Communicating **climate change**

Professor Brian Helmuth leads efforts to forecast and nowcast viable biological adaptation strategies for coastal species under threat from the inexorable course of climate change

What are the current objectives of the Helmuth Laboratory?

Work in our lab focuses on understanding how and where coastal organisms are most likely to be impacted by climate change and related stressors, and on communicating that information to decision makers. A hallmark of our research is that we combine computer models, deployment of novel sensors and laboratory and field experiments to detect the impacts of environmental change at the scale of organisms. We then integrate this information with data on organism vulnerability based on lab and field measurements.

What can be done to prepare for and minimise human-induced climate impacts?

There is no longer a question as to whether human-induced climate change is happening; the questions are how much will it continue to change and what must we do about it?

We know that climate change is highly heterogeneous in both space and time in its impacts. Biology can help by identifying 'winners' and 'losers' amongst species, providing guidance for capitalising crop or aquaculture species that we want to exploit and interceding with threatened species that we want to protect.

A hallmark of natural systems is that they are inherently nonlinear, so there is considerable concern regarding 'tipping points' or extreme responses of ecosystem function to comparatively small changes in environmental stressors. By understanding the mechanisms by which organisms interact with their physical environment, as well as how species interactions are affected by environmental change, we can identify what the likely triggers of tipping points are. In doing so, we may be able to prevent some of the worst impacts through the creation of 'guard rails' – mechanisms that prevent the triggers from happening. Climate change almost always interacts with other stressors. So in areas where the effects of climate change push organisms and ecosystems to their limits, we may be able to alleviate the pressure by reducing non-climatic stressors, such as intensive harvesting or pollution.

You mention mechanisms behind organism interaction; can you explain what mechanistic niche modelling is?

Mechanistic niche modelling views the effects of the environment through the 'filter' of the organism – in other words, environmental data can't be considered independently of the organism with which the environment is interacting.

For an animal currently living below its thermal optimum, an increase in temperature may lead to an increase in performance. For an animal already at its optimum, an increase in temperature could mean a decrease in performance or even death. Importantly, the shape, colour and behaviour of an animal greatly affect its temperature; for example, a black mussel may experience a very different body temperature than an adjacent sea star, even when exposed to the same environmental conditions.

We create biomimics – temperature data loggers that match the thermal characteristics of animals such as mussels and sea stars. We have deployed these on every continent except Antarctica, and they show that geographic patterns in temperature are far more complex than one might anticipate. They show 'thermal mosaics', where in some cases, sites far to the north can have mussels that are as hot or hotter than mussels far south as a result of local conditions. These results suggest that over-simplistic models of shifts in species range boundaries are likely to be violated in any but the broadest terms.

How does your research link to the larger Urban Coastal Sustainability Initiative (UCSI)?

The UCSI brings together academic researchers and practitioners to address pressing environmental challenges. The goal is to find creative solutions for cleaner, smarter and safer coastal communities. Our work fits well within this framework, because it explores how we share information among different stakeholders and scientists – for example, physical data affect ecological systems, which in turn affect socioeconomic systems. We ask how information is transferred among these levels, and how understanding mechanisms can help us to understand underlying sensitivities to environmental change.

Finally, do you have any exciting future plans?

We are creating an underwater observatory at the Nahant Field lab – the Marine Science Center – to monitor environmental parameters. It will be shared with our international collaborators who are deploying similar instrumentation. And in 2014, we are collaborating with the the International Network for the Study of Rocky intertidal Ecosystems (INSHORE) team to teach a course in Basra, Iraq on the shores of the East Hammar Marsh to help train Iraqi students in understanding how environmental change is affecting ecosystems in the Middle East.

Graduate student Cristian Monaco conducts work on the sea star *Pisaster* on the Pacific coast of the US.

Predicting winners and losers in the era of climate change

A team at Northeastern University, USA is analysing the responses of marine organisms to changes in temperature, with the ultimate goal of developing climate change guidance for coastal city and ecosystem policy makers

COASTAL ZONES ARE home to more than 40 per cent of the world's human population, and most of the world's megacities. They serve as critical habitat for fisheries and provide valuable ecosystem services. Yet coastal ecosystems are under increasing pressure from climate change and other stressors.

In 2011, Northeastern University set up the Urban Coastal Sustainability Initiative (UCSI), connecting scientific, legal, sociopolitical and engineering disciplines to study the influence of human activities on these ecosystems and to find creative solutions for cleaner, safer and smarter coastal cities. Within the framework of the UCSI, Professor Brian Helmuth has joint appointments in the University's School of Public Policy and Urban Affairs and the Department of Marine and Environmental Sciences.

