



# Mediterranean warming triggers seagrass (*Posidonia oceanica*) mortality

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Photograph: Juan Serón Aguirre

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# Global Change Research Line: Rationale

**Problem Statement:** Global Change defines the impact of human activity on the functioning of the biosphere. Driven by increased use of resources by humanity (energy, water, land, biodiversity, chemicals and key elements), Global Change acts through a number of motors, including Climate Change, Desertification, Land Erosion, Water Shortage, Eutrophication, Hypoxia, Ocean Acidification, Pollution and Biodiversity loss. Global Change is the major challenge our society shall face in the 21st Century.

**Aim:** This research line aims at understanding the processes of Global Change, as defined above, and inform the societal responses to address this problem. We emphasize the interactions between the two coupled geophysical fluids of planet Earth: the Atmosphere and the Oceans, and the Biosphere, addressing impacts on climate and atmospheric chemistry and the chemistry and biology of the oceans.

**Development:** The Global Change Department was initiated in 2008 by merging capacities in marine ecology, oceanography and biogeochemistry present at IMEDEA with capacities in climate modeling and extreme meteorological events, which will provide the necessary scenarios of climate change forcing.

# Global Change Research Line: Potentials

**Structural:** Build Critical Mass, Improve Balance across Disciplines, and Improve training activities through incorporation of Climate Science and Environmental Chemistry scientists from Univ. Balearic Islands to the Research Line.

## **Research:**

- Develop future scenarios of climate-related risks, including extreme events, in the Mediterranean as a framework to evaluate the possible impacts on marine ecosystems and organisms.
- Improve our understanding of the role of aquatic ecosystems in the global carbon budget, and the impacts of atmospheric inputs of materials on marine ecosystems.
- Assess the synergies between multiple pressures (UV increase, warming, hypoxia, etc.) on marine ecosystems and biodiversity.
- Further develop the conceptual framework and empirical analyses addressing threshold effects and abrupt changes in ecosystems in response to global change components.
- Evaluate the footprints of global change impacts on the global ocean ecosystem (leading the *Malaspina 2010 circumnavigation cruise*).

**Dissemination and Training:** Strengthen the dissemination and training efforts and their impact.

Global warming is emerging as a global threat to biodiversity, with a major loss of biodiversity predicted as warming progresses along the 21<sup>st</sup> Century (*IPCC 2007*)

Most of the evidence of impacts of climate change on biodiversity derives from terrestrial systems: 28 501 reports for terrestrial biodiversity vs. 85 for marine biodiversity



Most of the evidence of climate change impacts on marine biodiversity deals with corals, but marine habitats vulnerable to climate change abound beyond coral reefs (*Duarte et al 2008*).

Climate change may impact, particularly, marine ecosystems already stressed by other pressures.

marine undersampling. The number of time series from different environments included in the recent IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report differ widely. Marine systems are vastly underrepresented compared with terrestrial systems (1).

*Richardson and Poloczanska 2008*

## Seagrass ecosystems rank amongst the most threatened marine habitats

QuickTime™ and a decompressor are needed to see this picture.

Climate change emerges as a force possibly delivering the *coupe-de-grace* to already stressed seagrass meadows.

Causes of global seagrass decline: cumulative processes (Eutrophication, mechanical impacts, submarine erosion, *climate change*)

