

# Is climate change shrinking our fish?

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## Abstract

Imagine you are rushing home and need to breathe harder and harder, but there is less oxygen in the air around you. This is the situation most marine fish are facing with warmer ocean temperatures due to *climate change*. They breathe the same oxygen we do, except that they have to get it out of the water, which is a much harder task. Warmer water holds less oxygen than cold water. To make matters worse,

fish also need more oxygen in warmer waters. So with the higher demand and the lower supply of oxygen, the growth of the fish' *gills* (their breathing organs), cannot keep up. This is causing ocean fish species to grow to smaller sizes! We created a model that can predict by how much fish are shrinking, and also developed a theory called *GOLT* that explains what is going on.

## Introduction

Our current lifestyles are changing the living conditions for a lot of creatures on Earth (including ourselves!) Human-caused climate change is raising average global temperatures both on land and in the oceans. We have already seen a lot of changes in ocean life as a consequence. For instance, a lot of marine fish move away from warmer waters (they shift their *distribution*).

We have also seen fish species growing to smaller sizes over time. Could this also be happening because of climate change? And what would be the specific reason? Before we can address these questions, we need to understand what changing temperatures do to ocean environments in general. One major thing is that they change the oxygen content in the water. Warmer water holds less oxygen. Is that a big deal? Most likely so! All fish need oxygen, just like we do. They just have to get it from the water, with help from special organs called gills (Figure 1).

We suspected that the lower oxygen levels are making it harder for fish to breathe. At the same time, fish need more oxygen in warmer water because the warm water speeds up their *metabolism*. So what if the fish could not

get enough oxygen? Could this potentially "shrink" them?

We created a mathematical model and also looked at some *empirical* (real world) data to find out.



**Figure 1:**

Fish have special organs called gills that allow them to breathe under water. The gills are thin structures filled with blood vessels that extract oxygen from the water around them.

## Methods

We examined what impact climate change in the oceans (specifically changing water temperatures and oxygen levels) will have on the growth, *abundance* and distribution of fish. In our first study (in 2013), we calculated the effects on over 600 marine fish species. In the years that followed, we refined our theory and adjusted our models to get even more accurate results.

We also compared our calculated shrinking rates with actual measurements of changes in fish sizes over the years. The

## Results

Climate models show that if we don't reduce greenhouse gas emissions drastically, water temperatures in all the oceans will rise, and water oxygen levels will go down. Our first calculations predicted that this would cause most marine fish species to shrink by 14-24% in body weight between 2000 and 2050 (Figure 2).

The shrinking will be most dramatic in tropical regions (which already have higher water temperatures and lower oxygen levels). Our calculations also show that marine fish will likely move towards the poles by tens or even a hundred kilometers every 10 years to escape the warmer waters. Scientists and fishers have already observed such a poleward shift in distribution.

Our most recent calculations show that the shrinking will actually be worse than we anticipated a few years back. Now we have calculated that the body size of fish will shrink even more: by 20-30% for every 1 degree Celsius increase in water temperature. This is quite a lot! And the more active the fish species, the more it will shrink on average.

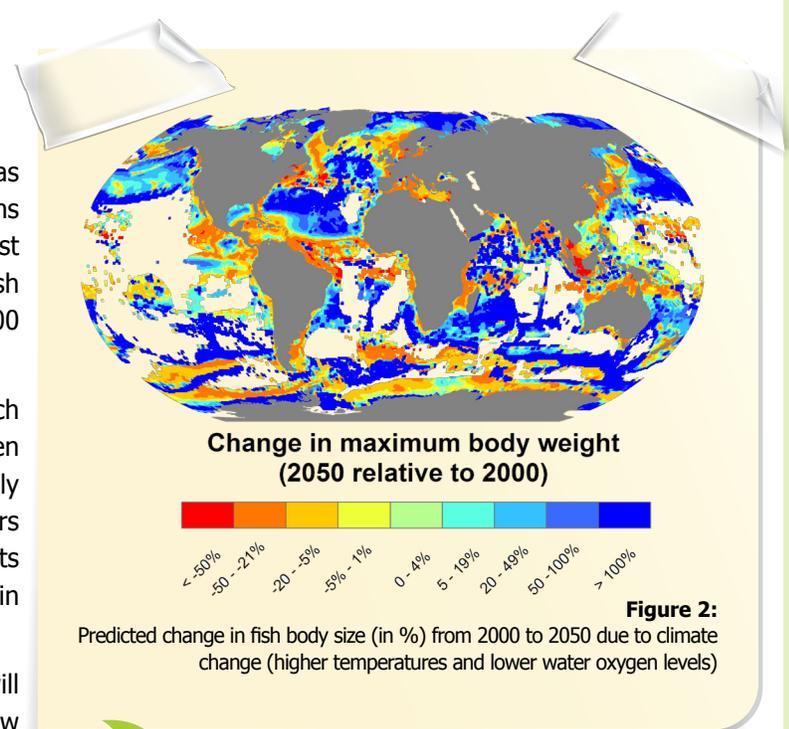
## Discussion

Our model predicts drastic decreases in the average size of ocean fish species due to changing ocean temperatures and oxygen content caused by global climate change. We have already observed that some fish are shrinking – not just in the oceans, but also in freshwater lakes and rivers.

