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# The Meadows of *Posidonia Oceanica* (Linnaeus) Delile in a Climate Change Scenario

**Nicola Cantasano* Retired**

*National Research Council, Institute for Agricultural and Forest Systems in the Mediterranean, Rende Research Unit, Italy.*

***Corresponding author:** Nicola Cantasano, National Research Council, Institute for Agricultural and Forest Systems in the Mediterranean, Rende Research Unit, Italy.

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## Abstract

*Posidonia oceanica* (Linnaeus) Delile is the most important seagrass species, endemic of Mediterranean Sea [1]. In coastal waters, characterized by good and pristine conditions, the species can form large and extensive meadows on the infalittoral bottoms of the basin [2], according to light conditions. Posidonia beds cover a global surface area valued between 2.5 and 5.0 million hectares [3], being the typical "climax" ecosystem on the mobile substrata of Mediterranean Sea. So, the meadows of *Posidonia oceanica* have become priority habitat as "*Posidonion oceanicae*" (Habitat Code 1120) within the Habitat Directive (92/43/EC). On the other hand, there is today a fast regression of the Mediterranean praires caused by marine pollution and by increasing human pressures. To counteract such regressive trend Posidonia beds have been inserted as "Best Concern" within the Red List of International Union for Conservation of Nature (IUCN) [4]. Amongst the main threats affecting the fate of *Posidonia oceanica* meadows it is observed a light but steady increase of Sea Surface Temperature (hereafter SST). This warming trend of seawater temperatures has been detected over the last decade as 0.04 °C yr-1 [5,6]. In particular, the Atmospheric Ocean Regional Climate (AORCM) has predicted a global increase of Mediterranean SST of 2.6 °C in the period 2070-2099 [7]. Generally, this climate change scenario could affect the reproductive phenology of some species of marine plants [8], inducing variations in the distributin and in the abundance of seagrass populations in the short and long run [9]. In this way, such an increase in seawater temperature, within a general trend of marine global warming, could have negative effects on *Posidonia oceanica* praires, causing their spatial reduction [10]. In fact, it has been recently observed some reduction in the growth of the plant's vertical rhizomes and a general regression of Posidonia meadows along the Spanish Mediterranean coast, just next some regional sea-warming peaks [11,12]. Therefore, it could be hypothesized a close relationship between the declining of Posidonia beds and the warming trend of Mediterranean waters. However, the species is characterized by an effective acclimatization capacity through its high thermotolerance against the increasing overheating of Mediterranean waters [13,14]. As a matter of fact, the reproductive trait of the species, always characterized by asexual reproduction, through rhizome fragmentation and clonal growth, shows in these last decades a gradual shift towards modes of sexual reproduction [15]. This trend is confirmed, also, by the clear increase of flowering events in the Mediterranean Sea, began in the seventies and is actually ongoing. In fact, it is reported a summarizing frame, deduced by scientific literature, of all the flowering records occurred in Mediterranean waters from 1970 to 2020 years (Table 1).

**Table 1:** Flowering records detected in the coastal waters of Mediterranean countries, in the time lag 1970-2020, drawn by scientific literature (Legend: N.=Number of records).

| YEARS | N. | COUNTRIES | CITATIONS |
|---|---|---|---|
| 1970 | 3 | Tunisia, Corsica, France | Pergent et al., 1989;Pergent and Pergent-Martini, 1988 |
| 1973 | 1 | Italy | Montefalcone et al., 2013 |
| 1976 | 2 | Spain, Balearic Islands | Diaz-Almela et al., 2006 |