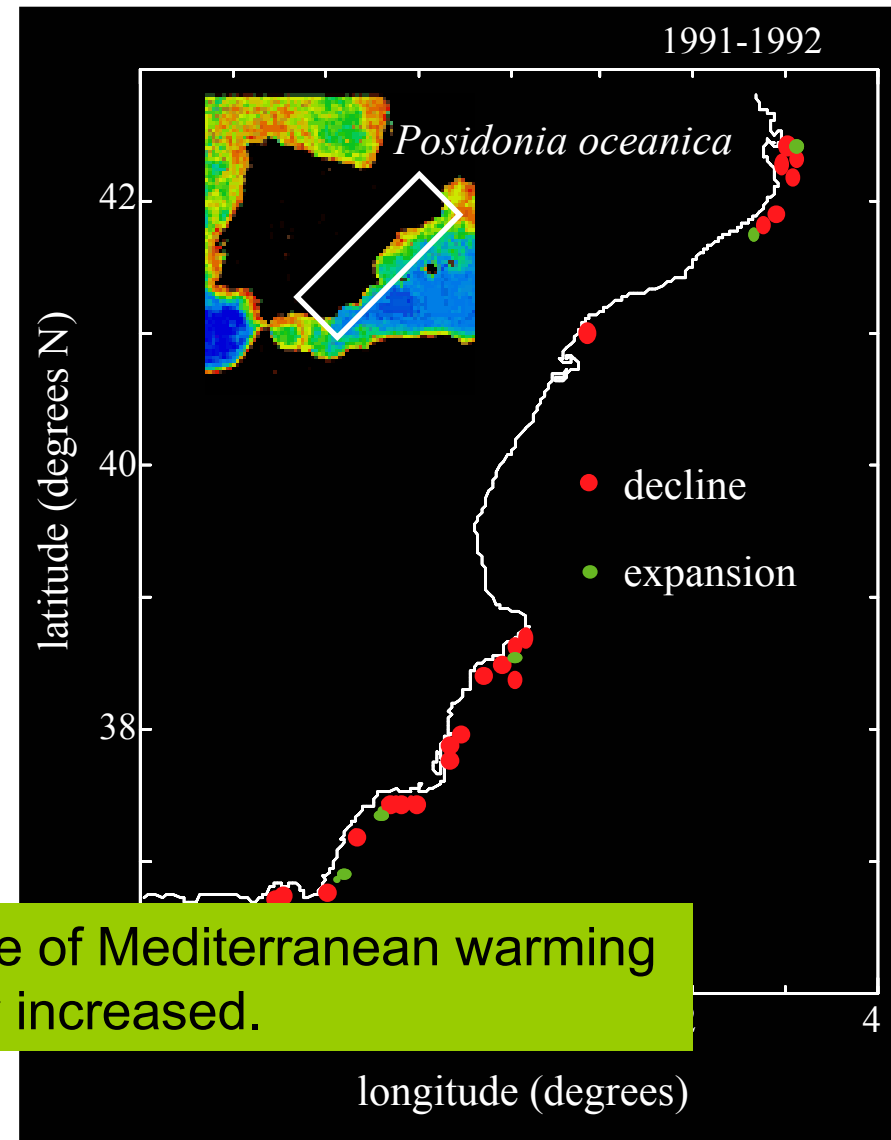
However...

Assessments of the demographic status of the seagrass *P. oceanica* in the 1970's and the end of 20<sup>th</sup> Century showed a trend towards general decline in the Spanish Mediterranean, also in pristine areas

- 80 % of the meadows in decline
- Reduction of shoot density by

50

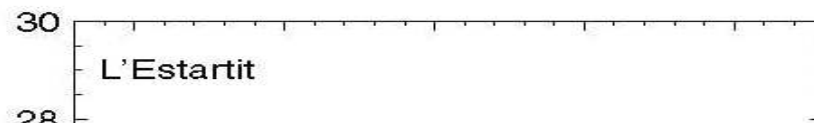
Since these studies, the rate of Mediterranean warming has clearly increased.



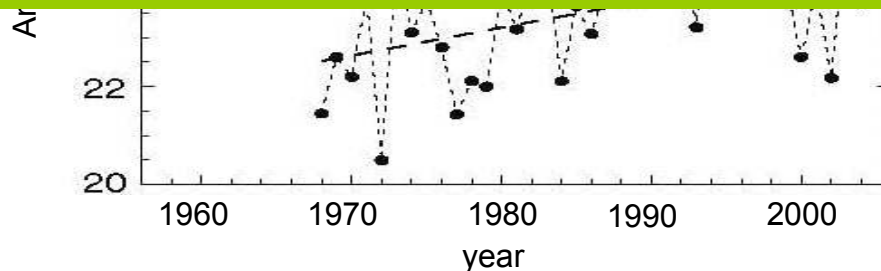
The Mediterranean Sea is particularly vulnerable to warming, rates of seawater warming exceeding by 4-fold those of the global ocean

QuickTime™ and a decompressor are needed to see this picture.

Mean Global SST warming  $\approx 0.13$  °C per decade (*IPCC WG1 2007*)



Thus, there is a need to test if seawater warming is triggering seagrass mortality only in already impacted meadows by other stresses or also in pristine ones



## Objective

To provide evidence of a close relationship between seawater warming and mortality of *Posidonia oceanica* meadows in a protected and relatively pristine Cabrera National Park (Spain)

