*Natural Resources Conservation and Research (2023) Volume 6 Issue 1*
doi:10.24294/nrcr.v6i1.1961

**Original Research Article**

# The effects of climate changes on *Posidonia oceanica* meadows in the Mediterranean Basin

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## ABSTRACT

Climate changes are affecting the fate of *Posidonia oceanica* meadows. Actually, the Mediterranean Sea is threatened by abiotic, biotic and climate changes coupled with human pressures regarding coastal regions. In this way, *Posidonia oceanica* is able to counteract the effects of climate changes through the high thermotolerance of the species, range shift processes of the meadows and variations in the community composition of this valuable marine ecosystem. Anyway, the power of acclimatization to temperature shifts and the adaptative capacity of *Posidonia oceanica* meadows against human pressures let to suggest a positive trend in the long evolutionary pathway of the species.

***Keywords:*** Climate Changes; *Posidonia Oceanica* Meadows; Thermotolerance; Adaptative Process

**ARTICLE INFO**

Received: 23 February 2023
Accepted: 23 April 2023
Available online: 5 May 2023



## 1. Introduction

The exploitation of coastal resources, marine pollution and biological invasions, coupled with climate changes, impact marine biodiversity at all levels of organization from genes, to species and populations, up to ecosystems, affecting also mankind[1–7]. The Paris Agreement, adopted by 196 Parties on 12 December 2015, was established to limit global warming below 2 °C compared to pre-industrial levels[8]. Really, scientific literature has foreseen serious modifications in Mediterranean biodiversity with the highest thermic levels, actually ongoing[9]. Historically, the Mediterranean Sea (**Figure 1**) is a complex set of marine ecosystems enriched by endemic species that are, nowadays, exposed to increasing human pressure[10–12] that could lead, in time, to species extinction[9].


**Figure 1.** Map of the Mediterranean Sea (drawn by Internet at: mitvim.org.it).

This study focuses on biological adaptations of *Posidonia oceanica* meadows according to the general definition of adaptation issued by the Intergovernmental Panel on Climate Change (IPCC) as "the process of adjustment to actual or expected climate change and its effects"[13]. Generally speaking, adaptation is a process able to mitigate ecosystem modifications and the risk of species extinction in the Mediterranean Sea[14,15]. For such purposes, it is discussed about the potential of adaptative capacity to climate changes of *Posidonia oceanica* meadows.

## 2. Methods

This paper starts with an in-depth study of scientific articles regarding the following keywords: sea temperature, salinity, pH, carbon dioxide, coastal urbanization and *Posidonia oceanica* meadows. In this way, it is realized a global overview of all international studies about these topics, published by Scopus until 31 December 2022. After an analytical review of the papers, deleting duplications and "grey literature", a total of 50 articles are selected, so to provide information about the effects of climate changes on *Posidonia oceanica* meadows in Mediterranean coastal waters. The resulting data, deriving from the research, are organized into three sections giving a better explanation of the results. The first step describes the main drivers as abiotic and climate changes occurring in Mediterranean coastal waters. The second stage regards the biotic factors threatened by climate changes, analyzing the buffering potential of *Posidonia oceanica* meadows, to highlight the more important determinants of the adaptative process. Finally, the third section discusses the main human pressures, especially coastal urbanization, affecting littoral regions.

## 3. Results and discussions

It is discussed the potential of the adaptive capacity of the species to counteract climate changes affecting *Posidonia oceanica* meadows. So, it is analyzed the historical and projected trends of the most important environmental changes caused by climate, biotic and human variables in the Mediterranean Sea (**Table 1**).

