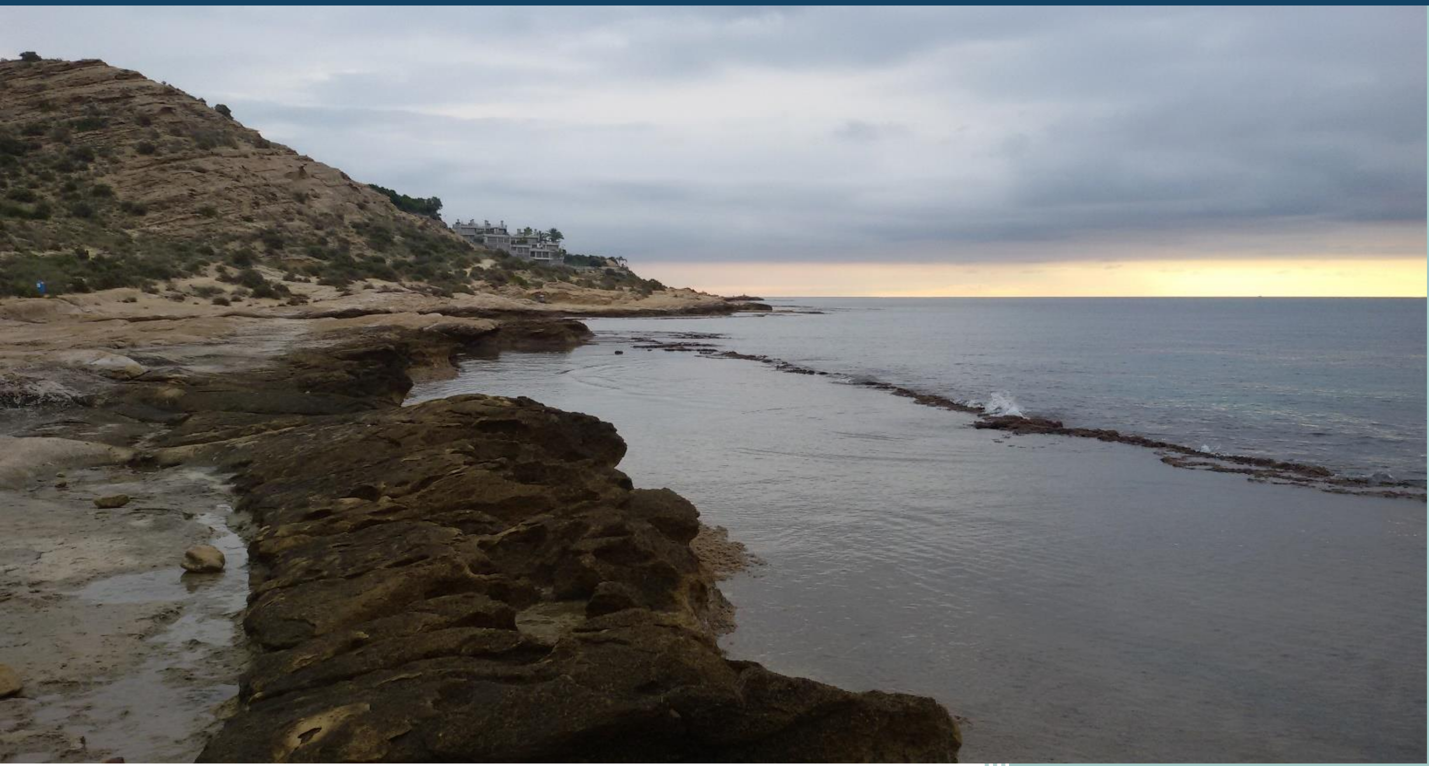
EXTREME-REEF Project: Research for adaptation: understanding the effects of extreme climate events on coastal reefs.

EXECUTIVE REPORT



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1. Introduction

The habitat reef (1170; fig. 1) is a marine habitat of community interest (habitat Directive (92/43/EEC)) that has the designation of Special Area of Conservation (ZEC) in Spain (Law 42/2007, of December 13, on Natural Heritage and Biodiversity). Reefs can have a biological or geological origin and shelter high diverse communities which provide important ecosystem services, such as protection against storms or being sinks of CO_2[1]. This habitat is highly sensitive to the current scenario of impacts derived from climate change, such as increased extreme weather events and ocean acidification[2].