The generalised way in which scientists often communicate the effects of climate change to policy makers and the public can unintentionally undermine the credibility of the scientific evidence. People's perceptions are simply rooted in their experience of weather in their particular locale, whereas climate change is measured by variations on a larger scale over decades, centuries and millennia. To Helmuth: "Understanding the weather-climate continuum is crucial. Changes in climate are very real, but the impacts of altered climate are manifest through weather".

CLIMATE CHANGE COMPOUNDS ECOSYSTEM STRESS

The group's work emphasises the fact that the effects of climate change are not globally uniform. Consequences, even for members of the same species of flora or fauna, will also vary according to an array of factors, most notably symbiotic or competitive interactions with other species, microclimates and time-dependent changes in temperature. Fundamentally, a small increase in ambient temperature will interact with other stressors and so exacerbate their impact: "We know that there are 'many ways to die', not only including extremes in conditions, but also chronic exposures to stress, or indirect effects on predators and competitors," Helmuth explains. "Climate change is a threat multiplier. Yet this is often not how we discuss it, especially with non-scientists."

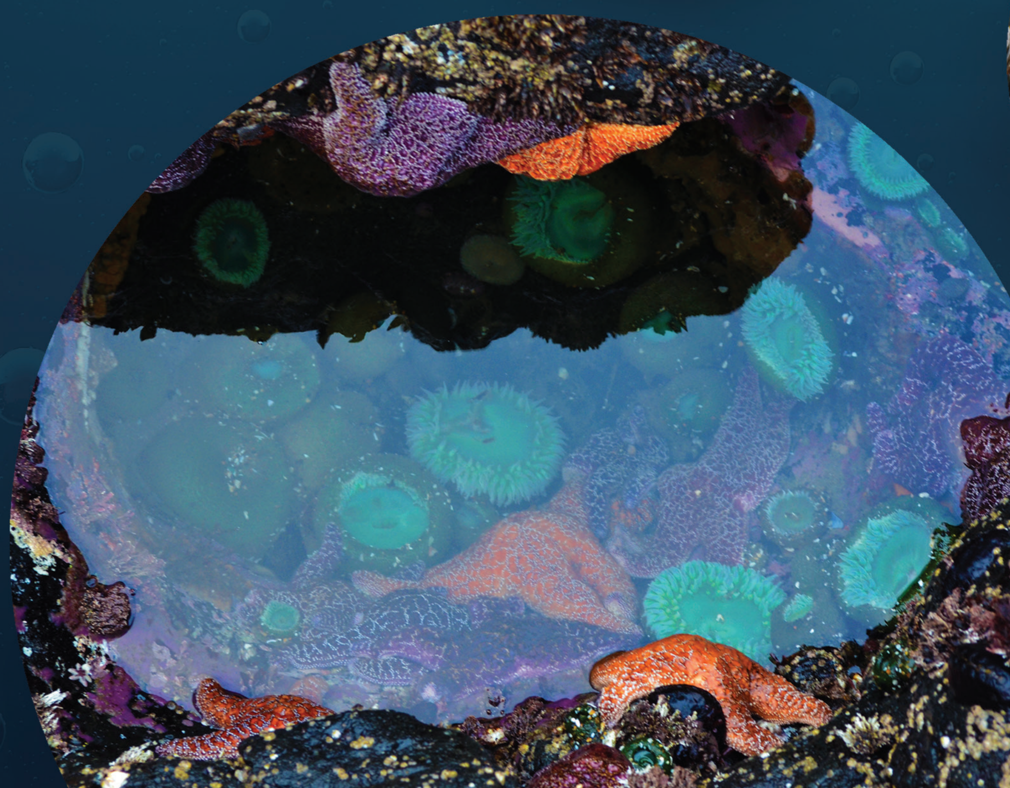
While continued efforts to contain the rate at which greenhouse gases are emitted into the atmosphere are critical to prevent potentially dangerous tipping points, there is also a need for adaptation strategies to cope with impending change. Funded by the National Science Foundation and NASA, the team's aim is to provide scientifically sound forecasts to policy and decision makers regarding which marine species will be under threat and which will thrive, as variability in the world's climate causes new weather patterns to unfold: "The questions we need to address now concern the most vulnerable species and ecosystems, the mechanisms by which changes operate, and where and when the worst impacts are most or least likely to occur," Helmuth elaborates. To calculate their predictions, the researchers collect a mixture of physiological and biophysical data, and apply mathematical and modelling methods to interpret them: "Ultimately, we hope to use our knowledge of how the natural environment works to stave off some of the most catastrophic impacts of climate change," states Helmuth. Northeastern University's Marine Science Center provides a unique location from which to conduct studies of the effects of environmental change on urban coastal environments, given its juxtaposition between the open waters of the Gulf of Maine and Boston Harbor.