| | | | |
|---|---|---|---|
| 1977 | 2 | Spain, Balearic Islands | Sanchez-Lizaso and Ruiz-Fernandez, 1993 |
| 1978 | 1 | Balearic Islands | Diaz-Almela et al., 2006 |
| 1979 | 1 | Ischia Island | Buia and Mazzella, 1991 |
| 1982 | 1 | Zembra Island | Boudouresque et al., 1986 |
| 1983 | 2 | Italy, Balearic Islands | Monefalcone et al., 2013; Diaz-Almela et al., 2006 |
| 1984 | 2 | Algeria, **B**alearic Islands | Semroud, 1993; Diaz-Almela et al., 2006 |
| 1985 | 4 | Italy, Ischia Island, Zembra Island, Tunisia | Bussotti and Guidetti, 1996; Buia and Mazzella, 1991; Boudouresque et al., 1986; Pergent et al., 1989 |
| 1986 | 2 | Egadi Islands, France | Buia and Peirano, 1986; Pergent, 1987 |
| 1987 | 4 | Spain, Balearic Islands | Diaz-Almela et al., 2006 |
| 1988 | 4 | Spain, Algeria | Moreno and Guirado, 2006; Diaz-Almela et al., 2006; Semroud, 1993 |
| 1989 | 3 | Spain, Italy, France | Sanchez-Lizaso and Ruiz-Fernandez, 1993; Diaz-Almela et al., 2006; Meinesz et al., 1993 |
| 1990 | 5 | Spain, Italy | Diaz-Almela et al., 2006 |
| 1991 | 6 | Spain, Balearic Islands, Italy | Diaz-Almela et al., 2006; Stoppelli and Peirano, 1996 |
| 1992 | 4 | Italy, Balearic Islands | Diaz-Almela et al., 2006 |
| 1993 | 6 | Italy, Egadi Islands, Balearic Islands, Turkey | Balestri and Cinelli, 2003; Balestri et al., 2017; Aktan and Aysel, 2013 |
| 1994 | 26 | Spain, Balearic Islands, Favignana Island, Croatia, Italy | Balestri and Cinelli, 2003; Bussotti and Guidetti, 1996; Stoppelli and Peirano, 1996; Diaz-Almela et al., 2006; Balestri et al., 2017; Gambi et al., 1996; Gambi and Guidetti, 1998; Balestri et al., 1998; Piazzi et al., 1999 |
| 1995 | 5 | Italy, Favignana Island, Turkey | Balestri et al., 2005; **B**alestri et al., 2017; Diaz-Almela et al., 2006; Dural, 2010 |
| 1996 | 4 | Italy, Sardinia Island, Spain, Balearic Island | Diaz-Almela et al., 2006; Guidetti and Bussotti, 2002; Moreno and Guirado, 2006 |
| 1997 | 6 | Italia, Ustica Island, Sicily Island | Diaz-Almela et al., 2006; Balestri et al., 2017; Buia et al., 2002 |
| 1998 | 8 | Ischia Island, Balearic Islands | Buia et al., 2002; Diaz-Almela et al., 2006 |
| 1999 | 6 | Ischia Island, Balearic Islands | Buia et al, 2002; Diaz-Almela et al., 2006 |
| 2000 | 1 | Balearic Islands | Diaz-Almela et al., 2006 |
| 2001 | 5 | Tunisia, Balearic Island | Ramzi Sghaier et al., 2013; Diaz-Almela et al., 2006 |
| 2003 | 16 | Italia, Tunisia, Balearic Islands, Spain | Balestri et al., 2005; Ramzi Sghaier et al., 2013; Diaz-Almela et al., 2006;Fernandez-Torquemada and Sanchez-Lizaso, 2013; Moreno and Guirado, 2006 |
| 2004 | 20 | Spain, Italy, Corsica Island, Favignana Island, Balearic Islands, Sicily Island | Moreno and Guirado, 2006; Balestri et al., 2009; Diaz-Almela et al., 2008; Diaz-Almela et al., 2009; Balestri and Lardicci, 2008; Alagna et al., 2013; Bedini et al., 2013; Badalamenti et al., 2015 |
| 2005 | 3 | Italy, Corsica, Tunisia | Balestri et al., 2009; Balestri ad Lardicci, 2008; Ramzi Sghaier et al., 2013 |
| 2006 | 3 | Corsica Island, Spain, Turkey | Balestri et al., 2017; Mateo-Ramirez et al., 2023; Aktan and Aysel, 2013 |
| 2007 | 1 | Algeria | Belbachir and Mezali, 2019 |
| 2009 | 3 | Spain, Ustica Island | Urra et al., 2010; Mateo-Ramirez et al., 2023; Balestri et al., 2017 |
| 2010 | 1 | Spain | Urra et al., 2010 |
| 2011 | 3 | Spain, Sicily Island | Jahnke et al., 2015; Tomasello et al., 2021; Urra et al., 2011 |
| 2012 | 4 | Spain, Italy, Montenegro, Corsica | Cedran and Marin, 2019; Montefalcone et al., 2013; Macic, 2013; Perklin and Tucker, 2015 |
| 2013 | 7 | Italy, Corsica Island, Balearic Islands, Sicily Island, Spain | Montefalcone et al., 2013; Lefebvre and Gobert, 2019; Hernan et al., 2016; Alagna et al., 2013; Terrados, 2013; Fernandez-Torquemada et al., 2013;Cedran and Marin, 2013 |
| 2015 | 4 | Italy, Sicily, Spain | Balestri et al., 2015; Alagna et al., 2015; Mateo-Ramirez et al., 2023 |
| 2016 | 10 | Corsica Island, Sicily Island, Spain | Balestri et al., 2017; Zenone et al., 2022; Guerrero-Meseguer et al., 2018; Hernan et al., 2016; Marin-Guirao et al., 2018 |
| 2017 | 4 | Algeria, Corsica Island, Spain | Belbachir and Mezali, 2019; Lefebvre and Gobert, 2019; Hernan et al., 2017; Guerrero-Meseguer et al., 2018 |
| 2018 | 5 | Algeria, Corsica Island, Spain | Belbachir and Mezali, 2019; Lefebvre and Gobert, 2019; Pereda-Briones, 2020; Guerrero-Meseguer et al., 2018 |

