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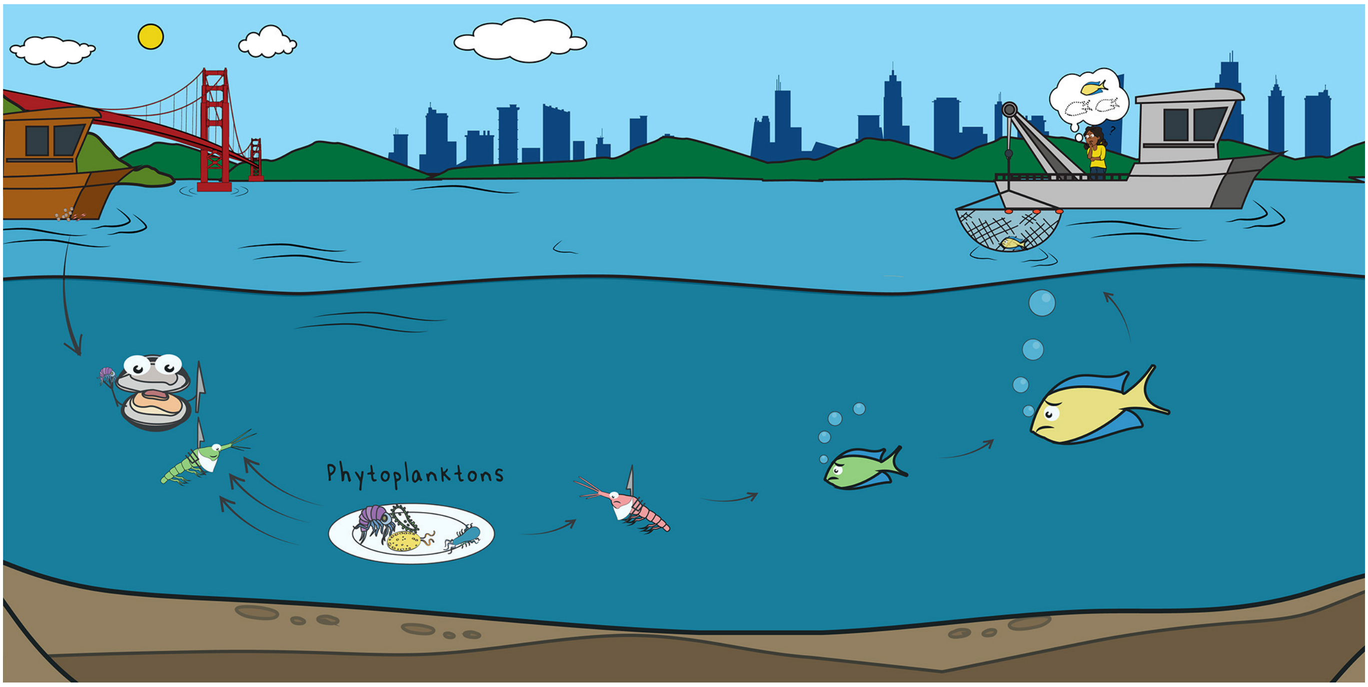

THE SMALLEST ANIMALS IN THE WATER: TINY BUT MIGHTY

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YOUNG REVIEWERS:


CHERYL
AGE: 9


PRICE
AGE: 13


PROVIDENCE
AGE: 10

Zooplankton are the smallest animals in the water. They feed on small floating plants and are food for fish. In some places, zooplankton have been studied for over 50 years because they give scientists information about water quality. In the San Francisco Estuary, many zooplankton species from far away came hitch-hiking on ships, settled, multiplied, and reduced native zooplankton. Then, the number of zooplankton dropped by half because a hitch-hiking clam ate all phytoplankton. These dramatic changes did not leave much food for fish, which also began to drop in number in the Estuary. Thus, changes that occur with the smallest plants and animals in the water can reach all the way to the top of the food chain, and can even affect humans.

ESTUARY

A water body where the river meets the ocean. Here freshwater from the river mixes with salty ocean water.

ZOOPLANKTON

Tiny animals that live in the water. Some resemble miniature shrimp, crabs, or snails, and you need a magnifying lens to see them properly.