Figure 1. Biogenic rock reef, *Dendropoma* sp.

Climate change alters, not only the average levels of environmental parameters such as temperature, but also the disturbance regime of ecosystems[3], increasing the occurrence of climate extreme events[4]. These extreme events are disturbances of a high intensity and a low frequency, such as heat waves, severe storms or low tide episodes due to high atmospheric pressure[5.6] (fig. 2). Due to their catastrophic nature, extreme events produce a remarkable impact on ecosystems[7]. The increased occurrence of extreme events is expected to have deleterious consequences on ecosystems[8,9].

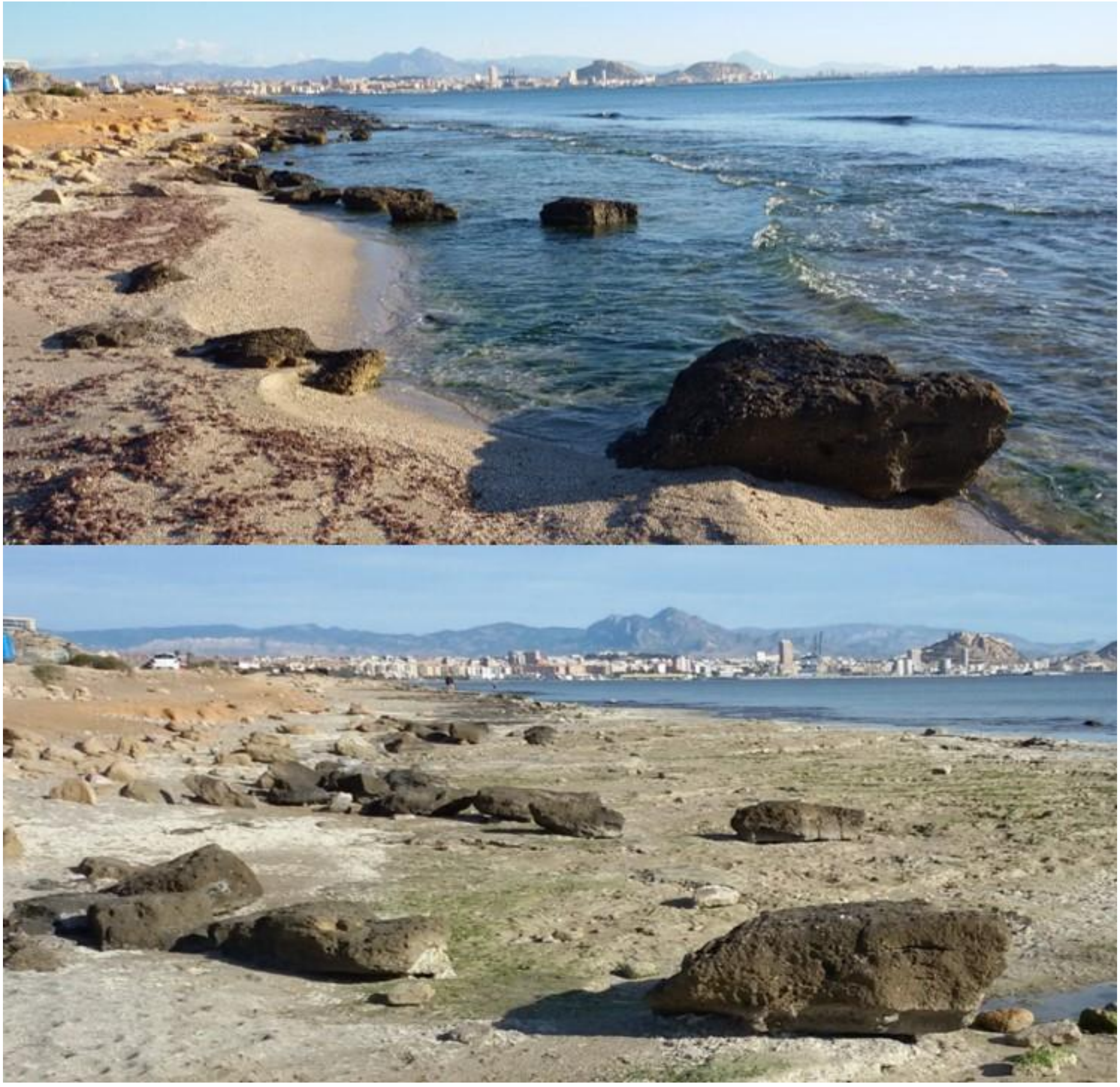


Figure 2. Comparison of a reef under normal conditions (photograph above) and suffering an episode of an extreme low tide as a result of high atmospheric pressure (photo below).

Other anthropic disturbances, such as pollution or eutrophication, have also negative effects on coastal reefs. Currently, ecosystems are, in many cases, affected by multiple environmental stressors simultaneously. The combination of various of these factors can have cumulative effects, affecting biological communities more severely than when they act in isolation [10,11].