**Table 1.** Historical data and projections on abiotic, biotic and human variables linked to climate and social changes (from Reference [16], modified)

| Climate, biotic and human variables | Historical data | Projections |
|---|---|---|
| Temperature | Surface water mean +0.37 °C/decade<br>Range of local data +0.09 °C/+0.61 °C | +0.22 °C/decade<br>Range +0.21 °C/+0.26 °C |
| | Upper water mean +0.03 °C/decade<br>Range of local data +0.008 °C/0.26 °C | Order of +0.2 °C<br>Order of +0.2 °C |
| | Intermediate water mean +0.26 °C/decade<br>Range of local data +0.21 °C/+0.67 °C | Order of +0.1 °C<br>Order of +0.1 °C |
| | Deep water mean +0.038 °C/decade<br>Range of local data +0.035 °C/+0.04 °C | Order of +0.01 °C<br>Order of +0.01 °C |
| Extreme heat waves | Increase of marine frequency and duration | Increasing trend |
| Salinity | No clear trend | No clear trend |
| Sea level rise | +1.2 cm/decade | Range +1.2 cm/+8.0 cm |
| pH | Order of –0.01/decade | Order of –0.02/decade |
| *Posidonia oceanica* meadows | Regression of –35%<br>Range of local data –13%/–50% | Regression of –75%<br>Range –70%/–80% |
| Coastal urbanization | +6.00%/decade | +3%/decade |

### 3.1 Abiotic factors

The Mediterranean Sea is a semi-enclosed basin with a thermohaline circulation inducing a tight relationship between physical and chemical conditions[17]. In fact, Mediterranean seascape is characterized by climate gradients for some abiotic factors. The general water circulation into the basin emphasizes strong differences in temperature, salinity and pH between the Eastern and the Western regions of the basin[18]. Then, it is summarized the trend of the most important abiotic factors in Mediterranean waters.

#### 3.1.1 Sea temperature

Actually, the rate of sea temperature increase of

+0.20 °C/decade and the projected rate of +0.22 °C could lead to adaptative mechanisms in *Posidonia oceanica* species. Indeed, apart from the general warming conditions of the Mediterranean Sea, the potential marine heat waves, becoming longer and more frequent in the next decades[19], could lead to the disappearance of some sessile species, including *Posidonia oceanica*[20]. In these conditions, the high capacity of the species to counteract the present state of thermal stress, linked to its acclimatization to temperature shifts, is the keyword to overcome the effects of climate changes.

### 3.1.2 Marine salinity

In Mediterranean waters, the abiotic factor of salinity shows no clear trend (**Table 1**) except in the Adriatic Sea and in the Levantine Basin where a slight rise in the salinity level is observed[21,22]. In this way, some scientific studies have highlighted that possible increases in marine salinity could reduce the process of leaf growth in Mediterranean seagrass species[23].

### 3.1.3 Sea Level Rise (SLR)

SLR is, actually, very slightly into the basin with a mean of +1.2 cm/decade but it shows a worrying increasing trend of +1.2 cm/+8.0 cm in the next decades as it is shown in **Table 1**. Soon, this abiotic factor could affect coastal ecosystems, such as *Posidonia oceanica* meadows while other plant communities, living in brackish waters, are already impacted by drought and extreme heatwaves[24,25].

### 3.1.4 pH

pH levels in the Mediterranean Sea present some variation as –0.02/decade (**Table 1**). This negative trend, leading to gradual acidification of coastal waters, could impact some calcifying marine organisms such as corals, mollusks, seaweeds and marine plants, including *Posidonia oceanica* species. However, most of this sessile biota is able to support pH fluctuations suggesting its potential in acclimatization and adaptative responses to acidification processes[26]. In fact, experimental studies have shown no or slight effects of acidification on *Posidonia oceanica* species[27–30].

## 3.2 Biotic factors

The Mediterranean Sea covers only 0.82% of the whole marine hydrosphere but it preserves somewhere between 4% and 18% of the global marine species[31,32]. This high biodiversity level, coupled with the presence of many marine endemism, makes the Mediterranean Sea one of the most important conservation hotspots worldwide[33]. As above, the endemic species are about one-quarter of the whole Mediterranean biota[34] which is, actually threatened by severe risks[35], amongst which climate changes exert a pivotal role in the adaptative process of *Posidonia oceanica* species.