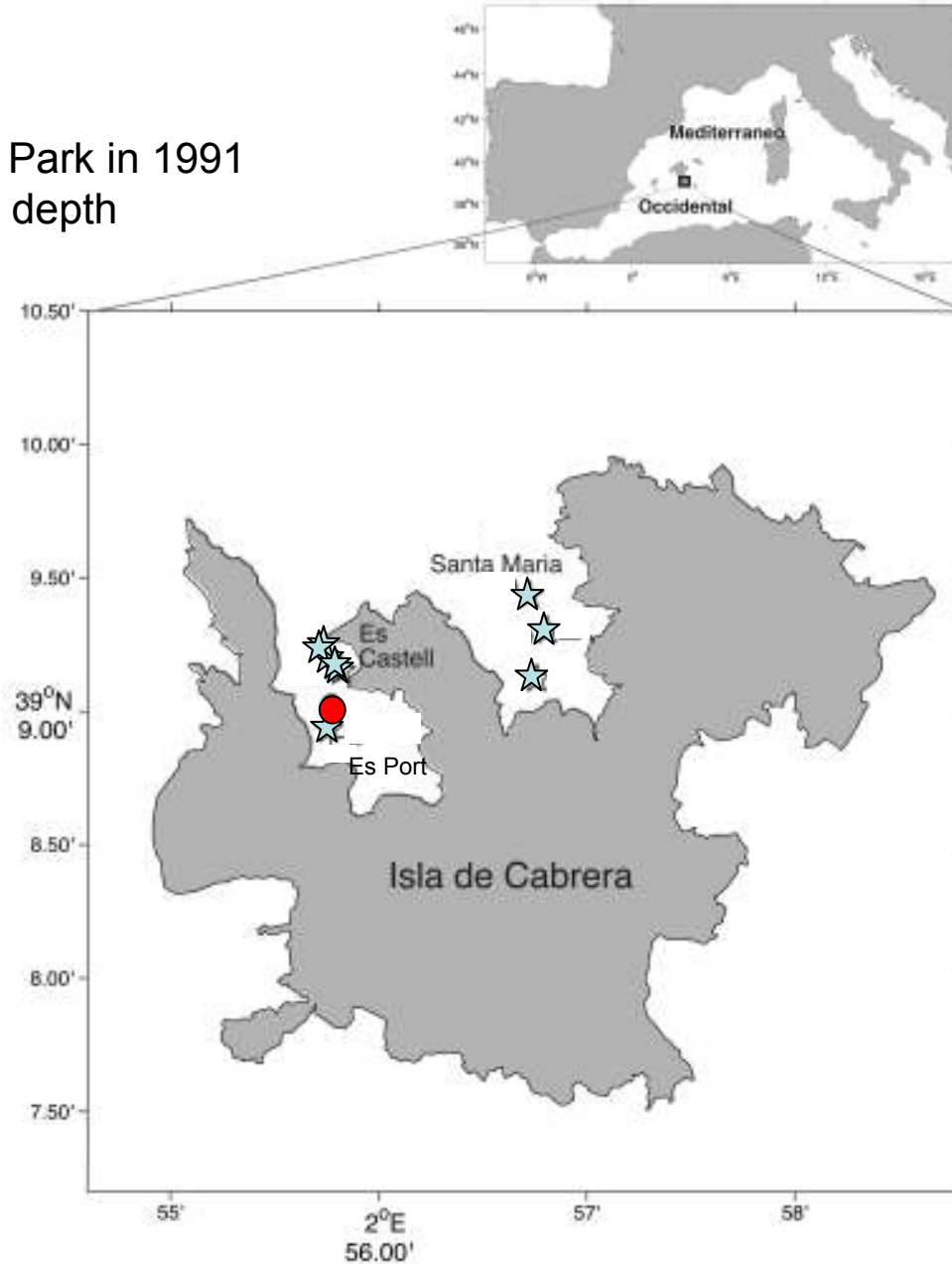
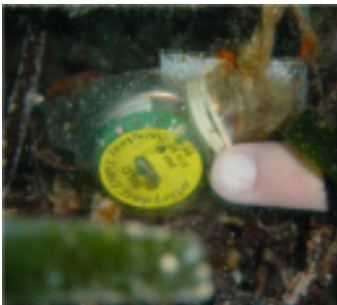


## Study site

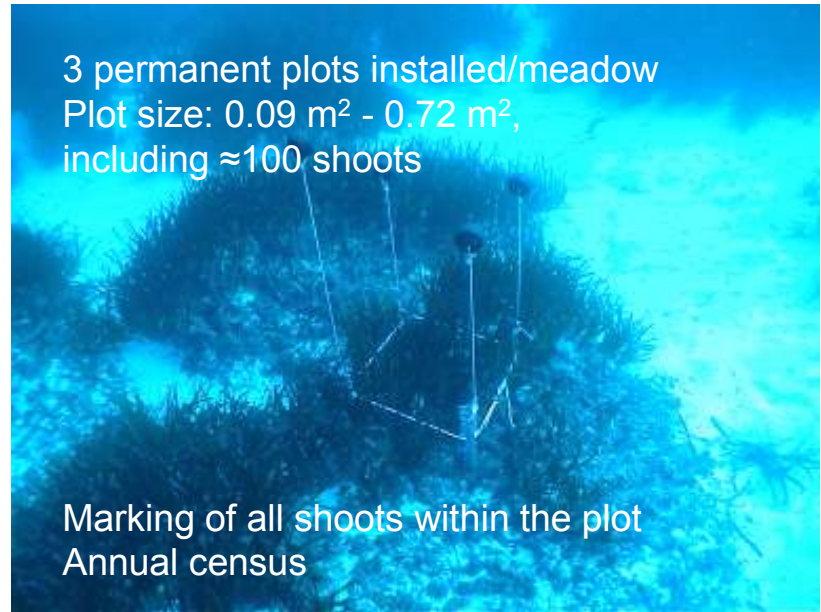
Archipelago declared National Park in 1991  
*P. oceanica* meadows to 45 m depth

