



Landscape ecologist Michael Kleyer is studying how islands form in the Wadden Sea. He coordinated the construction of a group of small artificial islands for his research.

An Open-Air Laboratory between High and Low Tide

There is nothing like it anywhere else in the world: the twelve artificial islands near the North Frisian island of Spiekeroog are a one of a kind large-scale project. Marine and terrestrial ecologists and biologists from the universities of Oldenburg and Göttingen are working together for the first time to gain transdisciplinary insights into the biodiversity of one of Europe's most dynamic habitats

Haematopus ostralegus is not a rare bird species in the mudflats – quite the contrary, the oystercatcher with its red beak and black and white feathers is a

common sight in the North Sea region. But last summer it was a source of some excitement for Professor Michael Kleyer and his team at the Institute for

Biology and Environmental Sciences (IBU) when, for the first time, a pair of oystercatchers set up a nest on one of the twelve artificial islands built

by terrestrial ecologist Kleyer and a team of students, PhD students and postdoctoral researchers off the coast of Spiekeroog in the summer of 2014. The metal containers used to construct the islands are clearly visible from the ferry; they flash in the sunlight, and in rainy or stormy weather they look like mini fortresses. Seen from the ship you would never guess that this is an unique large-scale project.

In the joint research project BEF-mate (Biodiversity effects on ecosystem functioning across marine and terrestrial ecosystems) marine and terrestrial scientists from the universities of Oldenburg and Göttingen are working side by side for the first time to gain transdisciplinary insights for biodiversity research. They have built a huge open-air laboratory covering a surface area of 120 square metres – a scientific Garden of Eden for biologists, geologists, ecologists and environmental scientists. Eight PhD students and several post doctoral researchers from Oldenburg and Göttingen are documenting how mudflat communities turn into salt marsh communities; how what was initially a marine ecosystem becomes a predominantly territorial ecosystem. Here, in one of Europe's most dynamic habitats, they are studying the functional importance of species diversity and how it changes as sea levels rise – a subject that is gaining importance against the backdrop of global climate change.

Only shovels and wheelbarrows are allowed at the UNESCO World Heritage Site

“The artificial islands help us to understand how plant and animal communities, and indeed entire ecosystems, would reassemble if new islands were to form in the Wadden Sea. So this is an experiment that recreates this process so that we can analyse it scientifically,” Kleyer explains. He coordinated and

organised the construction of the artificial islands – back-breaking work, as the researchers weren't allowed to use anything but shovels and wheelbarrows in this highly protected UNESCO World Heritage Site. The project suffered a terrible setback early on when the first island constructions built in the summer of 2013 were completely destroyed by Cyclone Xaver in December of the same year. “We were pretty disappointed,” Kleyer recalls, but the team refused to be discouraged and went ahead with a second attempt – this time successful. The new metal cages, made of the same steel used for ships, have withstood the wind, weather and storm tides for just over two years now. Situated at a distance of between 300 and 500 metres from the salt marshes near the National Park Centre Wittbülten, they are waiting to be colonised – by plant seeds washed up by the sea or carried by the wind, and also by insects, worms or birds – like the oystercatcher. But the researchers don't just want to know which plants and animals will cross the barrier between old and new habitat first, but also how they affect each other: who drives out whom? How important are the different communities for the new ecosystem? How much new biomass does the colonization process generate, and how much carbon dioxide is stored?

To answer all these questions the scientists walk out to the islands on a regular basis as soon as the tide goes out. Each time they have six hours to make key measurements such as salinity, temperature and soil moisture and to document the plants and animals that have settled there. So while some team members are working outdoors, others are sitting at their computers in Oldenburg and Göttingen using the collected data to develop models for long-term projections or designing simplified ecosystems in the laboratory. At the end of this process the researchers will put together all the pieces of the puzzle in order to understand the fundamentals of ecology and evolution.

The colonization of these miniature islands is a dynamic process that will continue for years – too long for this research project, which was initially designed to last just three years and comes to an end in 2017. “This is a long-term experiment: it involves the growth of generations of plants that could provide us with solid answers to urgent questions. We hope it will be extended to 12 years, but the funding is not yet secure,” says Kleyer. Ecological processes take time – especially in highly dynamic habitats like coastal areas. The balanced conditions found in woodland ecosystems never develop in this kind of habitat. The only constant in the Wadden Sea is the interaction between high and low tide.

