SEBHA UNIVERSITY JOURNAL OF PURE & APPLIED SCIENCES VOL.24 NO.3 2025
DOI: 10.51984/JOPAS.V24I3.3613

مجلة جامعة سبها للعلوم البحتة والتطبيقية
Sebha University Journal ofPure & Applied Sciences

Journal homepage: http://www.sebhau.edu.ly/journal/jopas

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

*Najla Mohamed Abushaala[1] and Haifa. M. Ben-Miloud[2]

[1]Department of Zoology, Faculty of Science, University of Tripoli, Libya.
[2]Department of Atmospheric Science, Faculty of science. University of Tripoli, Libya

Keywords:
Climate change,
Mediterranean Sea,
Sepia officinalis,
Temperature,
Representative Concentration Pathway (RCP4.5)

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 1.5×10^8, 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 3.2×10^7.5. 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.

تاثير درجة الحرارة على سيبيا (*Sepia officinalis*)في البحر الابيض المتوسط والشريط الساحلي الليبي باستخدام سيناريوالمناخ RCP4.5

*نجلاء محمد أبو شعالة[1] و هيفا بن ميلود[2]

[1]قسم علم الحيوان، كلية العلوم، جامعة طرابلس، ليبيا.

[2]قسم علوم الغلاف الجوي، كلية العلوم، جامعة طرابلس، ليبيا.

الكلمات المفتاحية:
البحر الأبيض المتوسط
تغير المناخ
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 نجد علاقة عكسية قوية في شرق وغرب البحر الأبيض المتوسط، مع العلم أن البحر يتميز بانخفاض درجات الحرارة في غربه عنها في شرقه،

*Corresponding author:
E-mail addresses: na.abushaala@uot.edu.ly,(H. M. Ben-Miloud) regcm00@Yahoo.com.
Article History : Received 14 October 2024 - Received in revised form 20 July 2025 - Accepted 27 July 2025

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 fishes and invertebrates moves in response to ocean warming, usually to deeper waters and higher latitudes [1]. A variety of biological levels, including the individual, population, and ecosystem, may be impacted by climate change (CC). Climate change, in particular, has a significant impact on species with limited dispersal abilities. It may also cause local extinctions, which would further reduce biodiversity. The Mediterranean Sea appears to be among the most vulnerable places to global climate change, partly because of its geographic location between the arid environment of northern Africa and the temperate climate of central Europe [1, 2, 3]. Extreme heat and drought events are predicted to cause the Mediterranean climate to warm and dry, with an increase in inter-annual variability [3, 4, 5]. Despite the fact that this warming trend most likely affects the entire Mediterranean Sea, data on these phenomena are primarily reported for the north-western Mediterranean [6]. Sponge, gorgonians, bryozoans, and molluscs were among the many species that perished in catastrophic mass deaths caused by Mediterranean temperature anomalies that were recorded in the summers of 1999 and 2003 [7, 8, 9]. The Mediterranean Sea's declining fisheries and their resources are expected to get worse in the absence of effective management plans, particularly in light of climate change [4]. The catch composition of the crustacean fisheries comprises deep-water rose shrimp, giant red shrimp, blue crab, caramote prawn, Norway lobster, blue and red shrimp, and Mantis shrimp, while the cephalopod fisheries include common octopus, common squid, common cuttlefish, and Eledone spp [10]. Unfortunately, the dataset titled Fish abundance and catch data for the Northwest European Shelf and Mediterranean Sea from 2006 to 2098 derived from climate projections" that can be found in the Copernicus EU database does not contain any of the listed species of crustaceans [11]. A study was carried out to demonstrate the effects of climate change, here represented by an increased Sea Surface Temperature (SST), on the abundance and fisheries catch of each species, representing the marine invertebrates, based on the facts that satellite data show a steady increase in the last decades of the Mediterranean Sea's surface temperature (upper few millimeters of the water surface) and reports of mass mortalities of benthic marine invertebrates increased in the same period [12].

Libya, one of the nation's bordering the Mediterranean Sea, will be affected by all of these factors, and marine fisheries will be particularly susceptible due to the combined effects of climate change and illicit fishing practices (overfishing and overexploitation of marine resources). The primary objective of this research is to examine the anticipated impacts of climate change on the quantity and capture of common cuttlefish (*S. officinalis*), a representative invertebrate species. The common cuttlefish is a nektobenthic species that lives in shallow coastal waters up to 200 meters deep. Its range in the Northeast Atlantic Ocean includes the Baltic Sea, the Mediterranean Sea, and the border between Mauritania and Senegal [13]. Based on statistical data, this species is one of the most frequently fished cephalopods. Libya is a country with a 2000 km coastline that looks out over the Mediterranean Sea. Libya's comparatively large fishing industry is noteworthy from a socio-economic perspective because it provides a sizable number of jobs in coastal areas. The most significant sub-sectors of the national fisheries are the marine and coastal fisheries. Libyan waters are home to common Mediterranean supplies of marine resources. Professional artisanal and professional industrial fisheries are the two categories of marine fisheries in Libya.