PROTOZOANS

A group of tiny organisms that consist only of one single cell.

THE SMALLEST ANIMALS IN THE WATER

Waters like oceans, lakes, and estuaries contain millions of small animals called **zooplankton**. These animals are so small that most can only be seen with a microscope (Figure 1A). Zooplankton range in size from the diameter of a hair to the diameter of a big tree. If you have ever looked at a drop of water under a microscope and seen small animals swimming around, then you have seen zooplankton. The smallest zooplankton are only made of one cell and are called **protozoans**. They can be as small as 20 micrometers (μm), which means that they can be 50 times smaller than a millimeter [2]. Most zooplankton species with multiple cells are bigger than 1 mm, but some are still so small that you need a microscope to see them. Jellyfish are the largest zooplankton and can be up to two meters long.

One type of zooplankton, called copepods, are particularly outstanding. They are important food for many fish and support their growth. This is of course in reality more complicated and involves many different species. For example, the copepod may eat a smaller zooplankton, called a rotifer. The rotifer eats a protozoan, which eats small phytoplankton and bacteria, and all of them get rid of waste that feed the bacteria.

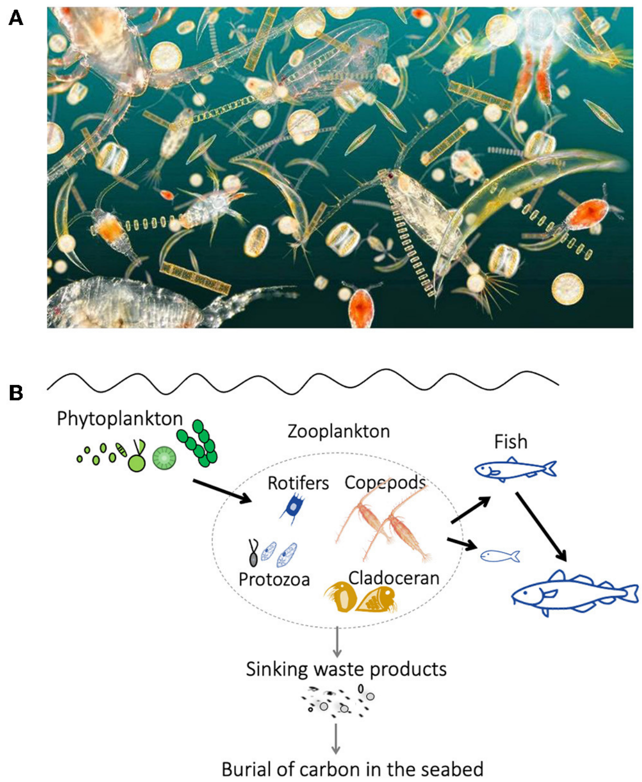

Figure 1

Figure 1

(A) Phytoplankton and zooplankton seen under the microscope. The small, greenish cells are phytoplankton. The larger, transparent organisms with legs and long antennae are copepod zooplankton (Source: `https://www.havet.nu`). **(B)** An aquatic food web, showing zooplankton that eat phytoplankton, and that are themselves eaten by fish. Zooplankton waste products (or poop) sink down to the sea floor, where the carbon they contain can remain buried for millions of years. Adapted from [1].

ZOOPLANKTON HELP TO KEEP BALANCE

Zooplankton are the most common animals on our planet and are an important part of the **food web**. Some zooplankton eat small floating plants, called **phytoplankton** (or algae), and some eat other zooplankton. Zooplankton themselves are then eaten by fish. One type of zooplankton, called **copepods**, are particularly outstanding. They are important food for many fish and support fish growth. When fish eat copepods or other zooplankton, this moves energy from small plants to larger animals, higher in the food chain—including animals that humans like to eat. The food chain from phytoplankton to copepods to fish is the most important flow of energy in the ocean. Of course, the story of who-eats-whom in the water is more complicated than this and contains many different species. That is why we call it a food web (Figure 1B).