| | | | |
|---|---|---|---|
| 2019 | 5 | Italy, Sicily Island, Ischia Island; Spain | Balestri et al., 2021; Pazzaglia et al., 2022; Pereda-Briones, 2020 |
| 2020 | 5 | Sardinia Island, Sicily Island; Italy; Spain | Stipcich et al., 2021; Alagna et al., 2020; Zenone et al., 2020; Pereda-Briones, 2020 |

## Introduction

This yearly report shows a total of 198 records in the whole Mediterranean Sea from the Spanish coastline to the Turkish one. Really, most of the records regard the western side of the basin while the reports in the eastern side are quite short, probably for the smaller amount of scientific data available by literature. These flowering events show an increasing trend, year by year, as highlighted by the dotted line of (Figure 1). Indeed, it is possible to observe, by the trend of the continuous line, some recording peaks of flowering records regularly recurring every 10-12 years (Figure1).

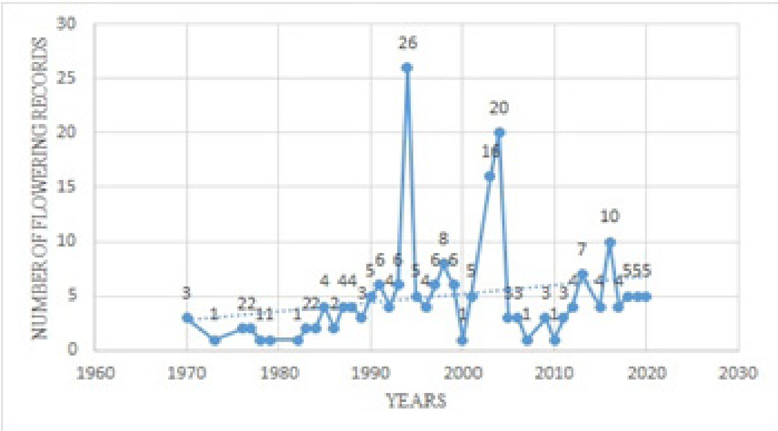


**Figure 1:** The increasing trend of Mediterranean flowering records in the period 1970-2020.

The trend of the course, characterized by some regular and spaced peaks, could be induced by conditions of thermal stress because such massive flowering events are closely related to corresponding peaks in seawater temperatures [16,17,18,19]. As regards the regional distribution of flowering records, it is shown a great variability between the Mediterranean countries with Spain, as the first country (92 records), Italy as second (70 records) and France as third (20 records) (Figure 2).

