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Should we let the ocean in or not?

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Abstract

Global sea levels are rising – there is no doubt about it. But what comes next? Some land near the coast is very likely to be flooded. Should we let it? Or should we try to build dams to keep the water out? We tried to answer this question by studying what happens when you flood uninhabited coastal land. Would it just turn into some sort of "underwater wasteland," or into a functioning aquatic habitat that both animals and people can use? To find out, we followed the creation of the Gyldensteen Coastal Lagoon, an area in Denmark set aside to become a natural reserve, for two years. We conducted lab experiments and field observations to see how some marine bristle worms respond to flooding. We found that they did well, they changed the chemistry of their environment, and the newly flooded land developed into something resembling a functioning new marine ecosystem.

Introduction

Sea levels are rising at a current average rate of 1.8 mm per year as a consequence of human-caused *climate change*, and are predicted to rise even faster (at 2-16 mm/year) in the future. This will cause some low-lying areas near the coasts to flood. Should we allow these lands to be flooded or build dams to keep the water out? The answer depends on what is currently on these lands. In cities or other high development areas on the coast, we need to take measures to protect human life and property. But what about coastal areas with fewer or no people living on them?

We wanted to know what would happen if we allowed uninhabited coastal land to be flooded. Would the land stay lifeless for a long time? Or might marine organisms (Figure 1) move in quickly and help it develop into a fully functional *ecosystem*?

We tried to get at the answer in two different ways:

1. with experiments in the lab, and
2. with field observation of a newly flooded coastal area in Denmark.

And of course we compared both results in the end. Read on to see what we found out!

Figure 1:
The "ragworm" (*Nereis diversicolor*) is one of the bristle worms we used in our experiments and also found in the newly formed lagoon. It lives in burrows in the sand or mud in coastal areas of the Atlantic ocean. By digging burrows, it helps transport water and nutrients into the ocean soil.

Methods

Study site:

We had an excellent opportunity to test our research question with the proposed flooding of coastal land in Denmark in what is now known as the Gyldensteen Coastal Lagoon (Figure 2)

Lab experiment:

For our lab experiment, we collected three different species of marine bristle worms (*Polychaeta*) from nearby waters. (We picked these species because they are common in the area and could become *pioneer species* in the lagoon). We also collected soil from the cultivated area where the lagoon was going to be created (before it was flooded) and brought it into the lab. There, we put the soil into tanks (four total, one for each worm species and one as a control with no worms), and then simulated coastal flooding by adding seawater. We put the worms inside and observed how well they survived, and what they did. Seawater contains lots of sulfate, so we measured where it ended up in the soil. That way we could track how deep the worms dug and see if our worms contributed to the transport of water into the soil.

We were especially interested in measuring their impact on the breakdown of *organic carbon* and the release of nutrients from the soils into the water. That's why we measured various chemicals regularly throughout the experiment, in particular the release of carbon dioxide and the exchange of nitrogen and phosphorus between the soil and surrounding water.

Field observation:

After the flooding and establishment of the lagoon, we conducted fauna (animal) surveys there for two years. We wanted to understand which animals were the first to colonize the new marine habitat, and also see if our bristle worms were among the first pioneers to arrive and establish there.

More about bristle worms

Bristle worms are *segmented* marine worms that are related to earthworms and leeches. However, unlike their relatives they have bristly hair all over their body. They come in many shapes and colors, and some even glow in the dark! Scientists have discovered over 10,000 different species. They are so cool that they even have their own "**International Bristle Worm Day.**" Most burrow or build tubes into the sediment. Find out more about them in our link in the References.