SENSING CHANGES IN THE ENVIRONMENT

The fundamental starting point is that each organism operates optimally at a specific body temperature and that most animals experience changes in the temperature of their surroundings very differently from humans. Mammals such as humans have natural coping mechanisms, such as sweating or shivering, to maintain a normal body temperature and have engineered means to adjust the warmth of their environment. 99 per cent of organisms, however, are ectothermic, and do not produce significant body heat on their own. Their lower body temperature is generally set by air temperature and then solar radiation, wind speed and other environmental factors which can cause it to rise or fall.

Ectotherm temperatures can normally fluctuate significantly, in some cases 20 °C or more over the course of a day. A small change in weather may therefore have major effects on the organisms, and an increase in global average surface temperature of one or two degrees caused by climate change will exacerbate the negative impacts of any other stressors to a point where the balance tips towards a struggle for survival. A crucial point that tends to get lost is that what sounds like a small increase in

Predictions can be made about future winners and losers and how ecosystem services may be altered



average global surface temperature can mean a huge change in weather patterns. A difference in average surface temperature of only 6 °C is equivalent to the difference between now and the last ice age.

Helmuth's research group at the Marine Science Center includes students and staff focusing on a diverse array of challenges related to sustainability in coastal environments. Jennifer Mocarski is a project manager who works with Helmuth and MSC Director Geoff Trussell on the UCSI. Graduate students in the lab include Cristian Monaco, who studies the impacts of climate change on predator/prey species interactions; Nick Colvard, who investigates the effects of climate change on intertidal algae; Allison Matzelle, who develops energetics models of the sub-lethal impacts of climate change; Jessica Torossian, who is currently working on a case study of the creation of oyster beds in the conversion of a salt dock to a multi-use community facility; Nicole Kish, who detects the impacts of climate change using classical weather data methods; Dr Mackenzie Zippay, a postdoctoral researcher who measures molecular- and cellular-level physiological responses to environmental stress and carries out energetics modelling; and Lab Manager Francis Choi, who creates new outreach material such as virtual tours using Gigapan technology and is now working on a new underwater observatory.

Helmuth's group is analysing ecologically and economically important coastal organisms and the ways in which their characteristics are altered by changes in temperature. This allows them to assess the likely cumulative impacts of pressures on already fragile systems from climate change. The team uses biomimetic devices that mimic the thermal characteristics of animals to get a 'mussel eye view' of the world. Biosensors recording temperatures relevant to animals such mussels, oysters and sea stars have now been deployed in coastal zones on continents around the world.

'Robomussels' that record temperature relevant to intertidal mussels are deployed at sites around the world

Structured and coloured to match their animal templates, the biomimetics collect information at a fine resolution of both space and time, continually recording variations in animal temperatures. The team then analyses the data in conjunction with energetics models to explore how climate change conduces to changes in distribution, growth and reproduction patterns – and ultimately might kill such organisms. This approach of quantitatively measuring changes from the organism's perspective and the fine scale of the measurements enable the scientists to develop reliable models at the microclimate level of the organisms' behaviours and physiological responses under different weather conditions, and in terms of long range climate change. From these findings, predictions can be made about future winners and losers and how ecosystem services may be altered.

Working in conjunction with Associate Professor Wenyuan Xu from the University of South Carolina's Computer Science and Engineering Department, the group is building sensors that communicate to cell phones to provide alerts of when environmental conditions hit levels that are lethal to coastal organisms, a sort of early warning system.

COLLABORATIVE TEAMWORK

The team's work has revealed some surprising results, and has suggested that our expectations of where to look for the effects of climate change in Nature can be more complex than previously anticipated. For example, along the Pacific coast of the US, animal temperatures at sites in Oregon and Washington can be as hot, or even hotter, than sites much farther to the south in California, due to the complex interaction of weather and tides in the region. As a result, mortality is likely to occur not only at the southern ends of species range boundaries, but also at these hotspots. These results suggest that many impacts of climate change may be going undetected because they are occurring at sites that otherwise may not be considered 'stressful'.

To achieve the main objective of the project, these findings must be communicated effectively to researchers, policy makers and the broader public alike, and the group works to develop indicators that can be used by a wide range of stakeholders. The project also spans international borders, and the lab collaborates with scientists in many countries. Last year the group co-founded the International Network for the Study of Rocky intertidal Ecosystems (INSHORE), to provide a forum for common data collection and sharing, and international student cross-training. The researchers also work with local teachers to develop educational materials relevant to national science standards, and bring the excitement of science to the classroom.

HELMUTH LAB

MARINE ECOLOGICAL FORECASTING, ECOPHYSIOLOGY AND PHYSICAL BIOLOGY

OBJECTIVES

- To explore the effects of climate change and other stressors on the ecology of commercially, ecologically and culturally important coastal organisms
- To inform decision makers with scientifically accurate and useful ecological forecasts

KEY COLLABORATORS

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