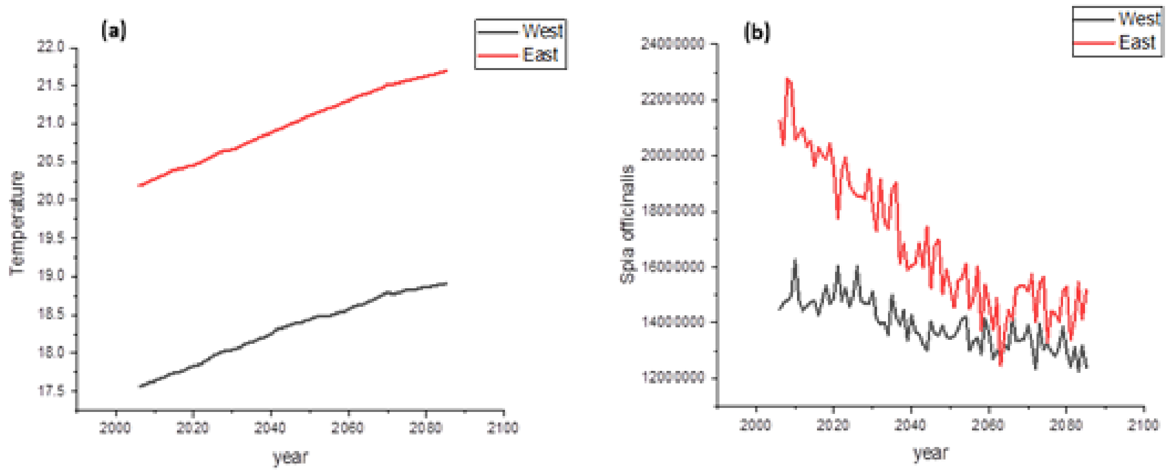

Figure 3: Time series, (a) average annual of the temperature (C°), (b) average annual of the number of *S. officinalis*, for the period 2006-2085 - RCP4.5.

5. Results and Discussion

In the current study, statistical techniques were employed to clarify the relationship between sea temperature and the abundance of *Sepia officinalis* under the RCP4.5 climate scenario. The analysis aimed to determine the type and strength of this relationship across the eastern and western Mediterranean regions. As shown in Table 1, Pearson correlation coefficient analysis revealed a strong inverse correlation between sea temperature and *S. officinalis* abundance in both areas, with values of -0.911 in the eastern Mediterranean and -0.822 in the western Mediterranean.

Table 1: Pearson correlation coefficients between sea temperature and *S. officinalis* abundance in the eastern and western Mediterranean.

	***S. officinalis* East Mediterranean**	***S. officinalis* West Mediterranean**
Number of Points	80	80
Degrees of Freedom	78	78
Residual Sum of Squares	8.12543E13	2.03793E13
Pearson's r	- 0.91155	- 0.82262
R-Square (COD)	0.83092	0.6767
Adj. R-Square	0.82875	0.67256

The percentage impact of temperature, the independent variable, on *S. officinalis*, the dependent variable, is 0.828 and 0.672 for the east and west Mediterranean, respectively, as shown in the above table. This indicates that *S. officinalis* is affected by temperature in the east and west Mediterranean by (82.8% and 67.2%), respectively. The percentage change in the dependent variable and the extent to which it can be independently predicted are ascertained using the correlation coefficient R square. After that, temperature was considered independent variable and S. officinalis a dependent variable in order to examine the effect of temperature on *S. officinalis*. Data from the two variables were analysed using a straightforward method for the years 2006 to 2085. In order to determine the significance of the model's quality, we used analysis of variance. Because we observed a linear relationship and a level of significance for F that is less than 0.05, which indicates that the independent and dependent variables are related and that the regression model is significant, therefore we reject the null hypothesis and accept the alternative hypothesis that the model an important statistic and whose results can be relied upon, see Table 2, 3.

Table 2: Parameters to determine the significance of the model's quality, used analysis of variance.