2. Area study

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

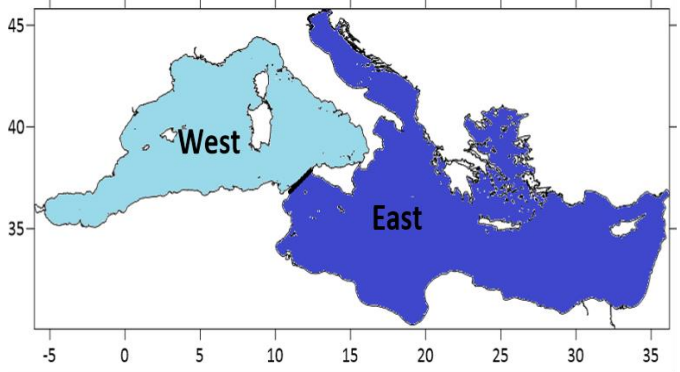

Figure 1. Area study Mediterranean Sea.

2. 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).

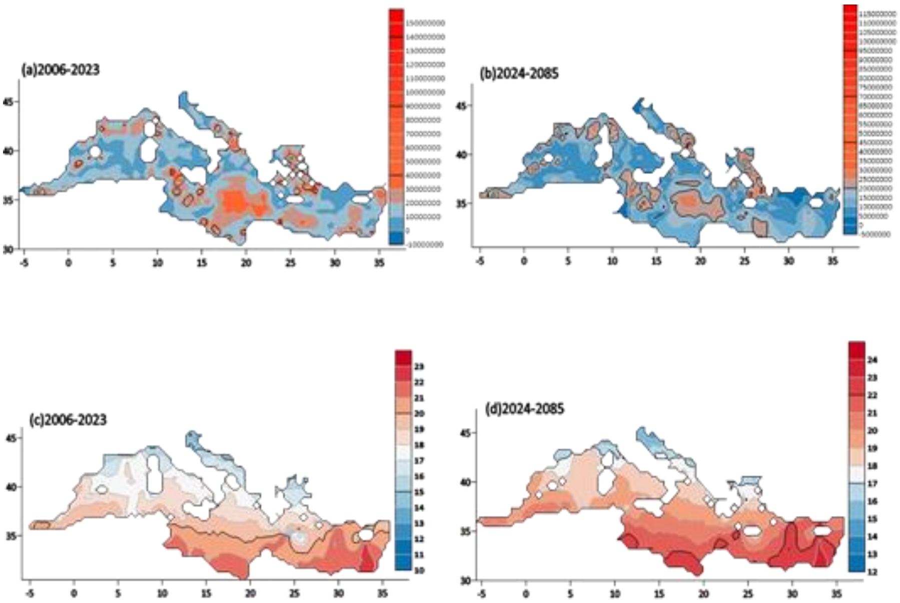

Figure 2. Effects of the temperatures on distributions of species *S. officinalis* (a,b) and Average annual of temperature (C°) (c,d) for the periods 2006-2023 and 2024-2085 - scenario RCP4.5.

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.

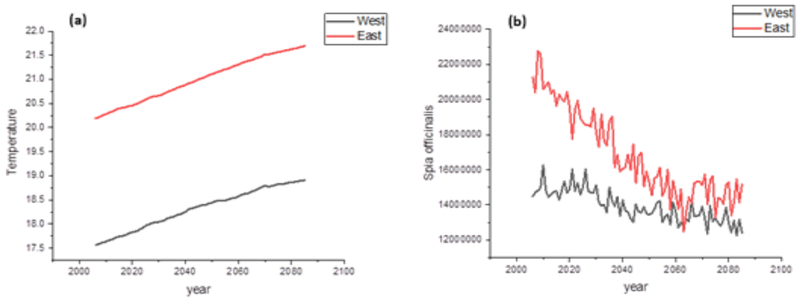

Figure 3. Time series, (a) average annual of the temperature (C°), (b) average annual of the number of *S. officinalis*, for the period 2006-2085 - RCP4.5.

5. Results and Discussion

In the current study, statistical techniques were used to provide clarification. To determine the type and strength of the relationship, for the RCP4.5 climate scenario, between each temperature variable (C°) and the quantity of *S. officinalis* in Mediterranean. Table 1 Pearson correlation coefficient analysis shows a strong inverse correlation between temperature and *S. officinalis* in east and west Mediterranean, with values of (-0.911) and (-0.822) respectively.

Table 1 Pearson correlation coefficient analysis between temperature and *S. officinalis* in east and west 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. Determine the significance of the model's quality, by using ANOVA analysis.

		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.