☆ Annual monitoring of  
*Posidonia oceanica*  
demography in 9 stations  
(5m - 25 m depth)

● Temperature recorded  
continuously in 1 station  
since year 2002 (17 m  
depth)



# Annual monitoring of *Posidonia oceanica* demography since year 2000



*Annual shoot recruitment*

$$R = \frac{(\ln(N_{T_1} / N_{S_1})) \cdot 365}{t_1 - t_0} \quad (\text{yr}^{-1})$$

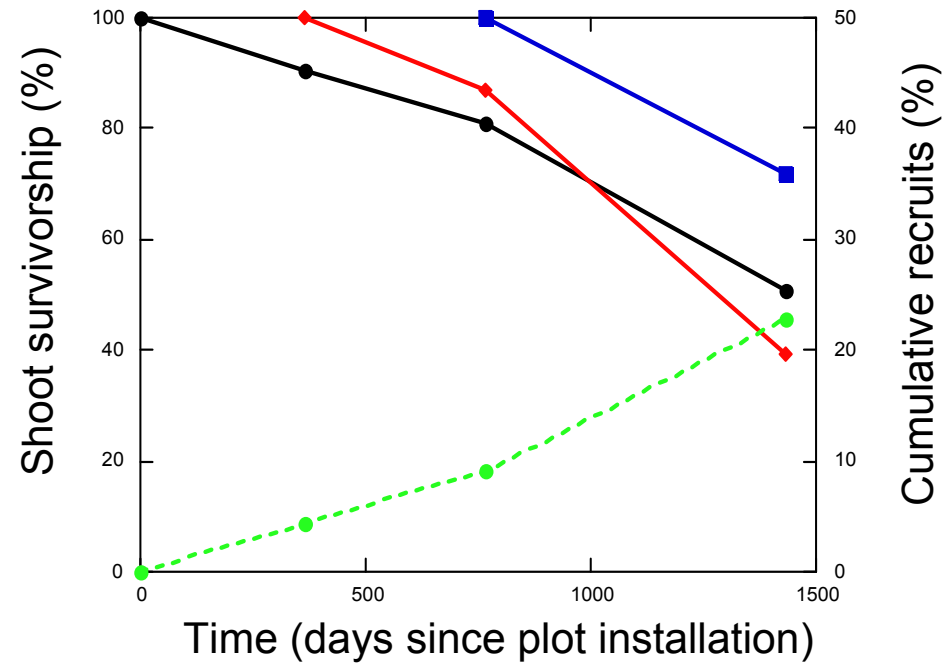
*Annual shoot mortality*

$$M = \frac{(\ln(N_{T_0} / N_{S_1})) \cdot 365}{t_1 - t_0} \quad (\text{yr}^{-1})$$

