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## RESEARCH ARTICLE

# Unexpected Refuge for Threatened Species Revealed by a Prolonged Low-Sea-Level Phase

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**Abstract:** The Sicily coast of Messina Strait (Central Mediterranean) is characterized by a rare beach rock formation, whose biotic features are poorly known. Situated near an amphidromic tidal point, the formation is not affected by tidal oscillations allowing the connected rocky pools to offer a relatively stable and suitable refuge for subtidal organisms. This environment, in February 2023, was affected by exceptional low sea levels caused by a prolonged high atmospheric pressure. The local fauna, not pre-adapted to such an unpredictable event, experienced a mass mortality episode that revealed an unexpectedly high biodiversity. Exclusively considering the megabenthic fauna, 63 species have been detected. Between them, species of great conservation interest, are the gastropods *Naria spurca*, *Luria lurida*, *Vermetus triquetrus*, and *Talisman scrobilator*, the bivalve *Pinna rudis*, and the echinoderm *Ophidiaster ophidianus*, which were reported for the first time from such formations. These records show that beach rock is a habitat worth conserving and one that is vulnerable to the effects of ongoing climate change.

### Anahtar kelimeler:

Sahil kayaları  
Tehdit altındaki türler  
Yaşam alanlarının korunması  
Kitlelölümler  
İklim değişikliği

## Uzun Süreli Düşük Deniz Seviyesi Süreciyle Ortaya Çıkan Tehdit Altındaki Türler İçin Beklenmedik Sığınak

**Öz:** Messina Boğazı'nın (Orta Akdeniz) Sicilya kıyıları, biyotik özellikleri az bilinen nadir bir sahil kaya oluşumuyla karakterizedir. Amfidromlu bir gelgit noktasının yakınında bulunan bu oluşum, gelgit dalgalanmalarından etkilenmemekte, bu da bağlantılı kayalık havuzların subtidal organizmalar için nispeten istikrarlı ve elverişli bir sığınak sunmasını sağlamaktadır. Bu çevre, Şubat 2023'te uzun süreli yüksek atmosferik basınç nedeniyle meydana gelen olağanüstü düşük deniz seviyelerinden etkilenmiştir. Yerel fauna, böyle öngörülemeyen bir olaya önceden adapte olmamış olduğundan, kitlelölüm olayı yaşamış ve bu durum beklenmedik derecede yüksek bir biyoçeşitliliği ortaya çıkarmıştır. Yalnızca megabentik fauna dikkate alındığında 63 tür tespit edilmiştir. Bu türler arasında büyük koruma önemi taşıyan gastropodlar *Naria spurca*, *Luria lurida*, *Vermetus triquetrus* ve *Talisman scrobilator*, çift kabuklular *Pinna rudis* ve derisidikenliler *Ophidiaster ophidianus* yer almaktadır ve ilk kez bu oluşumlarda kaydedilmiştir. Bu kayıtlar, sahil kaya habitatlarının korunmaya değer olduğunu ve devam eden iklim değişikliğinin etkilerine karşı savunmasız olduğunu göstermektedir.

## Introduction

Beach rock formations in the Strait of Messina, north-eastern Sicily coast (central Mediterranean), extend more than 2 km (Bottari et al., 2005) (Fig.1) along a stretch of littoral zone not subjected to tidal fluctuations, hence intertidal benthic communities are lacking. Lowermost, in the wave exposed upper subtidal "fringe", the sessile gastropod *Vermetus triquetrus* Bivona & Bernardi, 1832 is responsible for a monospecific vermetid formation, mingled with algal assemblages which host a high number of small sized mollusk species (Del Ricco, 1982). An apparently poor macrofauna, moreover, is recognizable in some rocky pools normally connected to the sea. Due to their alleged ultra-simplified structure, such rocky pool benthic assemblages have provided an example of prey-

predator interactions involving the grazer top snail *Phorcus turbinatus* (Born, 1778), and the carnivorous hermit crab *Clibanarius erythropus* (Latreille, 1818) (Savoca et al., 2020). Dated information on benthic organisms living in such environment are recognizable in local literature (Conato & Berdar, 1981), but no updated and verifiable reports exist on the biodiversity of such a beach rock formation. In this respect, we cannot consider as reliable a recent paper reporting several species unknown to the Mediterranean fauna, such as the tropical cowrie *Cypraea pantherina*, all listed without any explanation or comment (Capillo et al., 2018).