		Value	Standard Error	t-Value	Prob>|t|
S. officinalis East Mediterranean	Intercept	1.19327E8	5239191.80944	22.77582	3.31311E-36
	Slope	- 4885653.56113	249540.95751	-19.57856	7.74848E-32
S. officinalis West Mediterranean	Intercept	4.66778E7	2540645.96023	18.37243	4.61246E-30
	Slope	-1772336.86722	138708.65822	-12.77741	8.15379E-21

Slope is significantly different from zero (See ANOVA Table).
At the 0.05 level, the slope is significantly different from zero.

Table 3: ANOVA.

		DF	Sum of Squares	Mean Square	F Value	Prob>F
S. officinalis East Mediterranean	Model	1	3.99313E14	3.99313E14	383.32016	7.7485E-32
	Error	78	8.12543E13	1.04172E12		
	Total	79	4.80567E14			
S. officinalis West Mediterranean	Model	1	4.26559E13	4.26559E13	163.26211	8.15379E-21
	Error	78	2.03793E13	2.61273E11		
	Total	79	6.30352E13			

In the Figure 4 shows the relationship between the two variables and the strength of the inverse relationship between them.

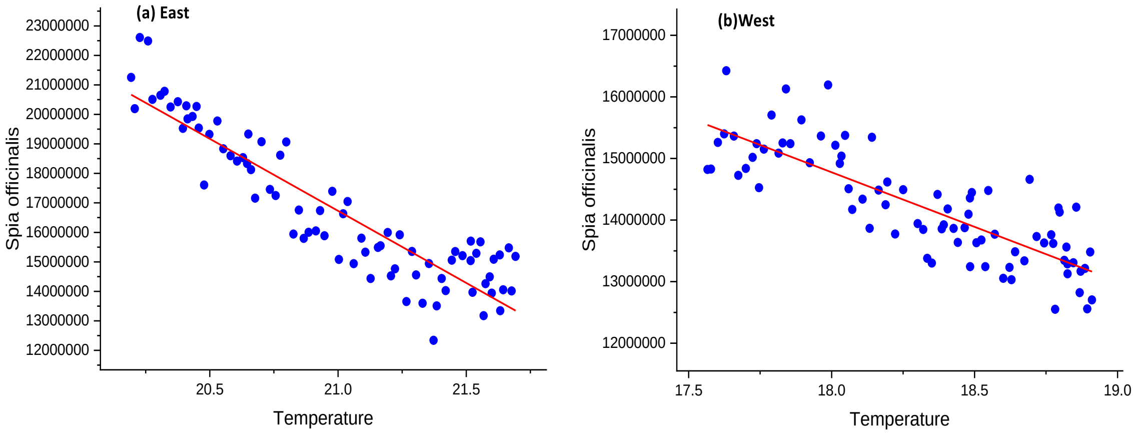

Figure 4: Scatterplot of number of *S. officinalis* and temperature (C°).

Table.4 shows locations of distribution *S. officinalis* for longitude and latitude opposite the Libyan coast. Where it was highest abundance (7.34E+07) at longitude and latitude (16.30LAT and 32.22LON), of the western coast of Libya during the time period 2006 to 2923. While it was the least at the longitude and latitude (19.67LAT and 31.80LON), it was (1.02E+08) for the same period of time. When we compare with the time period of 2924 to 2085; we find decrease in abundance. It was that the highest concentration of *S. officinalis* is found at longitude and latitude (15.36LAT and 32.62LON); it was (9.23E+07). While it was the least decreasing at the longitude and latitude (18.22LAT and 31.37LON) was (3.96E+07). This shows the most important concentration of abundance from the presence of *S. officinalis* and the extent of the impact of climate change on it during the period from 2006 to 2085 as shows in (Figure 5).

Table 4: Location of distribution of *S. officinalis* opposite the Libyan coast.