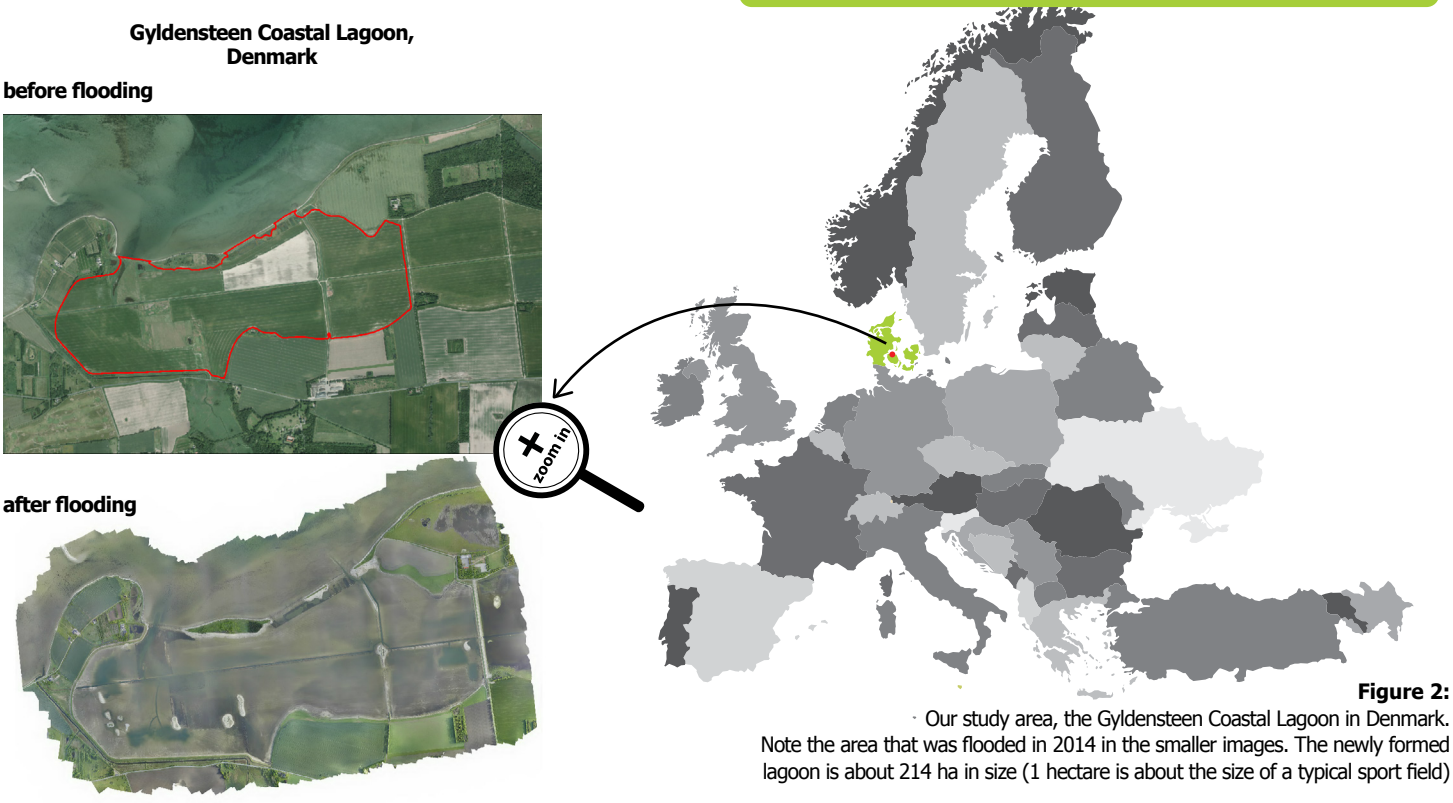

Figure 2:
Our study area, the Gyldensteen Coastal Lagoon in Denmark. Note the area that was flooded in 2014 in the smaller images. The newly formed lagoon is about 214 ha in size (1 hectare is about the size of a typical sport field)

Results

Lab experiment

- In our lab experiment, all three species of bristle worms survived well (44-86% from initial numbers).
- They stimulated the breakdown of organic carbon in the flooded soils (97-105% compared to control without worms).
- They also stimulated the release of nitrogen from the soil (at 72-176% compared to the control).
- No worm effect was observed in the release of phosphorus from the soil.
- Our sulfate measurements show that one of our worms – *Nereis (Hediste) diversicolor,* the one that we also found in the newly formed lagoon – transported the most amount of water into the soil (Figure 3).

Field observation:

- We found 12 different animal species that moved into the lagoon in the first two years, among them worms, *bivalves* and some crabs.
- As for the bristle worms species we tested in our lab, we only found *N. diversicolor* in the lagoon, but it was the most common animal there (with >1600 individuals per m^2 as opposed to 331-540 individuals per m^2 for other marine species).
- We also found other small worms (such as *Polydora cornuta*) in high numbers that also burrow into the ground.
- We calculated that the bristle worm more than doubled the breakdown of organic carbon in the lagoon.