### 3.2.1 *Posidonia oceanica* meadows

*Posidonia oceanica* meadows are one of the most important marine ecosystems of the Mediterranean Sea where the species can form, in pristine environmental conditions, large and extensive meadows on mobile substrata until 40–45 meters depth in the infralittoral bottoms of the basin[36]. Posidonia beds cover a surface area estimated between 2.5 to 5.0 million hectares[37], but today there is a fast regression of the meadows variable from 13% to 50%[38]. This declining trend could lead to the disappearance of about 75% of the meadows by 2100[39]. Generally, it is well known that climate changes could induce in time important modifications and adaptations at species and population levels from reproductive trends to ecosystem structures[40]. In particular, it has been recently remarked a clear warming trend in Mediterranean seawaters. Such a thermic increase could lead, in time, to predicted shifts in the spatial distribution of the meadows towards refuge areas in deeper waters[40,41] (**Figure 2**).

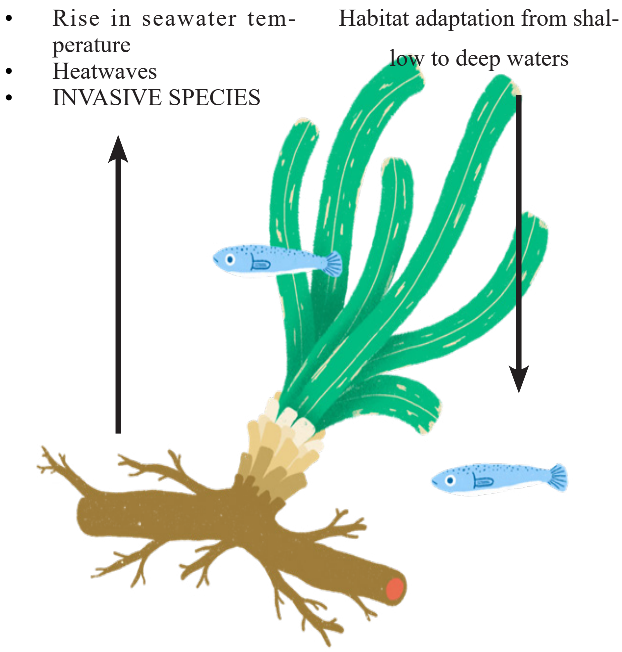


**Figure 2.** Climate changes and modifications at the ecosystem level of *Posidonia oceanica* meadows.

Indeed, the recurring flowering events of *Posidonia oceanica*, which occurred in these last decades in Mediterranean coastal waters, are showing a change in the reproductive traits of the species from asexual to sexual modes[42]. This course could support not only a better genetic diversity of the species but also its high resistance against variations in environmental conditions. This adaptative process is realized through five mechanisms as follows: acclimatization, genetic adaptations, range shift processes, community composition modifications and socio-ecological management (**Figure 3**).