In this scenario arises the project EXTREME-REEF, which has the support of the Biodiversity Foundation of the Ministry for the Ecological Transition and the Demographic Challenge.

OBJECTIVES

Assess the effect of climate change associated to extreme events and its interaction with eutrophication and the invasive algae *Caulerpa cylindracea* in marine protected areas in the marine habitat reef (1170; Habitats Directive, EU).

- Investigate the effect of extreme events due to storms and low tides on the biological communities of *Dendropoma* sp. biogenic reefs, their diversity and their interaction with eutrophication and *C. cylindracea*.
- Promote actions for the conservation and sustainable use of biodiversity oriented to the mitigation and adaptation of reefs to climate change.
- Promote management measures against extreme events for reefs.

The purpose of this executive summary is to make known to the different stakeholders the main results and conclusions of this project so that environmental managers have relevant information that helps them design efficient environmental management strategies aimed at the conservation of this habitat of community interest in the current framework of global change marked by the climate emergency.

2. Research studies

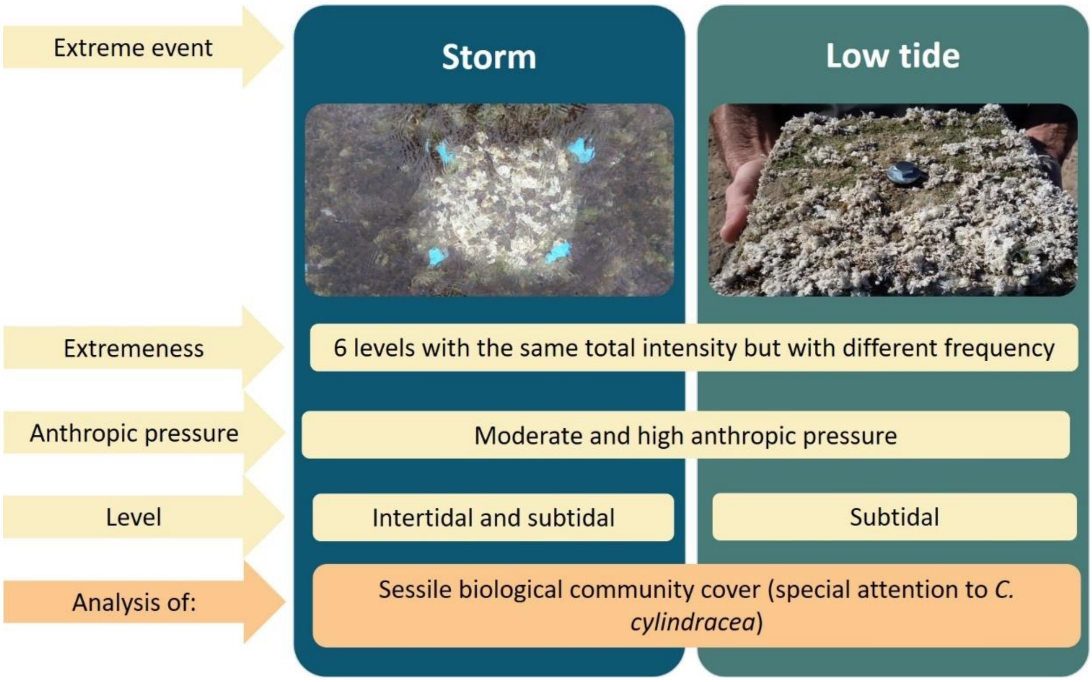
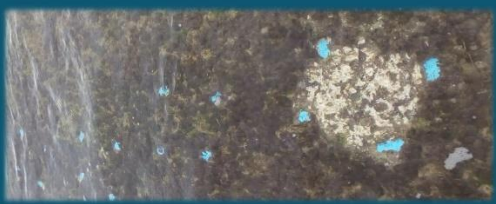