Three flood zones for “saltwater showers” of varying duration

Each little island has a surface area of 12 square metres and is split into three levels, each at a different height. These levels simulate the three flood zones of salt marshes and ensure that the plants are exposed to “saltwater showers” at varying intervals. The plants in the so-called “pioneer zone” need to be particularly robust: glassworts and cordgrass can withstand several hours of submersion twice a day. The lower salt marsh zone is also in the eternal battle zone between sea and land. It, too, is flooded every day, but only by a few centimetres of water and for 30 minutes maximum, so for a much shorter period than the pioneer zone. Typical for this zone are species such as common saltmarsh grass and sea-lavender. The upper salt marsh zone is only ever flooded by storm or spring tides. Species such as sea couch, red fescue and thrift grow here.

“Our hypothesis on this pronounced zoning is that at the stressful end of the gradient plants will be limited by their physiological ability to deal with the salt factor and the flooding, while the plants on the more benign side will



One of twelve artificial islands in Lower Saxony's Wadden Sea (above). When the tide goes out the scientists walk out to the islands – in the summer almost every day (centre). They gather samples that are then brought to the laboratory for further analysis (below).

be limited by competition with other species," Kleyer explains. To verify this hypothesis the researchers constructed six zones in Spiekeroog's salt marshes and cleared them entirely of plants and roots to eliminate all resident plants. "We expect that the plants that we find at the most stressful end of the gradient, namely glassworts and cordgrass, will also grow in the most benign zone, namely the upper salt marshes," he says. But in the long term, he explains, they will be displaced by the species of the upper salt marshes in their immediate vicinity because they are more competitive. The observations and data gathered so far appear to confirm this hypothesis.

Stress test for the plants: How resilient are they?

The researchers left six of the twelve islands as "bare" as the six areas in the salt marshes, filling them with sand only. This is where, alongside competition, another factor comes into play: dispersal. Which plant seeds will establish here first – far away from Spiekeroog – and which will come to dominate the community in the long term? Initial trends are already apparent: The team can now confirm the hypothesis that the islands would be mainly populated by plant species that are particularly good at dispersing: "Some seeds float, others are carried by the wind. We have found specimens of these species on the artificial islands even in the zones where they wouldn't normally exist in the salt marshes because there they would be eliminated by more competitive species." The conclusion is clear: if dispersal is hindered, it takes far longer for the kind of balance the researchers observe in the natural salt marshes to emerge here.

The researchers planted seeds on the remaining six islands: "We planted species that are typically found in low salt marshes in both the upper salt marsh zone and the pioneer zone," Kleyer explains. The idea is to deliberately expose these plants to stressful

conditions and observe how well they adapt to a "higher sea level" and changing environmental conditions. How long before they die out or are replaced by species better adapted to the more stressful conditions? How resilient are they? In view of rising sea levels, the increasing frequency of extreme weather events, changing species diversity and bioinvasions, these questions urgently need answers. Kleyer and his team expect common saltmarsh grass and sea purslane to die out quickly in the pioneer zone because they can't cope with the frequent flooding and high salinity, thus making way for typical pioneer zone plants. "We have data to confirm this," he says.

But it's a very different matter when common saltmarsh grass and sea purslane are planted in the upper salt marsh zone on the artificial islands – where at first they have zero competition from other species. "We had assumed that these plants would thrive here until the day came when the more competitive species of the upper salt marshes colonized the zone and eliminated the alkali grass and the sea purslane. But we haven't observed this process so far because it takes much longer here than in the comparison zones in Spiekeroog's salt marshes," Kleyer explains. The seeds of the upper marsh plants can disperse far more quickly there because they don't have to first pass the mudflats that form a spatial barrier between the "dry land" of Spiekeroog and the artificial islands.

This project is without doubt one of the most important research projects of recent years in the Wadden Sea National Park. By gaining an understanding of how balance is achieved in plant and animal communities, how ecosystems are formed and which factors lead to certain species surviving or dying out, the scientists will be able to make concrete predictions about biodiversity and ecosystem functions. So Spiekeroog is not just a touristic highlight but is also developing into a biodiversity research site with international appeal. (kl)



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