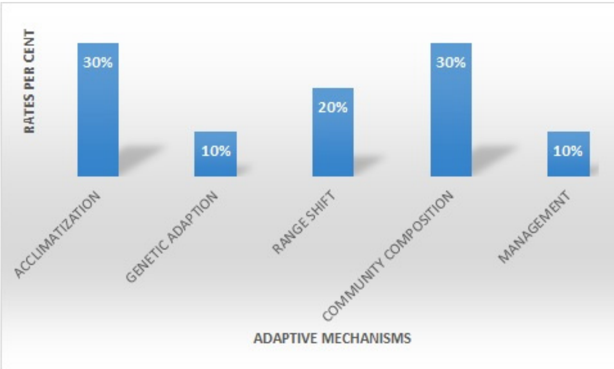


**Figure 3.** Adaptative mechanisms of *Posidonia oceanica* meadows.

In this way, **Figure 3** shows the main adaptative mechanisms, realized by *Posidonia oceanica* meadows, to counteract the warming trend of Mediterranean coastal waters. According to some scientific data drawn by reference[16], the factors of acclimatization and community composition, with a rate percent of 30% respectively, represent the most important adaptative responses against climate change, followed by range shift processes (20%), genetic adaptation (10%) and socio-ecological management (10%). Hence, amongst these evolutive responses, *Posidonia oceanica* meadows show a higher adaptative capacity through acclimatization, range shift and community composition processes. Then, the species is characterized by high thermotolerance[41,42] while, regarding range shift, the warming trend of Mediterranean waters could lead to downward migration of the species in deeper bottoms towards refuge areas (**Figure 2**)[40,41]. Indeed, as regards the factor of community composition, the species could be able to counteract the effects of climate change, not only through modifications in the trophic network but also with a complex re-assessment of species assemblages, all leading to adaptative processes in ecosystem structure[44,45]. Finally, the word "adaptation" becomes the main cornerstone by which the *Posidonia oceanica* ecosystem may counteract the effects of climate change.

### 3.3 Human pressures

Coastal regions are, actually, sensitive areas to the rising human pressure produced by a growing demographic trend and by heavy coastal urbanization, This process leads to a rough expansion of human settlements on seaboard areas, some of which are, actually, exposed to increasing coastal hazards.

### 3.3.1 Coastal urbanization

The increasing soil exploitation for building purposes, along the Mediterranean littoral belt, has produced the overloading of some environmental limits[46], causing a sharp decrease in the quality of life of local people[47]. The Mediterranean basin is, actually, overcrowded by 523 million people[48], becoming a changeable ecoregion where human development is dependent on short and overexploited natural resources[49]. The population of the 21 Mediterranean countries surrounding the basin, following an increasing trend, shows a projected rise of 3% per decade (**Table 1**). Certainly, this demographic pressure coupled with the upcoming climate warming will affect all coastal regions of the Mediterranean basin, influencing also the state of health of *Posidonia oceanica* meadows. However, the adaptative capacity of the species and its high thermotolerance could lead to biological mechanisms able to counteract the effects of climate change.

## 4. Conclusions

*Posidonia oceanica* meadows are, actually, threatened not only by human pressures and by the fluctuations of some abiotic factors but also by climate changes affecting the Mediterranean biota[9] (**Figure 4**).

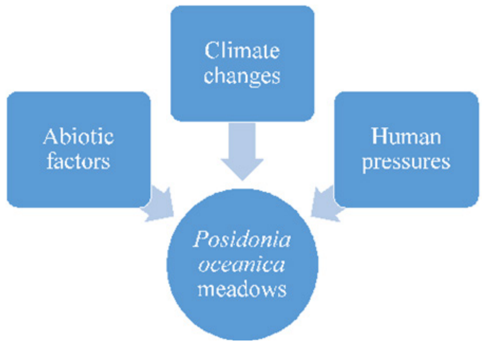


**Figure 4.** Driving forces affecting *Posidonia oceanica* meadows.

As a matter of fact, there is a close relationship between climate changes, biotic factors and abiotic features. In fact, cumulative and mutual effects between climate and human variables could stress population dynamics supporting changes in the community composition of marine species. In such context, Posidonia beds could lose a large part of their current range by 2100[39]. Anyway, *Posidonia oceanica* species shows a high thermotolerance against the increasing warming trend of Mediterranean coastal waters, contributing to climate change mitigation. Indeed, this endemic species, always characterized by asexual reproduction through rhizomes fragmentation, is showing in these last years a regular alternation between sexual and asexual reproductive modes[42]. In fact, it is recently observed an increase in massive flowering events is probably related to the ongoing seawater warming and the greater frequency of recurring heatwaves in the Mediterranean waters. In this way, the sexual reproduction mode of the species, induced by the heating of coastal waters, may enhance the genetic diversity of this marine plant, highlighting its high thermotolerance. Such a mixed solution suggests the adaptative capacity of the species to variable environmental conditions. However, until now, the scientific knowledge about the dynamics of flowering induction is very scanty and remains a debated issue. Really, the fate of *Posidonia oceanica* meadows largely depends on their potential to counteract anthropogenic pressures[50], but the effective adaptative mechanisms of the species and its high resilience against abiotic factors, warming conditions and human pressures could suggest a successful evolution for *Posidonia oceanica* meadows.