In this paper, field observations are reported on the megabenthic fauna occurring in the beach rock pools, as it

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was revealed by an exceptional low sea level episode. By describing the unexpected biodiversity that has been recorded, the present paper aims to shed new light on the ecological role of a natural formation generally developing between the intertidal and the upper subtidal fringe.

Although its importance has been mostly recognized in the geological field (Vousdoukas et al., 2007), we propose to include the beach rock formations to the list of high biodiverse habitats most threatened by the effects of ongoing climatic changes.



**Figure 1.** Location of "Messina beach rock" (red dot) in central Mediterranean (A); in the Strait of Messina area (B); along the Capo Peloro coast (C). A portion of emerging beach rock together with a partially dried pool is shown (D)

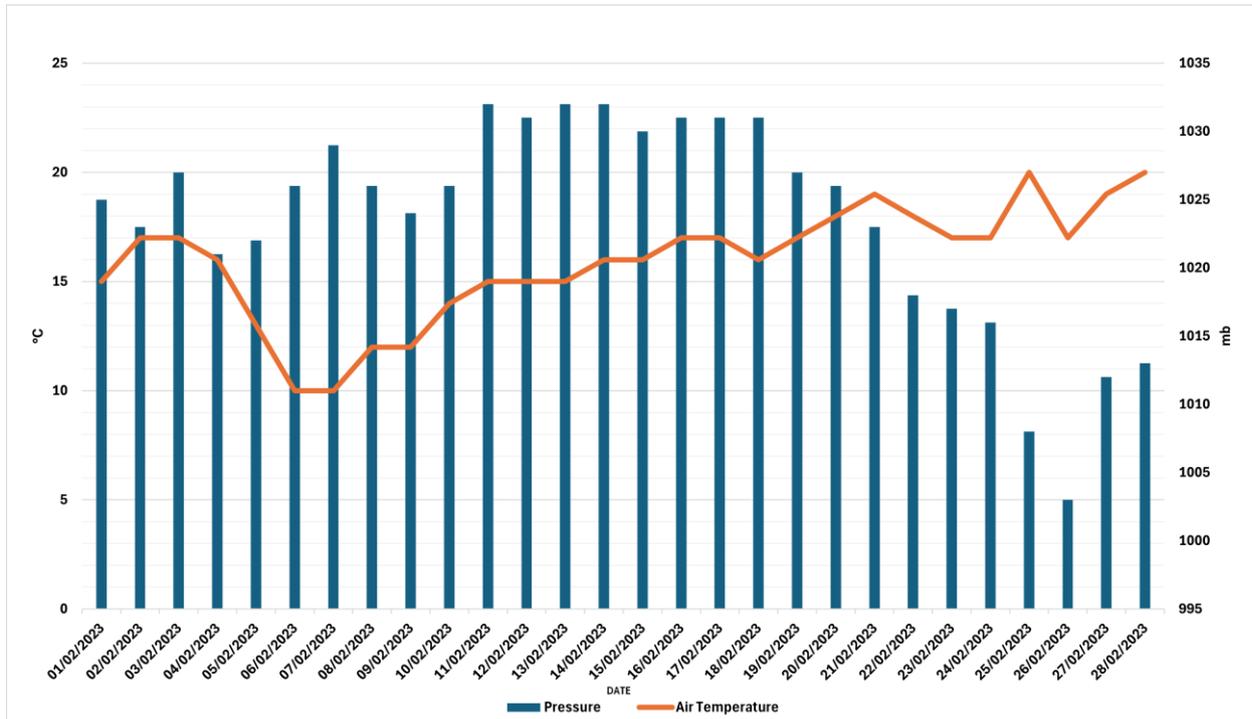
## Material and Methods

In the framework of a program aimed at investigating the geological and ecological features of the Capo Peloro coastal area (Somma et al., 2024), an exceptionally prolonged phase of high atmospheric pressure was detected, responsible for an anomalous low sea level. Consequently, a large portion of submerged beach rock emerged during a period of almost a month, allowing a photographically documented monitoring of the related fauna. The recognized megabenthic fauna (size >1 cm) was photographed on the field and identified as far as possible, at the species level according with Worms database (<https://www.marinespecies.org/>). Moreover, the surviving ability of different species in such an extreme condition was evaluated. Data on atmospheric pressure and air temperature during the sea level drop were obtained by accredited sites online (<https://www.woitalia.it/weather/maps/city>).