Zooplankton do even more to contribute to the food web. They take up important nutrients, such as the healthy fats produced by phytoplankton, and make those nutrients available for fish. So, the healthy fats in the fish that you eat are produced by phytoplankton and carried to fish by zooplankton [3]. Zooplankton also help balance the water environment by keeping algae levels down. Without zooplankton to eat the algae, the water would be much greener and slimier. Last, zooplankton also help regulate the **carbon cycle**. Just like all animals, zooplankton must get rid of their waste in the form of poop. Zooplankton waste can be food for other creatures, or it can sink to the seafloor and bury the carbon it contains for millions of years. The sinking of poop particles helps to control carbon dioxide levels in the air, which in turn helps to control climate warming [2].

CHECKING THE HEALTH OF WATER

The types of **plankton** species found in the water tell us a lot about the health of oceans, lakes, and estuaries. For this reason, plankton have been studied since the beginning of the twentieth century. Some studies have sampled plankton in the same location every month, over many years. These data are important because they tell us how the water is changing because of damage from people living nearby, or because of climate warming. This information helps managers and scientists to make choices that will assure we have clean water to drink and play in. For example, studying zooplankton is like a health check for the water.

In the San Francisco Estuary in California, especially in Suisun Bay and the Sacramento-San Joaquin Delta, scientists have studied zooplankton every month since 1972. That gives us a dataset of almost 50 years! Zooplankton samples were collected at the same stations, from Suisun Bay upstream into the Delta, by the California Department of Fish and Wildlife. These data tell many stories of how humans have

FOOD WEB

A diagram showing how various species of animals, like phytoplankton, zooplankton, and fish, are connected to help them survive.

PHYTOPLANKTON

Tiny, microscopic organisms living in the water that get their energy from the sun, just like plants.

COPEPOD

The most numerous multicellular zooplankton and an important food source for fish.

CARBON CYCLE

The way in which carbon, the building block of life, travels from the atmosphere to plants, animals and finally stored at the seafloor or travels back to the atmosphere.

PLANKTON

Tiny plants and animals that live in the water. These include multiple functional and taxonomic groups, from viruses and bacteria to phytoplankton and zooplankton.

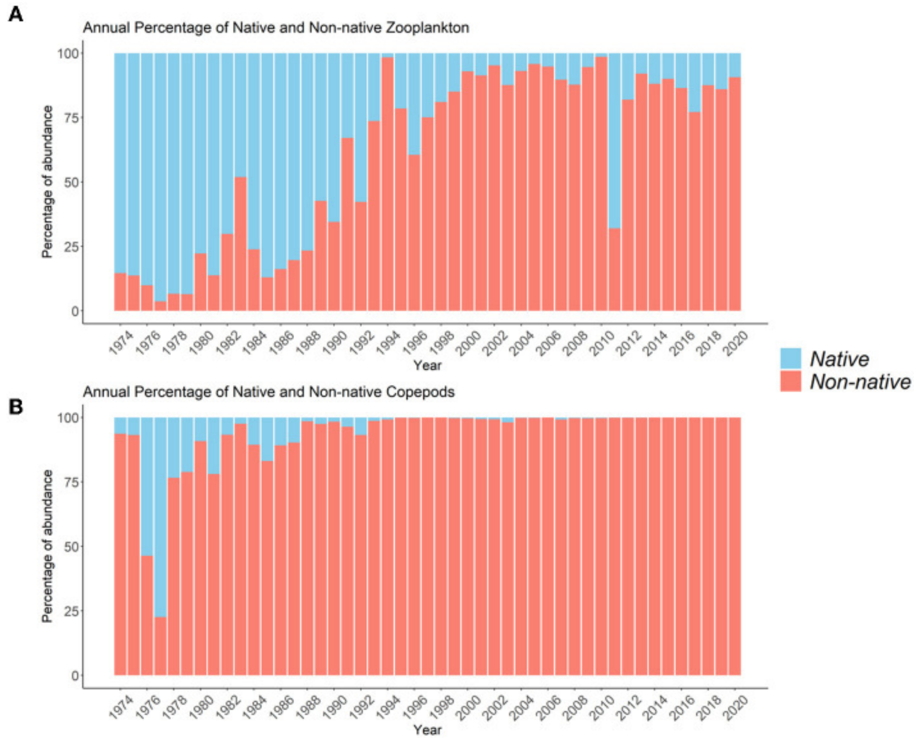

Figure 2

Figure 2

(A) The percentage of native and non-native (introduced) zooplankton and **(B)** copepods in the San Francisco Estuary from 1974 to 2017. You can see that native zooplankton, and particularly copepods where replaced by introduced species.

changed the water quality, as well as the animals and plants living in the Estuary.