We identified the limitations in growth of fish gills as the main factor that reduces the size of fish when less oxygen is available. Gills grow much slower than the rest of a fish's

shrinkage is difficult to demonstrate because fishing also affects the size of the fish we measure (since fishermen catch the big ones), so the two effects are difficult to quantify separately.

Previous studies focused primarily on what changing ocean temperatures will do to marine life. We chose to include the declining oxygen content in our analysis because it's a major factor for fish survival and growth.



Looking at our results, do you expect ocean fish to shrink equally all over the globe? If not, where do you see the biggest losses in body sizes?

body, so they cannot make up for the increased oxygen demand of fish in warmer water.

Some researchers have questioned these growth limitations of gills. They argue that gills can just grow bigger to meet the higher oxygen demand. However, all our research and calculations indicate the opposite is true: the growth of fish is limited by the slower growth of their gills, and the resulting insufficient oxygen supply. They simply cannot meet the

higher oxygen demand of bigger bodies in warmer waters with lower oxygen content due to the limitations of surface area growth of their gills.

Our *Gill-oxygen-limitation theory* (GOLT for short) not only accurately describes empirical observations of changes in fish sizes due to warming waters, but also helps to explain a lot of other features of fish biology. We still don't know what kind of impact all this fish shrinking will have overall on marine life

and the ecology of the oceans. But it is likely that such big changes in fish sizes will impact everything from fisheries to marine food webs, predator-prey relationships, the age when fish lay eggs, and much more.

And unfortunately, climate change is not the only big environmental stress factor for ocean creatures. All the pollution and overfishing that is happening already will only make matters worse for shrinking fish.

This is an important physical concept for animal growth: the bigger an animal, the smaller is its surface area relative to the volume of its body, and vice versa. (*Smaller animals have more surface area* relative to their body volume compared to bigger animals).

You can understand this better if you simplify the animal to look like a cube. The volume of a cube increases exponentially by the third power, but the surface area only by the second power. So as cubes or animals get bigger, their volume increases *faster* than their surface area.

In fish gills, the surface area is super important, because that is the area where oxygen is extracted from the water. Smaller fish have a bigger surface area (and so do their gills) than bigger fish relative to their body weight.

Thus, if the cubes were fish breathing through their six faces, the cells of the large cube-fish would have a much worse oxygen supply than the small cube-fish. So in order to increase their gills' relative surface area, fish have to grow to a smaller body size.

Larger surface area compared to volume.



Smaller surface area compared with volume.

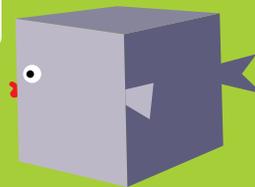


Figure 3

	1mm "cube-fish"	2mm "cube-fish"	4mm "cube-fish"
Surface area	6 sides x $1^2 = 6\text{mm}^2$	6 sides x $2^2 = 24\text{mm}^2$	6 sides x $4^2 = 96\text{mm}^2$
Volume	$1^3 = 1\text{mm}^3$	$2^3 = 8\text{mm}^3$	$4^3 = 64\text{mm}^3$
Surface area to volume ratio	6:1	3:1	1.5:1

## Conclusion

Sometimes researchers disagree, but that's actually really good! It means that we have a more thorough research discussion as well as more research to start with that might allow us to approach questions from different angles. Do you ever disagree with your friends about things that you see as facts? Try to understand where they are coming from and maybe you can find common ground.

We do agree however that there are still a lot of unanswered questions in regards to how climate change is going to impact all of us, including fish. But it's clear that there will be big changes, so we'd better try to reduce our impact on the climate. Do you have any ideas about what you can do? Look at some other Science Journal for Kids papers for inspirations.

## Glossary of Key Terms

**Abundance** – the quantity of a species (like fish) in a given area.

**Empirical** – based on observation or measurements as opposed to theory or computations.

**Climate change** – a change in climate patterns that has been clear since the mid 20th century. Most scientists recognize its cause to be the increased levels of atmospheric carbon dioxide produced by human activity like fossil fuel use.

**Distribution** – the area where an animal or a plant species can be found. If a fish species changes its distribution it moves to a different area.

**Gills** – respiratory organs of fishes (and some amphibians) that extract oxygen from water (i.e. allow fish to breathe under water).

**Limiting factor** – a factor that limits the growth or abundance of organisms.

**Metabolism** – the chemical processes that occur within a living organism in order to maintain life. Most of these processes (and thus the organism, like fish) need oxygen.

## Check your understanding

- 1 What problems does global climate change pose for marine creatures?
- 2 What does the Gill-Oxygen Limitation Theory (GOLT) describe?
- 3 So what is the limiting factor for fish growth, according to our theory?
- 4 What is the competing argument of some of our critics?
- 5 What other evidence besides calculations or models do we have that indicate our GOLT theory is valid?

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