Marie Curie IIF: 298594, CC and Marine Life

Final Report: Publishable summary

Marine habitats are socially and economically important to millions of people around the world, but accelerated global climate change poses a significant threat to organisms, communities and ecosystems. Accurate predictions of the effects seawater warming and other stressors on marine life are needed to successfully manage our seas and plan for future change. Of all the facets of global change, increasing temperature is perhaps the most important, as temperature affects all biological processes, from genes to ecosystems. In terrestrial systems, researchers have used polytunnels and cloches to manipulate climate to investigate the effects of warming on community structure, dynamics, and biodiversity. There have been very few such experiments conducted in the marine realm. As such, a major knowledge gap relates to the lack of field-based experiments conducted on marine organisms to date, and most knowledge stems from laboratory manipulations, which suffer from issues of artificiality and realism. This project aimed to develop a novel technology, the 'hot plate system' (hereafter HPS), to facilitate complex warming experiments in marine environments. The technique will allow temperature to be controlled *in situ*, to experimentally examine the responses of microbial biofilms, invertebrate populations and whole assemblages to warming. More generally, the project aimed to enhance understanding of the effects of discrete warming events on marine biodiversity.

A significant research effort has focussed on the development of the HPS, which has been tested and is fully operational. The system, which comprises 30 settlement panels that can be warmed to >10°C above ambient temperature, uses microprocessors and embedded temperature sensors to actively maintain required temperature treatments (Fig. 1). The HPS has a 'top-side' control unit that allows real-time temperature control and monitoring and ensures safe data logging (Fig. 1). The HPS has facilitated 2 successful experiments, in which temperature over the panels were maintained at 3°C and 5°C above ambient for a period of 30 days or more (Fig. 2). The warming treatments tracked natural temperature variability, driven by tides and storms, near-perfectly and the HPS generated very realistic warming treatments. Marine microbes and invertebrates were allowed to colonise the heated surfaces and were later examined to determine the effect of warming (Fig. 2). In experiments conducted to date, bacteria and metazoans have shown a marked increase in abundance under warmer conditions, and the structure of entire assemblages has also changed with increased temperature. This suggests that short-term warming can alter patterns of marine biodiversity and promote growth of marine organisms, including common biofoulers and non-native species. Further work is needed to examine warming effects during thermal maxima and on alternative assemblage types. The HPS will

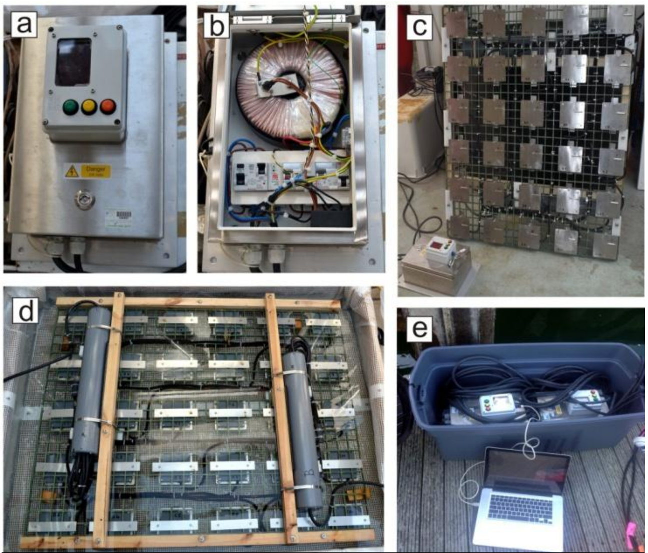

Fig. 1. The Hot Plate System. The system is controlled via a topside unit (a), which transforms mains electricity to a safe working current (b) and also sets the desired temperature treatments and logs data. Power is supplied to 30 individual plates (c) which are controlled by microprocessors within housings (d). During deployment, data can be extracted and treatments can be modified (e).

be used to examine synergistic effects of multiple stressors (i.e. temperature and elevated nutrients/acidity) by running 2 systems simultaneously in high/low nutrient habitats (i.e. near run-off outlet) and high/low acidification conditions (i.e. along a pH gradient caused by volcanic activity). The outcomes of the research will include a better understanding of how warming (and other stressors) will affect non-native species, commercially important species (e.g. mussels), biofouling species, and marine biodiversity more generally.