## Conflict of interest

The author declares no conflict of interest.

## References


1. Burrows MT, Schoeman DS, Buckley LB, *et al*. The pace of shifting climate in marine and terrestrial ecosystems. Science 2021; 334(6056): 652–655. doi: 10.1126/science.1210288.
2. Bellard C, Bertelsmeier C, Leadley P, *et al*. Impacts of climate change on the future of biodiversity. Ecology Letters 2012; 15: 365–377. doi: 10.1111/j.1461-0248.2011.01736.x.
3. Urban MC. Accelerating extinction risk from climate change. Science 2015; 348(6234): 571–573. doi: 10.1126/science.aaa4984.
4. Isbell F, Craven D, Connoly J, *et al*. Biodiversity increases the resistance of ecosystenm productivity to climate extremes. Nature 2015; 526: 574–577. doi: 10.1038/nature15374.
5. Pecl GT, Araùjo MB, Bell JD, *et al*. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science 2017; 355(6332): eaai9214. doi: 10.1126/science.aai9214.
6. Titeux N, Henle K, Mihoub JB, *et al*. Global scenarios for biodiversity need to better integrate climate and land use change. Diversity and Distributions 2017; 23(11): 1231–1234. doi: 10.1111/ddi.12624.
7. Halpern BS, Frazier M, Afflerbach J, *et al*. Recent pace of change in human impact on the world's ocean. Scientific Reports 2019; 9: 11609. doi: 10.1038/s41598-019-47201-9.
8. United Nations. Framework convention on climate change. Paris Climate Change Conference; 2015 Nov 30–2015 Dec 11; Paris. New York: United Nations; 2015. p. 1–36.
9. Balzan MV, Hassoun AER, Arouna N, *et al*. Ecosystems. In: Cramer W, Guiot J, Marini K (editors). Climate and environmental change in the Mediterranean Basin—Current situation and risks for the future. First Mediterranean assessment report. Marseille: MedECC, Union for the Mediterranean, Plan Blue, UNEP/MAP; 2020. p. 323–468. doi: 10.5281/zenodo.7101090.
10. Médail F, Quézel P. Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Annals of the Missouri Botanical Garden 1997; 84(1): 112–127. doi: 10.2307/2399957.
11. Coll M, Piroddi C, Steenbeek J, *et al*. The biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. PloS One 2010; 5(8): e11842. doi: 10.1371/journal.pone.0011842.
12. Coll M, Piroddi C, Albouy C, *et al*. The Mediterranean Sea under siege: Spatial overlap between marine biodiversity, cumulative threats and marine reserves. Global Ecology and Biogeography 2012; 21(4): 465–480. doi: 10.1111/j.1466-8238.2011.00697.x.
13. IPCC (Intergovernmental Panel on Climate Change). IPCC. Climate Change 2014: Synthesis Report. Core Writing Team, Pachauri RK, Meyer LA (editors). Geneva: IPCC; 2014. p. 1–151.
14. Bell G, Collins S. Adaptation, extinction and global change. Evolutionary Applications 2008; 1(1): 3–16. doi: 10.1111/j.1752-4571.2007.00011.x.
15. Otto SP. Adaptation, speciation and extinction in the anthropocene. Proceedings of the Royal So-

ciety B 2018; 285(1891): 20182047. doi: 10.1098/rspb.2018.2047.