HITCH-HIKERS SETTLED IN THE SAN FRANCISCO ESTUARY

Ongoing observations of the San Francisco Estuary waters tell us that many species from far away have settled and multiplied in the Estuary [4]. This occurs as more and more ships travel between countries. Many species "hitch-hike" on boats and ships and are transported between countries without humans noticing [5]. These non-native plants and animals can then establish themselves in their new environment. Because these species often have no predators in their new environment, they can become so numerous that they take over, becoming **invasive species** (Figure 2) [5]. These invasive species change the community because the native species of zooplankton can no longer find enough food to eat or space to live in, so their numbers decrease.

INVASIVE SPECIES

A species that is brought into a new ecosystem by humans and then takes over, harming native species and sometimes leading them to disappear from that ecosystem.

Over the years, changes in the San Francisco Estuary, including a decreased flow of fresh water from rivers and loss of habitats for native species, along with repeated invasions of non-native species, have made the Estuary one of the most invaded environments on the planet. After the Asian clam called *Potamocorbula amurensis* arrived in the Estuary in the late 1980s, it became so abundant and ate up so much of the phytoplankton that there was very little food left for zooplankton to feed on [6]. Fewer and fewer zooplankton were counted in water samples [7]. The total weight of all zooplankton in the Estuary dropped by more than half! Imagine losing half of your weight—that is a lot! Fewer zooplankton meant there was less food for fish in the Estuary, and the numbers of fish began to decrease too.

This is just one of many big changes that has occurred in the San Francisco Estuary. Over the last 50 years, new species have come in and pushed away many native species that used to live in the Estuary. In the saltier waters close to the ocean, large copepods and another type of zooplankton called rotifers were reduced, and instead a small copepod from Asia, called *Limnoithona*, became dominant in the water [7]. The adults can number up to 30 individuals per liter of water, and younger specimens can number up to 200 individuals per liter. This invasive copepod species is much smaller than the copepods and rotifers that used to live in these areas (Figure 2).

In the less salty part of the Estuary further upstream from the ocean, rotifers and a type of zooplankton called **cladocerans** that used to be present in high numbers were reduced when a newly arriving copepod species took over. Nowadays, cladocerans are mainly present in the upstream freshwater part (Figure 3). In addition, the numbers of certain shrimp zooplankton decreased in the entire Estuary. Some native shrimp even disappeared and were replaced by invasive shrimp species. Today, the zooplankton species that are present in high numbers in the San Francisco Estuary all came from other regions of the world.

CLADOCERA

A group of small crustacean zooplankton that is common in freshwater. The water flea is the most-studied organism of this group.

CHANGES IN ZOOPLANKTON HAVE BIG CONSEQUENCES

Newly arriving species often prefer to eat foods that are different from those eaten by the native species of the San Francisco Estuary. In upstream freshwater areas, the zooplankton used to be mainly herbivores, eating algae. But some of the newly arriving copepod species are carnivores that like to eat other zooplankton. The small copepod *Limnoithona*, which is now the most prevalent zooplankton species in the saltier part of the Estuary, prefers small animals and algae. This means that the food web in the Estuary changed dramatically over the last 50 years, due to invasive zooplankton.