LAT	LON	2006-2023	2024-2085
15.36	32.62	1.17E+08	9.23E+07
16.30	32.22	7.34E+07	5.41E+07
16.77	31.82	1.08E+08	8.43E+07
17.71	31.35	6.60E+07	4.81E+07
18.22	31.37	5.33E+07	3.96E+07
19.67	31.80	1.02E+08	8.51E+07

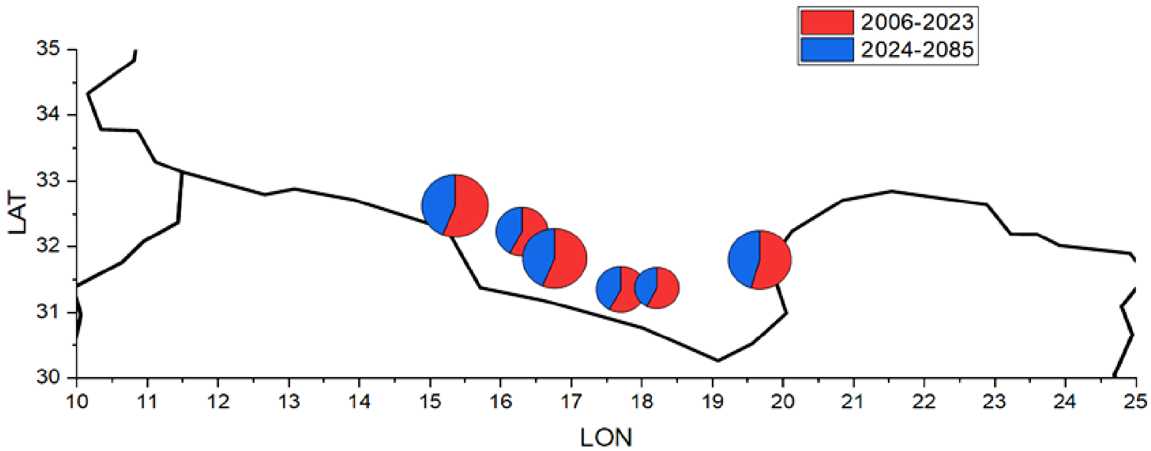

Figure 5: Location of distribution of *S. officinalis* versus the Libyan coastal strip. (Red high abundance and blue low abundance locations).

6. Conclusion

To calculate the biomass and distribution of *Sepia officinalis* in response to environmental changes, the Size Spectra–Dynamic Bioclimate Envelope Model was utilised. This model accounts for the effects of both human activity and environmental variation. The status of common cuttlefish stocks was assessed under a single climate scenario using Representative Concentration Pathways (RCPs) to evaluate the impact of climate change.

Using the RCP4.5 scenario, which includes projections of temperature and data on *S. officinalis* from the period 2006–2085, the analysis revealed an increase in *S. officinalis* abundance in the central Mediterranean opposite Libya, while a decrease was observed in other parts of the basin. Between 2006 and 2023, the population was relatively high, reaching approximately 1.5×10^8 individuals, as temperatures during this period were less variable, ranging from about 10–23°C. In contrast, during 2024–2085, temperatures rose significantly to around 12–24°C, correlating with a population decline to around 3.2×10^7 individuals.

Statistical analysis confirmed a strong inverse relationship between sea temperature and *S. officinalis* abundance in both the eastern and western Mediterranean, where the Pearson correlation coefficients were -0.911 and -0.822, respectively. The sea is generally cooler in the west than in the east, supporting the finding that higher temperatures negatively affect *S. officinalis* populations.

Regarding spatial distribution, the highest abundance was recorded off the Libyan coast (7.34×10^7 individuals) at 32.22°N, 16.30°E during 2006–2023. In comparison, the lowest recorded abundance during 2024–2085 was 3.96×10^7 individuals at 31.37°N, 18.22°E. These findings indicate that *S. officinalis* distribution is highly sensitive to sea temperature increases, highlighting the impact of climate change over the examined period.

The analysis demonstrates that both fishing management strategies and rising sea surface temperatures have significant but distinct effects on species abundance and fisheries yield. To protect these critical marine resources, it is essential to implement appropriate adaptation and mitigation strategies to minimise the impacts of climate change.

