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How does climate change make fish late for dinner?

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Abstract

Imagine you are a young and hungry fish looking for food in an *estuary* (the part of a river where it meets the ocean). You need to grow big and strong before you *migrate* to the ocean, and depend on tiny floating creatures (*plankton*) for food. However, the occurrence of these tiny creatures in the estuary varies seasonally. Lucky for you, nature has synchronized both your time in the estuary and that of your prey, and you survive. This *synchronization* depends on many different factors, among them the temperature of the water. Now imagine someone turning up the heat (like we humans are doing by changing the climate). Could the rising water temperatures mess up the timing for you, the predator, and your prey? To answer this question we looked at climate related changes in the synchronization of predator and prey in the biggest estuary in Western Europe. And indeed, we found signs of *temporal* mismatches in its aquatic food web. We fear that the observed changes can put this important ecosystem and its role as a big fish nursery at risk.

Introduction

A lot of research shows that human-made climate change already has significant impacts on animal and plant communities all over the world. Warmer temperatures shift the boundaries where living creatures (plants and animals alive) can survive and let some organisms thrive, while others suffer, migrate or die. This changes the habitat for a lot of species, in addition to the climatic changes they experience.

Another change scientists have observed is the timing of biological processes. If these processes are recurring seasonally, for instance the breaking out of buds or leaves, the flowering period, or animal migrations, they are called "*phenology*". Temperatures are an important timing cue for many biological processes, and we can expect (and also observe) that changes in temperatures will also affect the phenology of many organisms.

Take finding food, for example. It is easy for us humans to go to the supermarket and buy food from all over the world, completely out of season, whenever we want. Animals, however, depend on the seasonal and local availability of food.

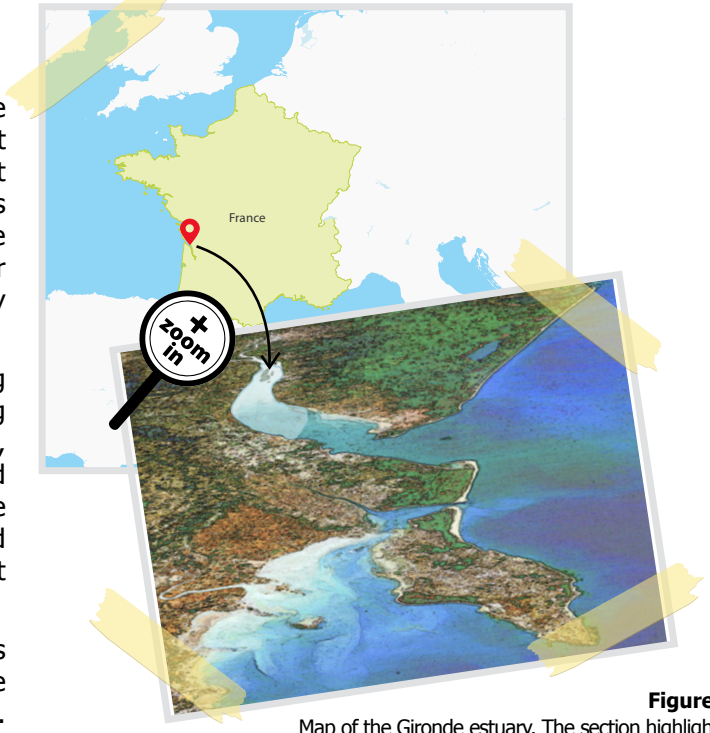

Figure 1:
Map of the Gironde estuary. The section highlighted in blue shows the sample area of the study. Map of France by FreeVectorMaps.com

A growing fish in an estuary might only be there for a relatively short amount of time before it moves on to the ocean. So it's crucial for the fish that its time in the estuary overlaps with that of its food.

We wanted to know if a changing climate impacted the *temporal overlap* of predators (fish) and their *zooplankton* prey in the Gironde estuary in France (Fig. 1). It is the biggest estuary in Western Europe, and an important nursery for many commercial fish species.