With the changes in zooplankton, fish in the San Francisco Estuary now have fewer zooplankton to feed on and the zooplankton that are available are much smaller. To eat a small copepod, a fish must be able to see it, which can be hard if the copepod is too small. Fish must eat many more small copepods to fill their stomachs, which means the fish must spend much more energy to catch enough food. So, fish in the Estuary now burn more energy and get less food, which is one

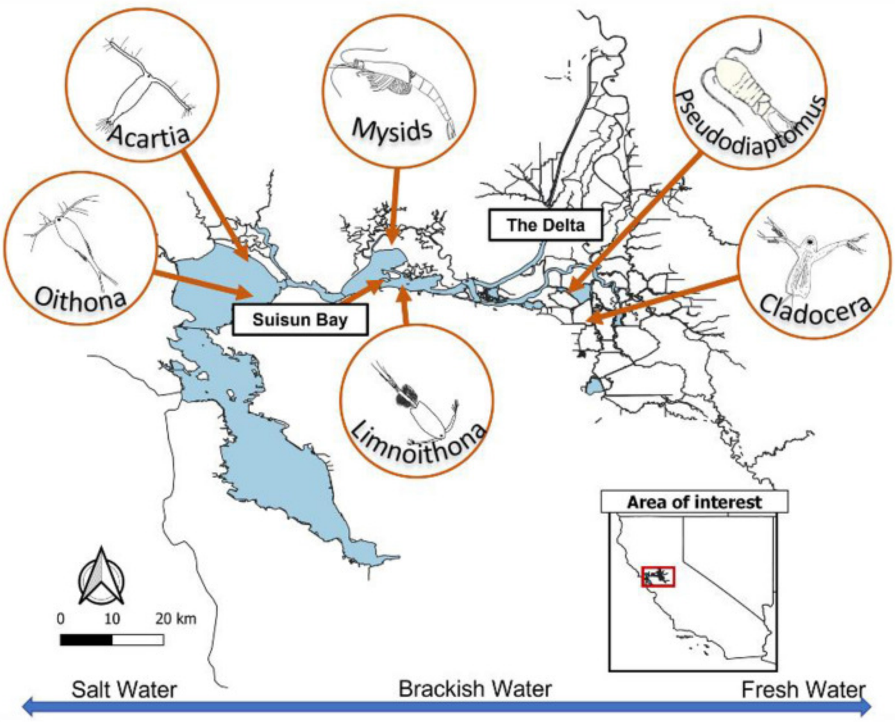

Figure 3

Figure 3

Current zooplankton species dominating in the San Francisco Estuary, from the saltier Suisun Bay to the upstream freshwater Delta.

reason why fish numbers have dropped and many fish have become smaller over the years [8].

In summary, while at first glance it might seem like changes to creatures as tiny as zooplankton should not have big consequences, when we look closer, we can see that they are tiny but mighty! Now you know that changes even in the smallest plant and animals can reach all the way to the top of the food chain. Since humans eat a lot of fish, changes to zooplankton eventually affect us, as well. That is why continued monitoring and zooplankton research are so important. We need healthy zooplankton to keep our water clean and to grow large, healthy fish that we can eat.

ORIGINAL SOURCE ARTICLE

Winder, M., and Jassby, A. D. 2011. Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco estuary. *Estuar. Coasts*. 34:675–90. doi: 10.1007/s12237-010-9342-x

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YOUNG REVIEWERS

CHERYL, AGE: 9

Hi, I am Cheryl. I have a cat named Delilah and 2 little sisters called Tanya and Alice. I live in a small city of Canberra. I am sometimes pretty shy and sometimes pretty cheeky. I absolutely love icecream especially "Cookies 'n' cream." Love you all.

PRICE, AGE: 13

Price loves making up stories and has also written a book (Ms. Wasteson and the waste empire). She enjoys gymnastics, athletics, volleyball, and basketball. She is brave and bouncy. Price also enjoys quality time with family and is very creative. At her school, she is part of a "green team" that works to protect the environment. She likes debating and has a passion to study and become an activist against social injustices.

PROVIDENCE, AGE: 10

Providence is the youngest amongst her three sisters. She is playful and bouncy. Providence is curious, talkative, and likes asking many funny questions, that leaves others laughing. She loves making new friends and traveling. Providence loves science experiments. During this process, she may destroy, repair or recycle some household items. As part of this adventure, Providence repaired a spoilt speaker. But after weeks of action, she modeled the speaker wires into skipping ropes. She is passionate about music and sports including volleyball.

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