The whole video-photographic archive is deposited in the Benthic Ecology Laboratory of Messina University, and available upon request..

## Results

In February 2023, an unusually prolonged phase of high atmospheric pressure occurred, starting from a value of 1025 mbar recorded on February 1<sup>st</sup>. Atmospheric pressure exceeded 1030 mbar from February 11<sup>th</sup> to 18<sup>th</sup>, before progressively decreasing up to a minimum of 1003 mbar on February 26<sup>th</sup>. Due to the high pressure, the sea level dropped, maintaining about 50 cm below the medium sea level from 1<sup>st</sup> to 20<sup>th</sup> February. In the same period, the air temperature dropped from 15 to 10 °C on February 7<sup>th</sup>, before gradually increasing up to 20 °C on February 25<sup>th</sup> (Fig. 2). Consequently, rocky pools lost their connection with the sea, causing a drastic water level decrease -up to complete local drying-, and to water overheating with temperatures above 30°C.



**Figure 2.** Daily atmospheric pressure (mb) and maximum air temperature (°C) in February 2023

These extreme conditions, which drove the aquatic fauna to retreat, revealed the unexpected occurrence of a rich megafauna that becomes susceptible to mass mortality under such circumstances. A total of 63 megabenthic species have been classified, mostly invertebrates belonging to mollusks (41 species), crustaceans (11 species), echinoderms (7 species), cnidarians (3 species) and annelids (one species). The phylum Chordata was represented only by six species of fish (Table 1).

Noteworthy, some of the recorded species are under strict protection by the Bern (<https://rm.coe.int/168078e2ff>) and Barcelona protocols (UNEP/MAP-SPA/RAC 2018). Among them, the dirty cowry, *Naria spurca* (Linnaeus, 1758) was particularly frequent, with 4 individuals/m<sup>2</sup>, but rarely in viable condition (Fig. 3A). Dead specimens of the lurid brown cowry, *Luria lurida* (Linnaeus, 1758) were also recorded (Figure 3B). Dying specimens of the purple starfish, *Ophidiaster ophidianus* (Lamarck, 1816), were also found (Fig. 3C). Juveniles of the spiny fan mussel, *Pinna rudis* Linnaeus, 1758, were observed alive in some residual pools, apparently not damaged by the contingent adverse conditions (Fig. 3D). A particular case involved the aforementioned *V. triquetrus* formations, which were notably affected by air exposure, resulting in mass mortality of the uppermost settled colonies (Fig. 3E). Vermetid reefs are listed as threatened bioconstructions in the UNEP/IUCN/GIS POSIDONIE (1990); however, this designation applies to the *Dendropoma* species complex (Picone et al., 2022). By contrast, *V. triquetrus* is listed as “Not Evaluated” in IUCN Red List, CITES, and CMS (<https://sealifebase.org/summary/Vermetus-triquetrus.html>). In the Messina beach rock, *V. triquetrus*

does not exclusively occur in massive colonial formations, but also represented by low density populations characterized by large sized individuals, which are apparently more resistant to drying and warming (Fig. 3F).

Despite the pitted frog-snail, *Talisman scrobilator* (Linnaeus, 1758) (Fig.4A), has not yet been recognized as an endangered species, the record of several living specimens was noteworthy. With an East-Atlantic endemism, in fact, *T. scrobilator* has been sporadically reported from western and central Mediterranean Sea (Ghisotti, 1977; Barletta, 1980; Trillò, 2001; Trono, 2006; Smriglio et al., 2019). The first and, so far, only record for the Strait of Messina dates back to Micali (1975). As underlined by Aparicio & Verdejo, (2021), *T. scrobilator* is included in the Libro Rojo de los Invertebrados de Andalucía, although not mentioned in the Catálogo Español de Especies Amenazadas, probably due to lack of data. According to Verdejo (2001), the presence of this species is in regression in the western Mediterranean. *T. scrobilator*, being considered by malacologists as an iconic species, suffers of uncontrolled collection. Moreover, depletion and fragmentation of its preferential habitat, namely caves and dark environments, have been recently suggested as ongoing threats (Santin et al., 2021). Among the species of commercial interest, specimens of the green ormer, *Haliotis tuberculata* Linnaeus, 1758 (Fig.4B) have been observed in critical conditions. Among the five abalone species recognized in the Eastern Atlantic and Mediterranean (Chiappa et al., 2022), only *H. tuberculata* (variously named in accordance with the alleged subspecies and “morphs”) is subjected to commercial fishing. In Italy, in contrast to other European countries, no conservation measures are implemented, despite

considerable decline in worldwide populations, with few signs of recovery and suspected connections with the ongoing climatic changes (Peters et al., 2024), as proven

by mass mortality events related to high sea surface temperatures (Huchette & Clavier, 2004).