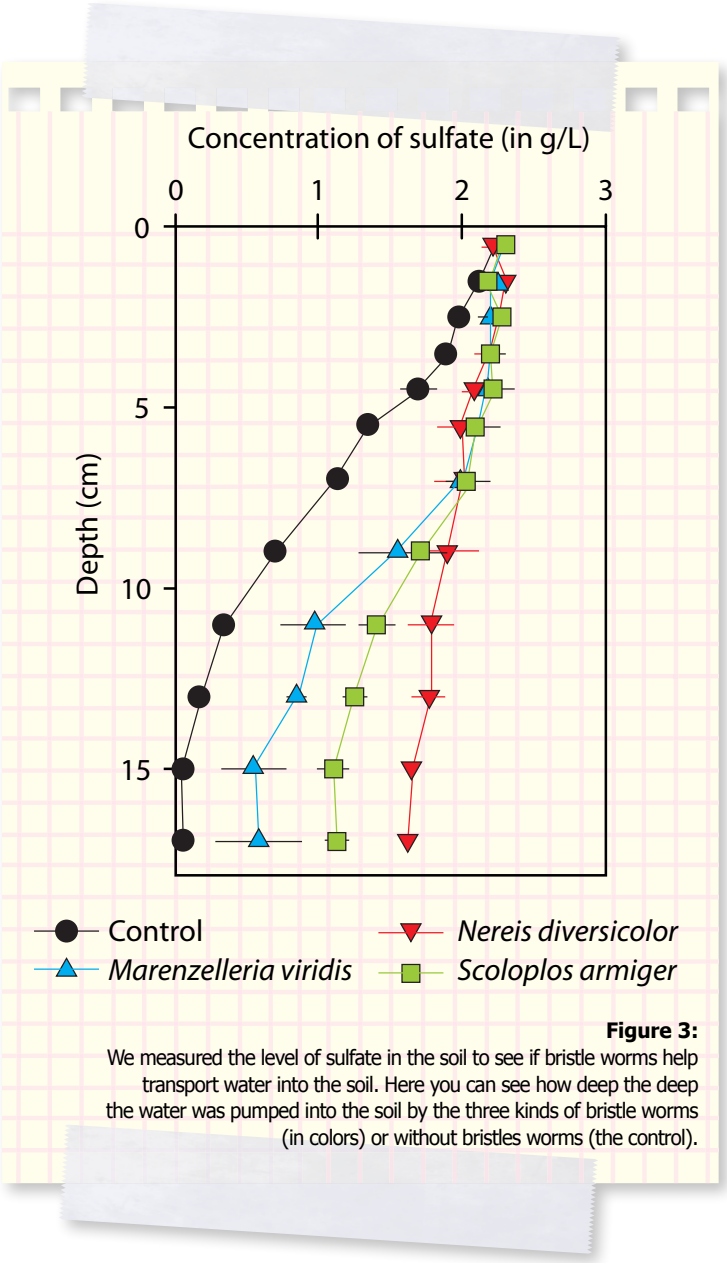

Figure 3:
We measured the level of sulfate in the soil to see if bristle worms help transport water into the soil. Here you can see how deep the deep the water was pumped into the soil by the three kinds of bristle worms (in colors) or without bristles worms (the control).

Discussion

We saw that bristle worms (especially *N. diversicolor*) survived flooding well and are among the early colonizers of newly flooded areas in the lagoon. By moving the sand around and creating holes for water and oxygen to enter, they alter the chemistry of the ocean floor and stimulate the exchange of nutrients. This improves the environmental conditions of the newly flooded lagoon, preparing the way for the arrival of other species. And of course the worms themselves are food for other marine organism, like fishes, which in turn are food for somebody else, like birds… So when bristle worms thrive, they also help build up the *food web* in the lagoon and increase its overall *biodiversity*.

We documented the change that bristle worms cause to nutrient flow and the breakdown of organic carbon in our lab experiments, and observed the arrival of pioneer species in the field. We therefore believe that newly flooded soils have the potential to develop into well-functioning marine ecosystems.

Conclusion

We humans alter the environment for many species. That can be directly by changing land for agriculture or construction, but also indirectly by producing greenhouse gases that alter the climate and lead to rising sea levels. Many changes are slow and difficult to observe in our own lives, but they are still going on and are already changing living conditions on Earth. Our study shows that in some cases, species can adapt and deal with new environments (like newly flooded soils). But do you think we can let nature run its altered course everywhere? Can you think of some examples where it might not be that easy?

Glossary of Key Terms

Biodiversity – the variety and range of organisms that live in any given ecosystem. We say that there is high biodiversity when there are lots of different types of plants and animals in an ecosystem.

Bivalves – invertebrate aquatic animals with two shells, like clams and oysters.

Climate change – a change in climate patterns apparent since the mid 20th century and attributed largely to the increased levels of atmospheric carbon dioxide produced when humans burn fossil fuels. Global temperatures are increasing on average, which leads to melting of land ice in the Arctic and Antarctic, causing sea levels to rise.

Ecosystem – a community of animals that interact with each other and their physical environment.

Food web – an interlocking set of species that eat and are eaten by each other in an ecosystem.

Nutrients – a tiny compound that organisms use to live and grow. Phosphorus and nitrogen, for instance, are very important nutrients for plants. You get your nutrients from the food you eat.

Organic carbon – carbon that comes from decomposing plants or animals.

Pioneer species – hardy (strong) species that are the first to colonize a disrupted or disturbed ecosystem.

Sea-level rise – increase in the mean global level of the oceans as a results of more water (=a higher volume) in them. The current sea level rise is attributed to melting land ice due to human caused climate change.

Segmented – with segments, i.e. parts that repeat each other. Maybe you have noticed rings before on earthworms? Each "ring" is a segment. Bristle worms have similar rings/segments, but have bristly hairs on each of their segments.

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Check your understanding

1 Why are sea levels rising?

2 Why is that a problem? And what can be done about it?

3 Can you think of pros and cons of letting the water in versus keeping it out?

4 What is a bristle worm? And why did we pick them for our study?

5 What do bristle worms do that improves the newly flooded habitat?

6 What can you do to minimize your effects on rising sea levels?