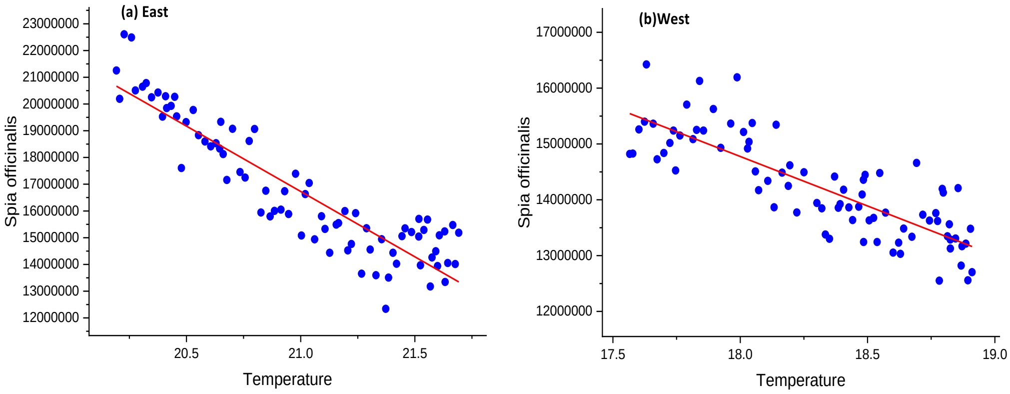

Figure 4. Scatterplot of number of *S. officinalis* and temperature (C°).

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

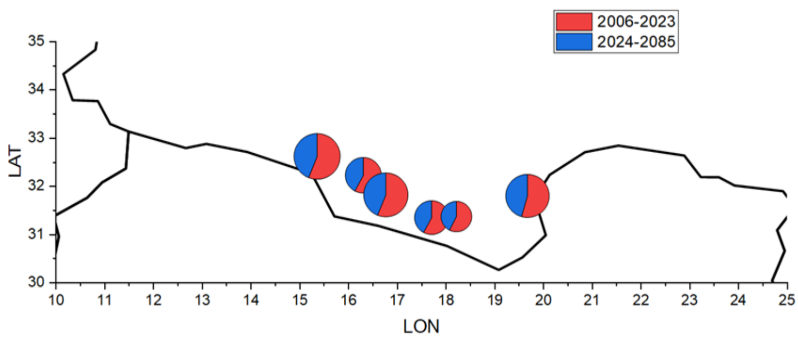

Figure 5. Location of distribution of *S. officinalis* versus the Libyan coastal strip. (Red high abundance and blue low abundance locations).

6. Conclusion

In order to calculate the biomass and distribution of these species in response to environmental changes, the Size Spectra–Dynamic Bioclimate Envelope Model model was utilized, which takes into consideration the effects of both human activity and environmental changes. The state of common cuttlefish stocks was established in one climate scenario based on different Representative Concentration Pathways in order to evaluate the impact of climate change. Using the RCP4.5 climate scenario for the factor's temperature and *S. officinalis* from the period 2006-2085, and upon analyzing the data it became clear that the numbers of S. officinal are increasing in the central Mediterranean opposite Libya, but they are decreasing in numbers in the rest of the Mediterranean. In the period from 2006-2023, the numbers of *S. officinalis* were large, reaching 15 E7, because the temperatures in this period are considered less variable by about 10-23C° compared to the period 2024-2085, where the increase was noticeable by about 12-24 C°, and consequently the temperature affected the numbers of *S. officinalis*, which decreased by about 11 E7.5. in this period. By calculating statistical methods, we find a strong inverse relationship in the eastern and western

Mediterranean, knowing that the sea is characterized by lower temperatures in its west than in its east, and from here it becomes clear to us that the higher the temperature, the lower the number of *S. officinalis*, and the Pearson correlation coefficient was about -0.911 and -0.822 in the East and West, respectively. And the locations of distribution *S. officinalis* for longitude and latitude opposite the Libyan coast. Where it was highest abundance (7.34E+07) at (16.30LAT and 32.22LON), of the western coast of Libya during the time period 2006 to 2923. When we compare with the time period of 2924 to 2085; we find decrease in abundance. While it was the least decreasing at the (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.

It is demonstrated that the impacts of fishing management strategies and climate change (an increase in sea surface temperature) have distinct effects on the abundance of each species and the amount of fisheries harvest. The effects of climate change on these fishing resources should be reduced as much as possible by implementing appropriate adaptation and mitigation strategies.

7- Recommendations

1- Follow up on international organizations that meet annually and warn of rising sea temperatures resulting from natural climate phenomena, which negatively impact marine life.

2- The state should ensure that specialists in marine climatology raise awareness of pollutants occurring in the marine environment.

Author Contribution: The authors were responsible for writing the research paper and analyzing the data.

Funding: This research received no financial support.

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

8. Acknowledgments

We are grateful to the Copernicus services for providing us with high-quality data to cover the event in a distinguished manner. We also thank all of the contributors for their hard work.

Special thanks and appreciation to the anonymous reviewers for their helpful comments and revisions.

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