Figure 3. Outline of the experimental design of the experiments carried out in the EXTREME-REEF project.

In this project, the effect of two types of disturbances (storms and low tides) on the reef habitat has been studied through a manipulative approach on two rocky shores with contrasting levels of anthropic pressures (mainly eutrophication) in the Spanish marine demarcation levantino-balear. Extreme events were simulated by inversely modifying the frequency and intensity of each type of disturbances, storms and low tides, ranging from several low-intensity disturbances to one disturbance of a high intensity (extreme event); so that all simulations/treatments had the same total intensity. The experiment was performed at the intertidal level for the storms and at the shallow subtidal level (0.1-0.4m deep) for the storms and extreme low tides. The effect of these types of extreme events was studied in the sessile biological community for the short and long term (fig. 3 and 4).

Storm

- 160 plots (50x50 cm)
- Simulation → elimination of cover of sessile species by hammer and chisel.
- Performed at the intertidal and shallow subtidal level.
- 2 times of the year → winter and summer
- 10 samples x 160 plots
- 1600 samples



Low tide

- 50 plates (25x25 cm)
- Previously plates were allowed to colonize.
- Simulation → extraction of plates out of the water.
- Performed at the shallow subtidal level.
- In winter (when these events occur).
- 6 samples x 50 plots
- 300 samples

Figure 4. Number of experimental units, methodology, tidal levels, times of year and sampling carried out for each experiment of extreme events simulation as a result of climate change.

3. Featured results

Storm

- The impact was greater in the community suffering a greater anthropic pressure (eutrophication).
- One extreme storm had a greater effect on the biological community than several low-intensity extreme storms.
- The effect was greater in the subtidal than in the intertidal community.
- Communities subjected to extreme storms took more than a year to return to their natural biodiversity status.
- The recovery time was longer in the subtidal than in the intertidal community.

Low tide

- The impact was similar in reefs with moderate and high anthropic pressure (eutrophication).
- Frequent, short low tides produced more prolonged biological community changes than infrequent, prolonged low tides.
- Reef communities subjected to extreme low tides took more than a year to recover.

Caulerpa cylindracea

- The invasibility of *C. cylindracea* increased with the decrease in the extremeness of storms.
- Storm disturbances had a greater effect on *C. cylindracea* than disturbances by low tides.
- Maintaining a good habitat ecological status limits the expansion of this invasive species.

4. Management measures

PREVENTION	Urgent measures are needed to reduce the emission of greenhouse gases to mitigate the effects of climate change such as the increased occurrence of extreme events that negatively affect reefs. Although reducing greenhouse gas emissions is a global challenge, it is advisable to maximize reduction efforts at the different possible levels of action (local, regional, state and global).
ADAPTATION	Maintaining a good environmental status of reefs is a priority to maximize the resilience of biological communities and their diversity in the face of extreme events arising from climate change. It is recommended: ▪ Establish strict limits on pollutants discharged into the sea, to avoid environmental impacts (such as eutrophication) on reef habitat, which limit the ability to adapt to climate change. ▪ Know the ecological status of the reef habitat to detect degraded areas and establish corrective measures to reverse the state of degradation of this habitat in the face of the increase in extreme events derived from climate change.

5. Future challenges

Next, we comment future challenges oriented to increase our knowledge on reefs in relation to extreme events, which can help in the management of this habitat, to maximize its capacity to adapt to climate change:

- To study the effect of extreme events on other invasive species.
- To study the effect of other extreme events, such as heat waves on reef habitat.
- Conduct similar studies in all demarcations of the Spanish coast to have a more complete view of the effect of extreme events on this habitat.

6. References

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