Figure 2: Photograph of one type of zooplankton who live in the estuary

Figure 4: Fishing in the Gironde estuary

Figure 3: Photograph of the Gironde estuary

Methods

To find out, we looked a lot of different *data* from a 25-year period (1985 - 2010):

Abiotic factors (concerning non-living things):

- Daily air temperatures in the estuary
- Regular samples of water salinity (info on how salty the water is)
- Amount of daily water discharge from the river (this is a factor that together with the 2 previous ones is known for triggering seasonal patterns in the estuary)

Biotic factors (concerning living things in the estuary):

- Number and diversity of species of fish living in the estuary (from regular monitoring studies)
- Number and diversity of species of zooplankton in the estuary during the season when different fish species are present

A lot of different people and agencies helped us to collect all this important information. We then ran a special statistical analysis with all these data to find potential mismatches in the timing between the fish predators and their zooplankton prey.

Specifically, we wanted to answer the following questions:

- Did changes in climate change the phenology for any of the predator and prey species? If so, in what way? Did species arrive or peak in *abundance* (numbers) earlier or later in the estuary? Did they leave sooner, or later?
- Did their overall length of stay in the estuary change?
- And lastly, how did potential individual changes in the length of time species spent in the estuary impact their overlap as predator and prey?

Results

The climatic data we analyzed for the 25-year period in the estuary showed a long-term *trend* of rising air temperatures and salinity in the spring, accompanied by decreased freshwater flow.

We also observed changes in the duration of time that individual fish or zooplankton species spent in the estuary, or the time they arrived or peaked in abundance. These changes occurred in more than half of the cases we analyzed. In most cases, fish tended to arrive (or zooplankton peak in numbers) earlier in the estuary than they used to. They also spent less time there than before. Our statistical analysis proved that these changes were not due to chance, but likely caused by the changing *climate parameters*.

Did these changes affect the relationship between predatory fish and their zooplankton prey? We are pretty certain they did! In fact, roughly one third of predator prey interactions we looked at have changed during these 25 years. Overall, the duration of temporal overlap between predator and prey species decreased.