In a complementary experiment, the response of mature assemblages of marine invertebrates to simulated warming was examined through a complex mesocosm experiment. Settlement panels were deployed in a marine habitat and naturally-occurring assemblages were allowed to develop to maturity. Panels were then transferred to a mesocosm facility where they were subjected to simulated heat waves of differing magnitudes, timings and durations. The experiment examined the impacts of short-term seawater warming on species' performance (i.e. growth, mortality), ecological interactions (i.e. competitive outcomes) and the development of entire assemblages and the relative success of native versus non-native species. Results to date suggest that, contradictorily to our expectations, the realistic warming treatments did not have negative impacts on mature sessile assemblages. This experiment highlights the importance of life stage, biogeography and assemblage-type on the susceptibility of marine organisms to climate variability.

In addition to the HPS experiments, research has focussed on examining ecological impacts of extreme warming events observed in nature, specifically the 2011 marine heat wave recorded off Western Australia. The heat wave was the highest-magnitude warming event on record, with temperatures 3-5°C above the long-term summer average recorded for >8 consecutive weeks. This project has examined how populations of ecologically-important species (i.e. habitat-forming seaweeds, sea urchins) were impacted by the warming event. Extensive surveys showed that a critical canopy-forming seaweed was decimated by the heat wave, which caused widespread mortality and the species to undergo a poleward range contraction of >100 km. This is ecologically-significant, as the seaweed formerly contributed considerably to benthic productivity and habitat provision. The responses of sea urchins and other mobile invertebrates have also been examined. Improved understanding of how extreme climatic events, which are predicted to increase in severity as a direct consequence of anthropogenic climate change, affect marine ecosystems will enhance our ability to predict, and plan for, ecological responses to environmental change.

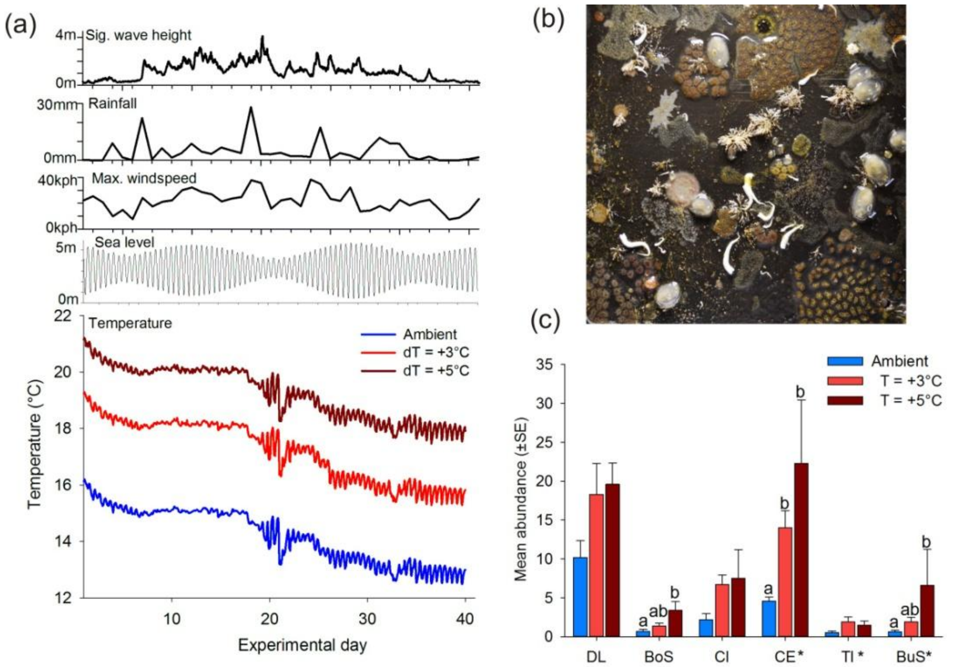

Fig. 2. Results of the first hot plate experiment, Plymouth 2013. Temperatures over the heated panels were maintained with high precision and tracked natural variability (a). After 40 days, heated plates were colonised by a range of marine invertebrates (b), many of which exhibited positive responses to micro-habitat warming (c).