Finally, it is noteworthy to observe that the flowering records reported in these last fifty years are fairly distributed between continental (97 records, as 49%) and island regions (101 records, as 51%) (Figure 3).

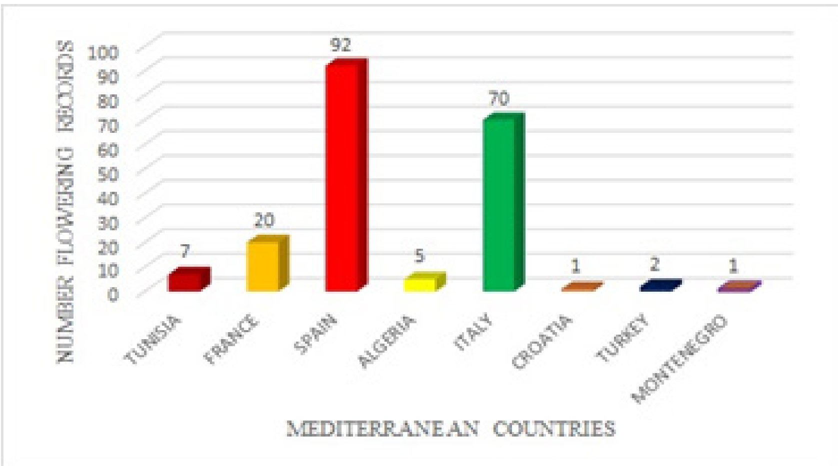


**Figure 2:** Regional distribution of Mediterranean flowering records in Mediterranean countries.

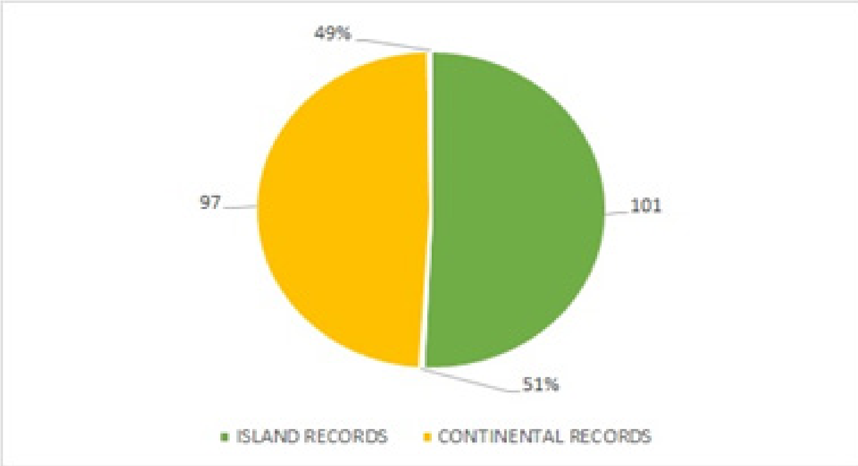


**Figure 3:** Number and percentages of flowering records distinguished in continental and island ones.

## Conclusion

Probably, the high number of flowering records, detected in island's waters, is reported by scientific literature because the recruitment sites of seedlings are very often located in the shallow seawaters of Marine Protected Areas (MPA) along the insulated coasts of Mediterranean Sea as Balearic, Corsica, Sicily, Sardinia and Egadi islands. In last decades it has been noted an increase in flowering records probably related to the gradual rise of SST. So, the increasing temperature of Mediterranean seawaters might support the sexual reproduction of the species [20], as highlighted by the increasing trend of flowering events in these last fifty years. This process could induce a greater genetic diversity in the gene pool of the species improving its high thermotolerance to warming conditions and, more generally, a better adaptive response against the variations of environmental conditions. However, until now, the dynamic of such process is little known, and it remains a debated issue. In this way, it is necessary to analyze in depth the annual variability of Posidonia flowering to better understand the process and its meaning in a climate change scenario. In conclusion, Posidonia oceanica species could be an important and early ecological indicator of the current climate changes induced by the warming trend of Mediterranean seawaters.

## Acknowledgments

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## Conflict of Interest

Author declares no conflict of interest.

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