**Table 1.** Megabenthic species recorded in the Messina beach rock formation during February 2023 low sea level

<b>ANNELIDA</b>	<b>MOLLUSCA</b>
<i>Hermodice carunculata</i> (Pallas, 1766)	<i>Aplysia fasciata</i> Poiret, 1789
<b>CNIDARIA</b>	<i>Aplysia depilans</i> Gmelin, 1791
<i>Anemonia sulcata</i> (Pennant, 1777)	<i>Aplysia dactylomela</i> Rang, 1828
<i>Actinia cari</i> Delle Chiaje, 1822	<i>Brachidontes pharaonis</i> (P. Fischer, 1870)
<i>Actinia equina</i> (Linnaeus, 1758)	<i>Barbatia barbata</i> (Linnaeus, 1758)
<b>CHORDATA</b>	<i>Bulla striata</i> Bruguière, 1792
<i>Chelon auratus</i> (Risso, 1810)	<i>Calliostoma laugierii</i> (Payraudeau, 1826)
<i>Lepadogaster candolii</i> Risso, 1810	<i>Cerithium lividulum</i> Risso, 1826
<i>Muraena helena</i> Linnaeus, 1758	<i>Cerithium renovatum</i> Monterosato, 1884
<i>Parablennius sanguinolentus</i> (Pallas, 1814)	<i>Cerithium vulgatum</i> Bruguière, 1792
<i>Tripterygion delaisi</i> Cadenat & Blache, 1970	<i>Chama gryphoides</i> Linnaeus, 1758
<i>Tripterygion tripteronotum</i> (Risso, 1810)	<i>Columbella rustica</i> (Linnaeus, 1758)
<b>CRUSTACEA</b>	<i>Conus ventricosus</i> Gmelin, 1791
<i>Dromia personata</i> (Linnaeus, 1758)	<i>Diodora gibberula</i> (Lamarck, 1822)
<i>Eriphia verrucosa</i> (Forskål, 1775)	<i>Euthria cornea</i> (Linnaeus, 1758)
<i>Herbstia condyliata</i> (Fabricius, 1787)	<i>Fissurella nubecula</i> (Linnaeus, 1758)
<i>Maja crispata</i> Risso, 1827	<i>Gibbula turbinoides</i> (Deshayes, 1835)
<i>Microeuraphia depressa</i> (Poli, 1791)	<i>Haliotis tuberculata</i> Linnaeus, 1758
<i>Pachygrapsus marmoratus</i> (Fabricius, 1787)	<i>Hexaplex trunculus</i> (Linnaeus, 1758)
<i>Palaemon elegans</i> Rathke, 1836	<i>Luria lurida</i> (Linnaeus, 1758)
<i>Percnon gibbesi</i> (H. Milne Edwards, 1853)	<i>Mitrella scripta</i> (Linnaeus, 1758)
<i>Pisa corallina</i> (Risso, 1816)	<i>Mytilaster minimus</i> (Poli, 1795)
<i>Xantho hydrophilus</i> (Herbst, 1790)	<i>Naria spurca</i> (Linnaeus, 1758)
<i>Xantho poressa</i> (Olivier, 1792)	<i>Patella caerulea</i> Linnaeus, 1758
<b>ECHINODERMATA</b>	<i>Patella rustica</i> Linnaeus, 1758
<i>Arbacia lixula</i> (Linnaeus, 1758)	<i>Patella ulyssiponensis</i> Gmelin, 1791
<i>Coscinasterias tenuispina</i> (Lamarck, 1816)	<i>Phorcus articulatus</i> (Lamarck, 1822)
<i>Holothuria (Holothuria) tubulosa</i> Gmelin, 1791	<i>Phorcus richardi</i> (Payraudeau, 1826)
<i>Marthasterias glacialis</i> (Linnaeus, 1758)	<i>Phorcus turbinatus</i> (Born, 1778)
<i>Ophidiaster ophidianus</i> (Lamarck, 1816)	<i>Pinna rudis</i> Linnaeus, 1758
<i>Paracentrotus lividus</i> (Lamarck, 1816)	<i>Pisania striata</i> (Gmelin, 1791)
<i>Sphaerechinus granularis</i> (Lamarck, 1816)	<i>Rhyssoplax olivacea</i> (Spengler, 1797)
	<i>Pseudochama griphina</i> (Lamarck, 1819)
	<i>Steromphala divaricata</i> (Linnaeus, 1758)
	<i>Steromphala rarilineata</i> (Michaud, 1829)
	<i>Steromphala varia</i> (Linnaeus, 1758)
	<i>Stramonita haemastoma</i> (Linnaeus, 1767)
	<i>Talisman scrobilator</i> (Linnaeus, 1758)
	<i>Tarantinaea lignaria</i> (Linnaeus, 1758)
	<i>Tritia corrugata</i> (Brocchi, 1814)
	<i>Tritia incrassata</i> (Strøm, 1768)