16. Aurelle D, Thomas S, Albert C, *et al*. Biodiversity, climate change, and adaptation in the Mediterranean. Ecosphere 2022; 13(4): e3915. doi: 10.1002/ecs2.3915.
17. Lascaratos A, Roether W, Nittis K, Klei B. Recent changes in deep water formation and spreading in the Eastern Mediterranean Sea: A review. Progress in Oceanography 1999; 44(1-3): 5–36. doi: 10.1016/S0079-6611(99)00019-1.
18. Millot C, Taupier-Letage I. Circulation in the Mediterranean Sea. In: Saliot A (editor). The Mediterranean Sea. Heidelberg: Springer Berlin; 2005. p. 29–66. doi: 10.1007/b107143.
19. Garrabou J, Ledoux JB, Bensoussan N, *et al*. Sliding toward the collapse of Mediterranean coastal marine rocky ecosystems. In: Canadell JG, Jackson RB (editors). Ecosystem collapse and climate change. Cham: Springer Cham; 2021. p. 291–324. doi: 10.1007/978-3-030-71330-0_11.
20. Garrabou J, Coma R, Bensoussan N, *et al*. Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. Global Change Biology 2009; 15(5): 1090–1103. doi: 10.1111/j.1365-2486.2008.01823.x.
21. Rixen M, Beckets JM, Levitus S, *et al*. The Western Mediterranean deep water: A proxy for climate change. Geophysical Research Letters 2005; 32(12): L12608. doi: 10.1029/2005GL022702.
22. Adloff F, Somot S, Sevault F, *et al*. Mediterranean Sea response to climate change in an ensemble of twenty first century scenarios. Climate Dynamics 2015; 45(9): 2775–2802. doi: 10.1007/s00382-015-2507-3.
23. Fernández-Torquemada Y, Sánchez-Lizaso JL. Responses of two Mediterranean seagrasses to experimental changes in salinity. Hydrobiologia 2011; 669: 21–33. doi: 10.1007/s10750-011-0644-1.
24. Noto AE, Shurin JB. Early stages of sea-level rise lead to decreased salt marsh plant diversity through stronger competition in Mediterranean-climate marshes. PLoS One 2017; 12(1): e0169056. doi: 10.1371/journal.pone.0169056.
25. Vicente O, Boscaiu M. Will halophytes in Mediterranean salt marshes be able to adapt to climate change? AgroLife Scientific Journal 2020; 9(2): 369–376.
26. Cornwall CE, Comeau S, DeCarlo TM, *et al*. A coralline alga gains tolerance to ocean acidification over multiple generations of exposure. Nature Climate Change 2020; 10(2): 143–146. doi: 10.1038/s41558-019-0681-8.
27. Vela A, Pasqualini V, Leoni V, *et al*. Use of SPOT 5 and IKONOS imagery for mapping biocenoses in a Tunisian Coastal Lagoon (Mediterranean Sea). Estuarine, Coastal and Shelf Science 2008; 79(4): 591–598. doi: 10.1016/j.ecss.2008.05.014.
28. Meinesz A, Cirik Ş, Akcali B, *et al*. *Posidonia oceanica* in the Marmara Sea. Aquatic Botany 2009; 90(1): 18–22. doi: 10.1016/j.aquabot.2008.04.013.
29. Cox TE, Schenone S, Delille J, *et al*. Effects of ocean acidification on *Posidonia oceanica* epiphytic community and shoot productivity. Journal of Ecology 2015; 103(6): 1594–1609. doi: 10.1111/1365-2745.12477.
30. Cox TE, Gazeau F, Alliouane S, *et al*. Effects of *in situ* $CO_2$ enrichment on structural characteristics, photosynthesis and growth of the Mediterranean seagrass *Posidonia oceanica*. Biogeosciences 2016; 13(7): 2179–2194. doi: 10.5194/bg-13-2179-2016.
31. Bianchi CN, Morri C. Marine biodiversity of the Mediterranean Sea: Situation, problems and prospects for future research. Marine Pollution Bulletin 2000; 40(1): 367–376. doi: 10.1016/S0025-326X(00)00027-8.
32. Boudouresque CF. Marine biodiversity in the Mediterranean: Status of species, populations and communities. Scientific Reports of the Port-Cross National Park 2004; 20: 97–146.
33. Giaccone G. L'origine della biodiversità vegetale nel Mediterraneo (Italian) [The origin of Mediterranean plant biodiversity]. Genova: Notiziario della Società Italiana di Biologia Marina; 1999. p. 35–51.
34. Lejeusne C, Chevaldonné P, Pergent-Martini C, *et al*. Climate change effects on a miniature ocean: The high diverse, highly impacted Mediterranean Sea. Trends in Ecology & Evolution 2010; 25(4): 250–260. doi: 10.1016/j.tree.2009.10.009.
35. Myers N, Mittermeier RA, Mittermeier CG, *et al*. Biodiversity hotspots for conservation priorities. Nature 2000; 403: 853–858. doi: 10.1038/35002501.
36. Ghirardelli E. La vita nelle acque (Italian) [Life in the waters]. Torino: UTET; 1981. p. 610.
37. Pasqualini V, Pergent-Martini C, Clabaut P, Pergent G. Mapping of *Posidonia oceanica* using aerial photographs and side scan sonar: Application off the Island of Corsica (France). Estuarine, Coastal and Shelf Science 1998; 47(3): 359–367. doi: 10.1006/ecss.1998.0361.
38. Marbà N, Díaz-Almela E, Duarte CM. Mediterranean seagrass (*Posidonia oceanica*) loss between 1842 and 2009. Biological Conservation 2014; 176: 183–190. doi: 10.1016/j.biocon.2014.05.024.
39. Chefaoui RM, Duarte CM, Serrão EA. Dramatic loss of seagrass habitat under projected climate change in the Mediterranean Sea. Global Change Biology