7. Recommendations

1. Monitor and collaborate with international organisations that issue annual warnings about rising sea temperatures and natural climate phenomena that adversely affect marine life.

2. **Ensure marine climatology specialists** play a key role in raising public awareness about pollutants affecting the marine environment.

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Data Availability Statement: The climatic data used in this research paper were obtained from Copernicus Climate Data Store.

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9. References

[1] - Cheung, W., Watson, R. Pauly, D. (2013). Signature of ocean warming in global fisheries catch. Nature, 497: 365–368.

[2] - Boero, F., Fe´ral, J.P., Azzurro, E., Cardin, V., Riedel, B. (2008). Climate warming and related changes in Mediterranean marine biota. In: Briand F, editor. Climate Warming and Related Changes in Mediterranean Marine Biota: CIESM Workshop Monographs N˚ 35. Monaco. pp. 5– 21.

[3] - Briand, F. (Ed.). (2008). Climate warming and related changes in Mediterranean marine biota. In CIESM Workshop Monographs (No. 35). CIESM, Monaco.

[4] - Change, I. C. (2013). The physical science basis.

[5] - IPCC Climate Change (2013). The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2013. p. 1535

[6] - Lejeusne, C., Chevaldonné, P., Pergent-Martini, C., Boudouresque, C. F., and Pérez, T. (2010). Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends in ecology and evolution*, *25*(4), 250-260. *https://doi.org/10.1016/j.tree.2009.10.009*

[7] - Rodolfo-Metalpa, R., Bianchi, C. N., Peirano, A., and Morri, C. (2005). Tissue necrosis and mortality of the temperate coral Cladocora caespitosa. *Italian Journal of Zoology*, *72*(4), 271-276. *https://doi.org/10.1080/11250000509356685*

[8] - Giorgi, F., and Lionello, P. (2008). Climate change projections for the Mediterranean region. *Global andplanetary change*, *63*(2-3), 90-104. *https://doi.org/10.1016/j.gloplacha.2007.09.005*.

[9] - Bensoussan, N., Romano, J. C., Harmelin, J. G., and Garrabou, J. (2010). High resolution characterization of northwest Mediterranean coastal waters thermal regimes: to better understand responses of benthic communities to climate change. *Estuarine, Coastal and Shelf Science*, *87*(3), 431-441. *https://doi.org/10.1016/j.ecss.2010.01.008*.

[10] - Martín-Vélez, V., and Abellán, P. (2022). Effects of climate change on the distribution of threatened invertebrates in a Mediterranean hotspot. Insect Conservation and Diversity, 15(3), 370-379. *https://Doi.org/10.1111/icad.12563*

[11] - Bakiu, R. (2022). Expected Climate Change Effects on Common Cuttlefish (*Sepia officinalis*) and Brown Shrimp (*Crangon crangon*) Abundance and Catch in Albanian Waters.

[12] - Rivetti, I., Fraschetti, S., Lionello, P., Zambianchi, E., and Boero, F. (2014). Global warming and mass mortalities of benthic invertebrates in the Mediterranean Sea. *PloS one*, *9*(12), e115655. *https://doi.org/10.1371/journal.pone.0115655*

[13] - Guerra, Á., Hernández-Urcera, J., Garci, M. E., Sestelo, M., Regueira, M., Gilcoto, M.,and González, Á. F. (2016). Spawning habitat selection by the common cuttlefish Sepia officinalis in the Cíes Islands (Northwest Spain). *Fisheries research*, *183*, 44-54. *https://doi.org/10.1016/j.fishres.2016.04.023*

[14] - Ben-Miloud, H. M., and Ali, A. A. (2021). Impact of carbon dioxide (CO^2) on Mediterranean temperature using CMIP[5] climate model. Solar Energy and Sustainable Development Journal, 10(2), 1-12. Vol. 10 No. 2 (2021): JSESD

[15] - Shaltout, M., and Omstedt, A. (2014). Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. *Oceanologia*, *56*(3), 411-443. *https://doi.org/10.5697/oc.56-3.411*