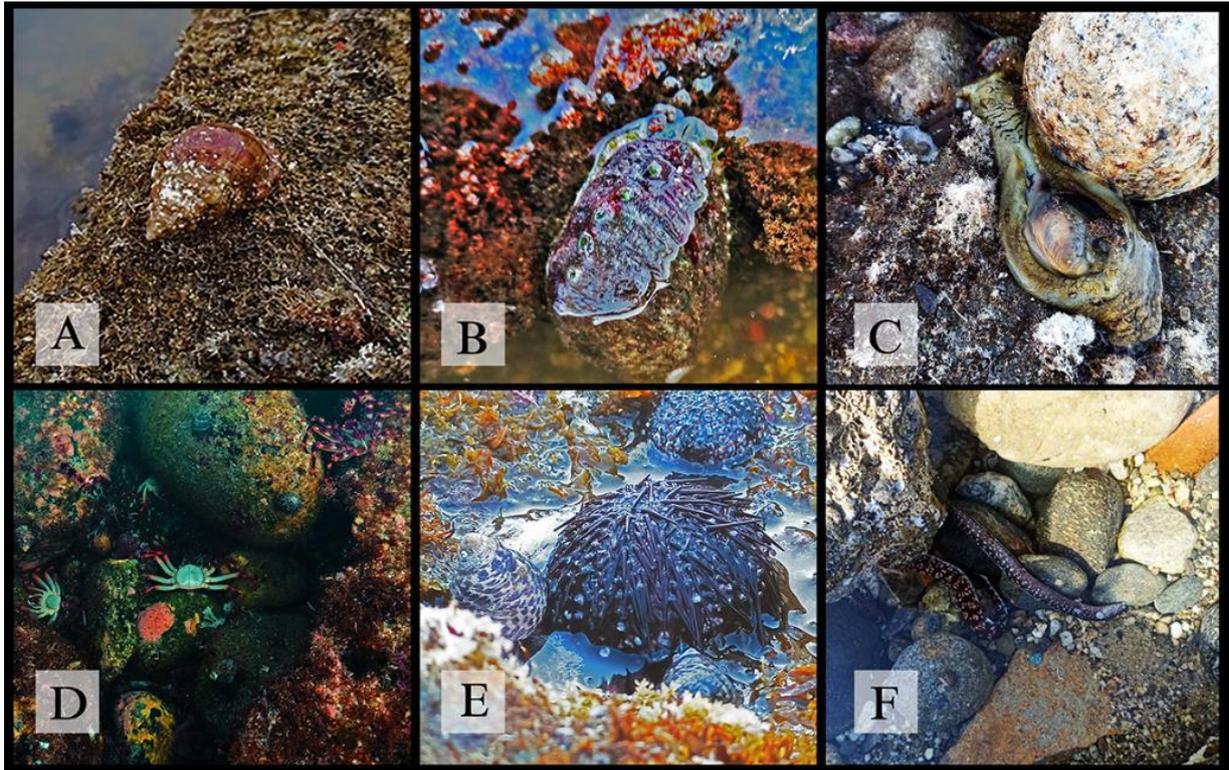
**Figure 3.** Dead or suffering organisms affected by the low sea level episode. **A)** Dying specimens of *Naria spurca*. **B)** Dead specimen of *Luria lurida*. **C)** Air exposed, dying specimen of *Ophidiaster ophidianus*. **D)** Alive *Pinna rudis* specimen. **E)** Dead *Vermetus triquetrus* formation. **F)** Air exposed, scattered specimens of *Vermetus triquetrus*