*Annual net population growth*

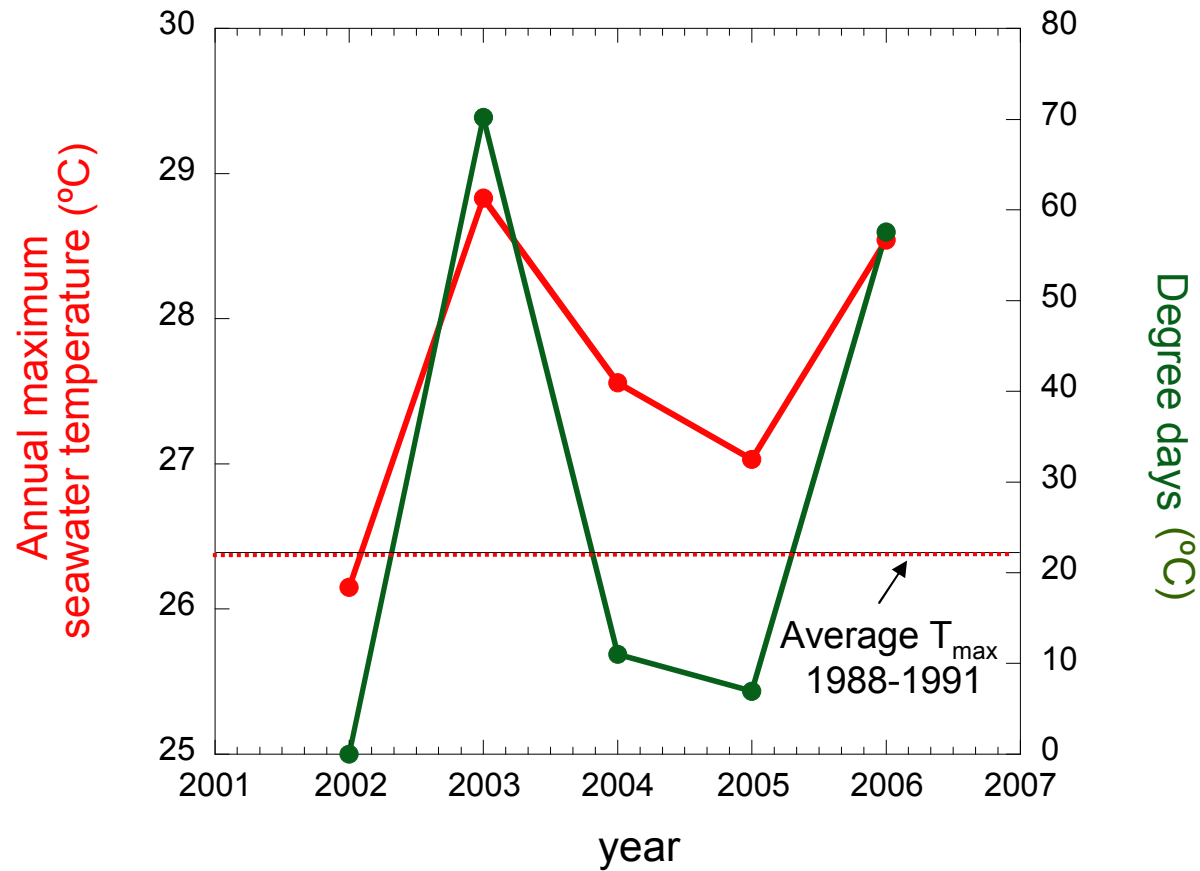
$$R_{\text{net}} = R - M$$

$R_{\text{net}} > 0$  expanding  
 $R_{\text{net}} < 0$  declining  
 $R_{\text{net}} = 0$  steady-state