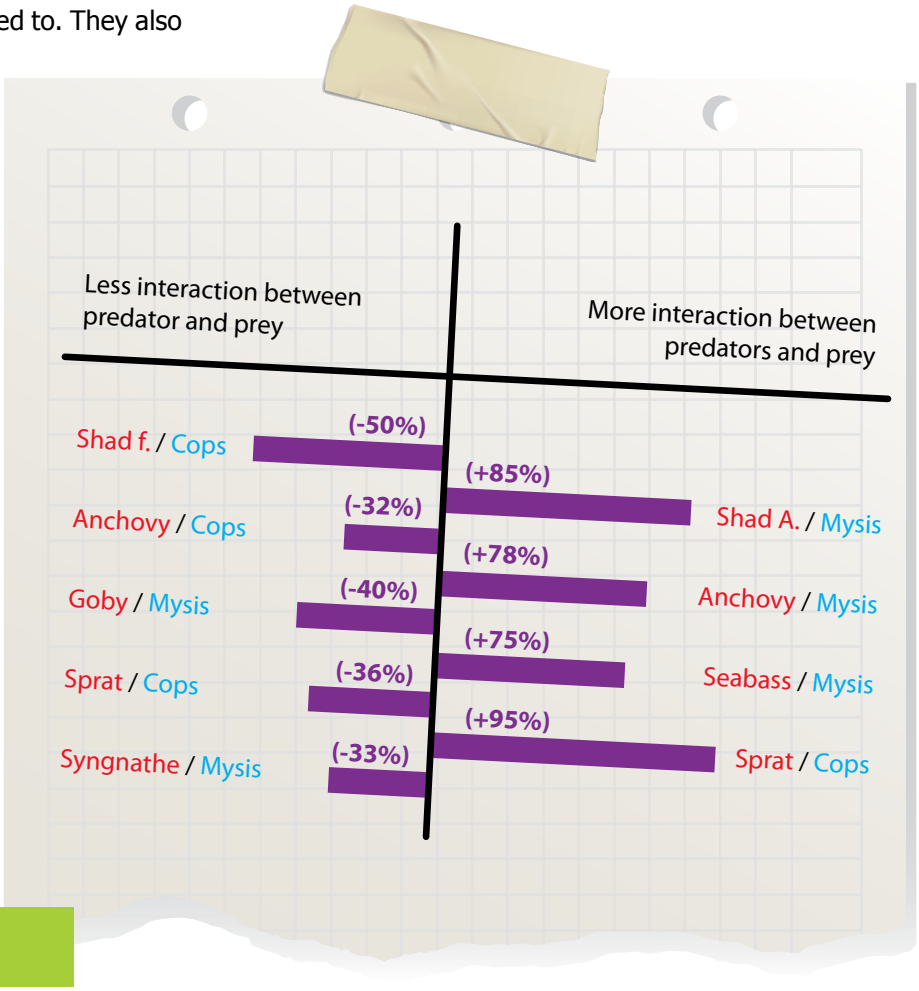

Figure 5:
Likelihood of interaction between predators (red) and their prey (blue), where % represents the proportion of increase or decrease of overlap.
Cops : copepodea species, Mysis : mysidacea species.

Can you see how all the interactions between predator and prey have changed in the estuary?

Discussion

Several previous studies have looked at changes in the life and phenology of individual species in aquatic systems. Researchers also found that climate change could change fish communities all together. Ours is one of the first studies to look at potential changes of the timing of predator-prey interactions in estuaries. We found that most species we studied were present earlier in the estuary, probably because of warmer temperatures earlier in the year. Moreover, most fish spent less time there, which lead to a shorter temporal overlap between them and their prey. Our results raise concerns that young fish might find less food in estuaries when temperatures rise. Estuaries are important nursery grounds for many juvenile fish that later migrate into the ocean, among them many economically important species. This important estuary function might be at risk in a warming world.

Conclusion

Our study is yet another example that highlights the negative impact of human-made climate change on animal communities. We are just beginning to understand how complex these changes are and what implications they might have. If we continue in a 'business as usual' scenario and don't change the way we are using fossil fuels, we will put many animal communities or even entire ecosystems at risk. This will also diminish the important services we get from these ecosystems – such as helping to raise the fish that we like to eat, and that a lot of our global economy depends upon.

Glossary of Key Terms

Abundance – the quantity (number) of something. We noticed that the seasonal abundance of zooplankton changed, that is higher numbers of plankton were found earlier in the year during the duration of our study.

Climate parameters – measurements of climatic factors, like water temperature, air temperature, amount of rainfall etc.

Estuary – the tidal mouth of a large river, where the ocean meets the stream and freshwater and saltwater mix. Estuaries are very important habitats for thousands of creatures, crucial places for fish to reproduce (mating grounds), young fish to grow up (fish nurseries), or food and rest stops for migratory birds.

Migrate – when animals move seasonally from one area to another. Many fish, like the ones we studied, migrate between freshwater and saltwater within their life time.

Phenology – the timing of important life events.

Temporal – related to time.

Temporal overlap – when we use this term to talk about predator and prey, it means the time both groups spend in an area together; in this case, the estuary.

Trend – in scientific terms, this describes a pattern of gradual change in a condition or process, or an average or general tendency of a series of data points to move in a certain direction over time. For instance, most studies about climate change show the trend of rising temperatures on Earth. It is often important to look at **long-term trends**, as the short term does not necessarily provide accurate information. Even though in the short term, temperatures might be cold (like during colder winters), the long-term trend clearly shows that global average temperatures have been rising.

Synchronization – the activity of two or more things or creatures at the same time or rate.

Zooplankton – small lightweight creatures that drift in oceans, rivers, or other bodies of water. Unlike phytoplankton, zooplankton cannot grow through photosynthesis (like phytoplankton can) but instead need to obtain energy and biomass from their food (phytoplankton and/or smaller zooplankton).

REFERENCES

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Irstea

Check your understanding

1 Which important function of estuaries did you learn about in this paper?

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2 What other important functions could estuaries have for humans or animals?

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3 Why could climate change put fish survival at risk?

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4 What could our own behavior have to do with warmer temperatures in the Gironde Estuary in France, even though you might live far away?

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5 What other ecological mismatches with dramatic consequences could you think of, apart from the ones you read about here?