Particularly affected by mortality were some naturalized alien species, such as the "spotted sea hare", *Aplysia dactylomela* Rang, 1828 (Fig. 4C), and the nimble spray crab, *Percnon gibbesi* (H. Milne Edwards, 1853) (Fig. 4D). However, it is difficult to explain how this species, known to be capable of invading both natural and anthropogenically impacted areas (Cannicci et al., 2008; Thessalou-Legaki et al., 2006), is highly mobile, and therefore, able to move away from dangerous situations. Not surprisingly, by contrast, was the mortality that affected more sensitive species such as *Arbacia lixula* (Linnaeus, 1758) (Fig. 4E) and other echinoderms. Lastly, although living specimens of small sized benthic fish species were frequently observed in residual pools (Table 1), almost unexpected was the great number of juveniles and adults of the Mediterranean moray, *Muraena helena* Linnaeus, 1758, found dead or dying (Fig. 4F).

### Discussion

Recurrent natural disturbances in marine benthic habitats are important determinants of zonation patterns and biodiversity in shallow water benthic communities, favoring the periodic exclusion of competitively dominant

taxa (Connell, 1978; Rogers, 1993). Among them, spring low tides are the most predictable events, rarely causing mass mortality, except for the rare physical disturbance represented by prolonged extremely low tides that coincide with supra-optimal irradiance (Anthony & Kerswell, 2007). Biological effects of such stochastic events have been described for intertidal tropical communities (Yamaguchi, 1975), especially for their consequences on coral reefs (Hoarau et al., 2023). Mass mortalities due to other unknown causes than air exposure have been also reported (Collard et al., 2000). The increasing effects of global warming, in terms of both frequency and intensity of marine heatwave have been described as causes of unprecedented regional mass bleaching of thermally resistant corals (Le Nohaïc et al., 2017). However, scientific literature does not report about mass mortality of subtidal benthic communities directly attributable to lowered sea level. An indirect consequence, however, has been recently reported for the Strait of Messina area, where a mass mortality episode affected the cowry *Naria spurca*, due to the imbalance between marine inputs and brackish water outputs, after an extended period of low sea level (Gati et al., 2024).



**Figure 4.** Dead or suffering organisms affected by the low sea level episode. **A)** Living specimen of *Talisman scrobilator*. **B)** Living specimen of *Haliotis tuberculata*. **C)** Air exposed, dead specimen of *Aplysia dactylomela*. **D)** Mass mortality of *Percnon gibbesi*. **E)** Dead *Arbacia lixula*. **F)** Dying *Murena helena* specimens.

Although different types of beach rock formations are known worldwide, some biological implications need to be highlighted. In a local geographic scale, in fact, it is relevant that beach rocks are the only natural rocky shore habitat recognizable along the Sicilian coast of the Strait of Messina. On a global scale, the Messina beach rock represents a rare –possibly unique- example of rocky seashore that is not affected by tidal fluctuations. Such relatively stable environment offers more effective refuge and protection than the adjacent more exposed environments, hosting a large number of threatened species that is rarely reported in literature from the Strait of Messina, and which become concentrated within a habitat of very limited extent.

### Conclusion

The beach rock formations, located between the intertidal and the upper subtidal fringe are particularly vulnerable to drying and warming. The increasing occurrence of such events, resulting in an excessive disturbance, could act as a de-structuring rather than regulating factor. In this context, the Messina beach rock represents a peculiar case-study as it hosts a relatively high biodiversity and provides a profitable refuge for threatened, and/or ecologically relevant species. Moreover, as a shallow water habitat not affected by tidal oscillations, it is extremely vulnerable to stochastic weather-related disturbances, and especially to extended periods of drying.

Thus, under a global warming scenario, increasing frequency and intensity of sea level fluctuations driven by climatic, rather than astronomic forcing, can be expected, raising important questions for species and habitat conservation.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Author Contributions

Conceptualization, S.G. and G. I.; methodology, G.S.; software, G.I.; validation, G.S. and G.I.; formal analysis, S.G. and G.I.; investigation, S.G. and G. I.; resources, S.G.; data curation, S.G. and G. I.; writing-original draft preparation, S.G.; writing-review and editing, S.G. and G. I.; visualization, S.G.; supervision, S.G.; project administration, S.G.; funding acquisition, not applicable. All authors have read and agreed to the published version of the manuscript.

### Ethics Approval

Ethical review and approval were waived for this study due to no animal testing was performed during this study. This research received no external funding.

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