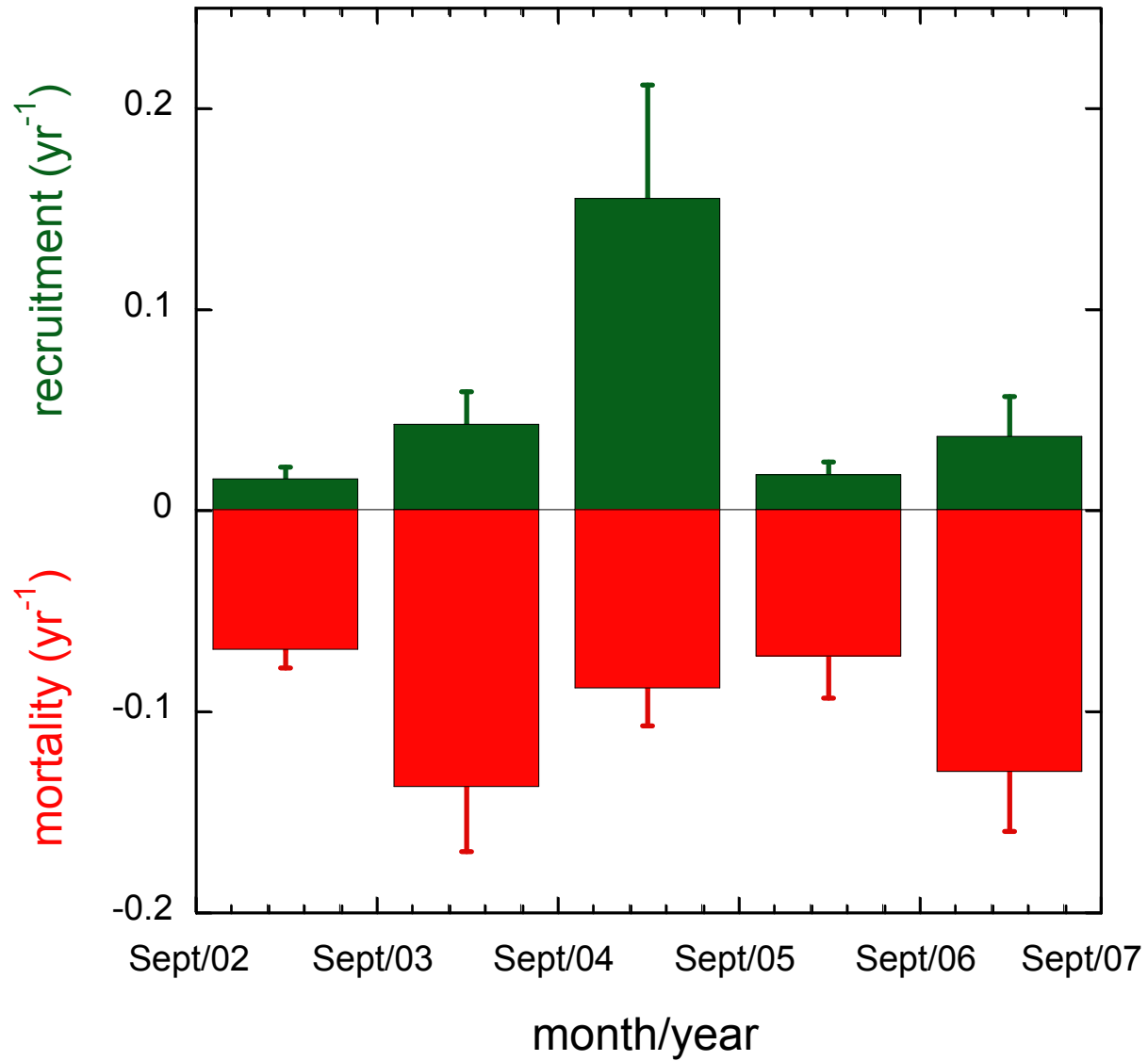


## During 2002-2006 seawater was warmer than during 1988-1991

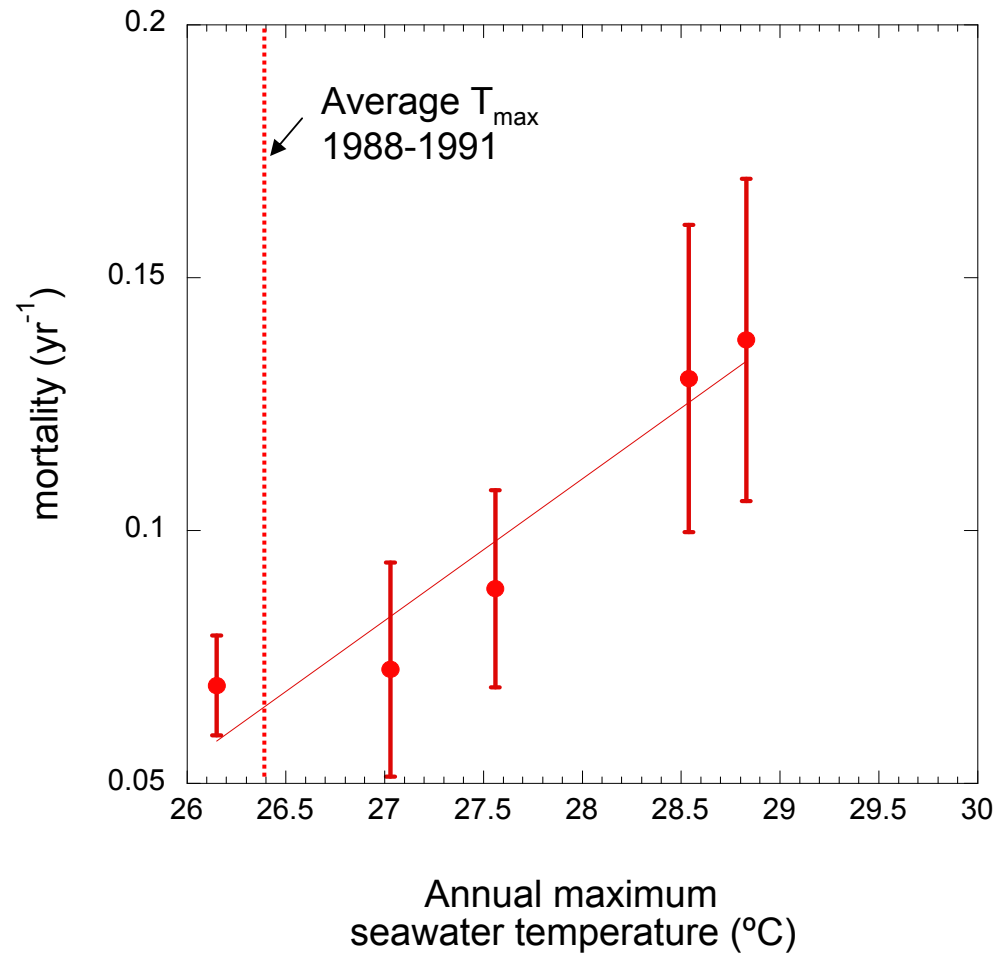
- annual  $T_{\max}$ , on average, exceeded by 1 °C that for the period 1988-1991
- annual  $T_{\max}$  for all years but 2002 was higher than average annual  $T_{\max}$  for 1988-1991
- the number of days exceeding 26.4 °C ranged from 0 (year 2002) to 58 (year 2006)
- the accumulated degrees above 26.4 °C during the growth season ranged from 0 to 70.2 °C