2018; 24(10): 4919–4928. doi: 10.1111/gcb.14401.
40. Parmesan C. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 2006; 37: 637–669. doi: 10.1146/annurev.ecolsys.37.091305.110100.
41. Boudouresque CF, Blanfunè A, Fernandez C, *et al*. Marine biodiversity warming vs. biological invasions and overfishing in the Mediterranean Sea: Take care, "One train can hide another". MOJ Ecology and Environmental Science 2017; 2(4): 172–183. doi: 10.15406/mojes.2017.02.00031.
42. Martínez-Abraín A, Castejón-Silvo I, Roiloa S. Foreesing the future of *Posidonia oceanica* meadows by accounting for the past evolution of the Mediterranean Sea. ICES Journal of Marine Science 2022; 79(10): 2597–2599. doi: 10.1093/icesjms/fsac212.
43. Marín-Guirao L, Ruiz JM, Dattolo E, *et al*. Physiological and molecular evidence of differential short-term heat tolerance in Mediterranean seagrasses. Scientific Reports 2016; 6: 28615. doi: 10.1038/srep28615.
44. Marín-Guirao L, Bernardeau-Esteller J, García-Muñoz R, *et al*. Carbon economy of Mediterranean seagrasses in response to thermal stress. Marine Pollution Bulletin 2018; 135: 617–629.
45. Sánchez-Jerez P, Barberá-Cebrián C, Ramos-Esplá AA. Influence of the structure of *Posidonia oceanica* meadows modified by bottom trawling on crustacean assemblages: Comparison of amphipods and decapods. Scentia Marina 2000; 64(3): 319–326.
46. Guilini K, Weber M, de Beer D, *et al*. Response of *Posidonia oceanica* seagrass and its epibiont communities to ocean acidifications. PloS One 2017; 12(8): e0181531. doi: 10.1371/journal.pone.0181531.
47. Nijkamp P. Urban environmental quality improvement in developing countries: Socio-ecological possibilities and limits. Amsterdam: Vrije Universiteit; 1993. p. 1–50.
48. Ietto F, Salvo F, Cantasano N. The quality of life with reference to the local environmental management: A pattern in Bivona country (Calabria, Southern Italy). Ocean & Coastal Management 2014; 102(Part A): 340–349. doi: 10.1016/j.ocecoaman.2014.10.014.
49. United Nations. World population prospects 2019–Data booklet. New York: United Nations; 2019. p. 1–25.
50. Birot Y, Gracia C, Matteucci G, *et al*. L'eau pour la forèt et les hommes en région méditerranéen (French) [Water for forests and people in the Mediterranean region]. Forêt Méditerranéenne 2011; XXXII(4): 359–362.