*Posidonia oceanica* demography exhibited wide interannual fluctuations

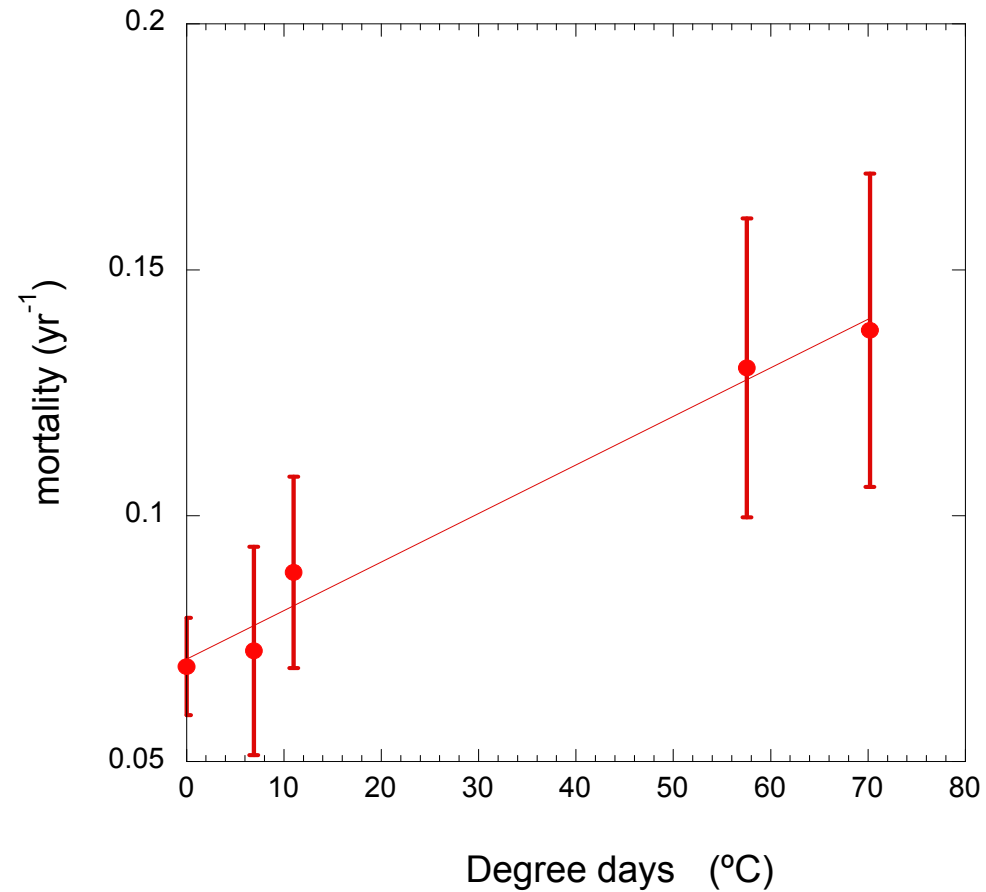


*P. oceanica* mortality increased by 0.03 yr<sup>-1</sup> for each degree of warming



$$\text{mortality (yr}^{-1}\text{)} = -0.71 + 0.03 (\pm 0.004) T_{\text{max}} (\text{°C})$$
$$R^2 = 0.90; P < 0.005$$

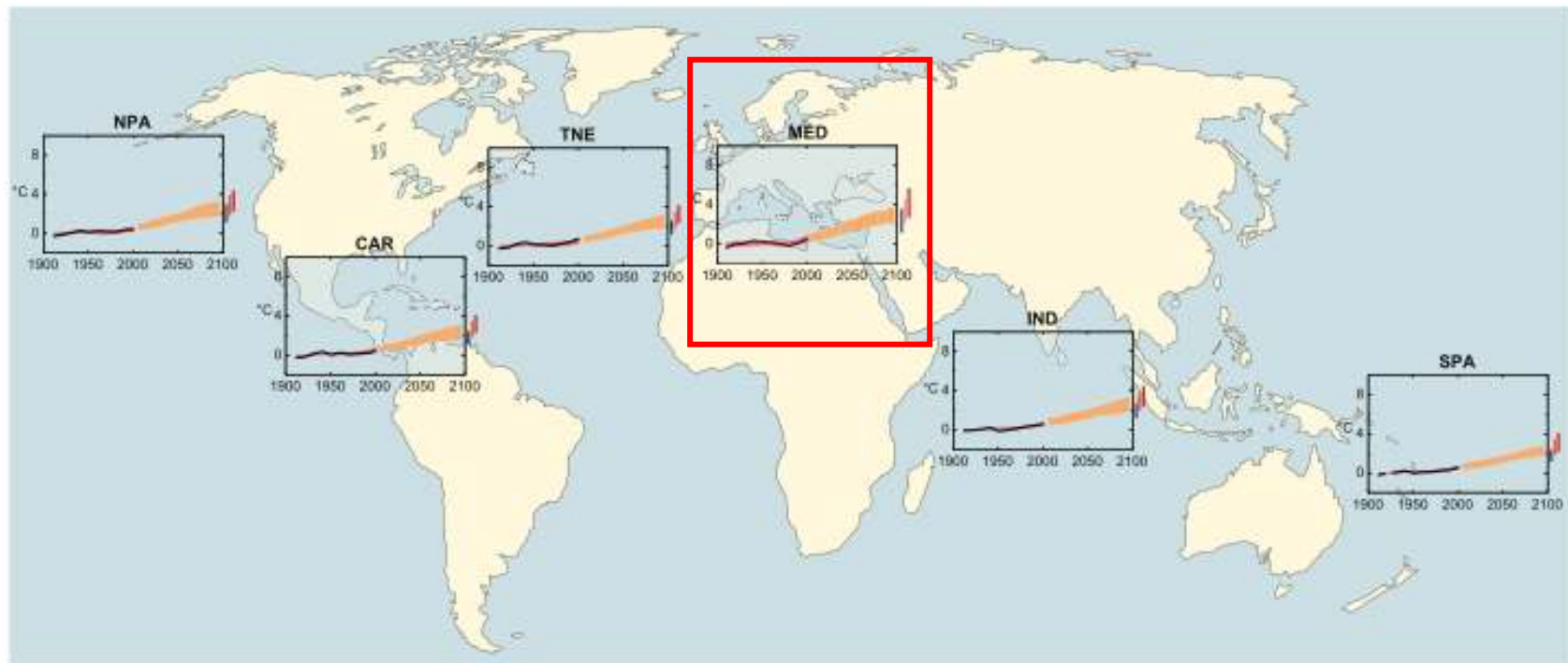
*P. oceanica* mortality increased by 0.001 yr<sup>-1</sup> for each degree day above 26.4 °C



$$\text{mortality (yr}^{-1}\text{)} = 0.07 + 0.001 (\pm 0.0001) \text{ degree days (}^{\circ}\text{C)}$$
$$R^2 = 0.96; P < 0.0005$$

## Conclusions

- There is a clear relationship between seagrass mortality and increased warming for nearly pristine meadows. The seagrass mortality and declining rates during 2002-2006 in Cabrera National Park has been higher than that during 1990's (*Marbà et al 2002*).
- *P. oceanica* is the dominant Mediterranean seagrass, forming lush meadows with high conservation value. This species ranks amongst the slowest growing plant in the Biosphere, requiring long life spans for meadow recovery. Hence, *P. oceanica* meadows are extremely vulnerable to impacts, including climate change, as any losses are irreversible.
- *P. oceanica* losses following heat waves double those in other years. Despite seawater warming also enhances sexual reproduction (Diaz-Almela et al 2007), it is not sufficient to compensate for shoot losses. Provided two such heat waves occurred within 6-year study, the meadows could be decimated in a couple of decades.
- Plant metabolism alone cannot explain the high increase of *P. oceanica* mortality with increasing seawater temperature. The increase of community respiration, sediment sulfate reduction rate, resource investment to reproduction, ... enhanced by seawater warming may accelerate *P. oceanica* mortality.
- Considering the IPCC scenarios of global warming, the rate of decline of *P. oceanica* meadows during the 21st century could be twice (or 3-fold) the current rate.



**Figure 11.22.** Temperature anomalies with respect to 1901 to 1950 for six oceanic regions for 1906 to 2005 (black line) and as simulated (red envelope) by MMD models incorporating known forcings; and as projected for 2001 to 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the orange envelope represent the range of projected changes for 2091 to 2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). The black line is dashed where observations are present for less than 50% of the area in the decade concerned. More details on the construction of these figures are given in Box 11.1 and Section 11.1.2.



Mediterranean extension: 50,000 Km<sup>2</sup>

(*Bethoux and Copin-Montégut 1986*)

Depth range: 0 m- 43 m

Dominant ecosystem on sandy coasts

Clonal plant

Clone longevity > 1000 yr (clone at Formentera of at least 8 km ~  
100 000 yr, *Arnaud-Haond et al submitted*)

Shoot life span up to 50 yr

Horizontal growth 1-6 cm yr<sup>-1</sup> (*Marbà and Duarte 1998*)

Low flowering intensity and scarce seed production (although it  
varies interannually, largely in response to temperature stress,

*Díaz-Almela et al 2005*)

Patch formation rate very low: 0.004 - 0.02 patches m<sup>-2</sup> yr<sup>-1</sup>

(*Díaz-Almela et al submitted*)