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HELPING NATURE IN THE SAN FRANCISCO ESTUARY COPE WITH CLIMATE CHANGE

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AGES: 12–13

Estuaries are special places that form where freshwater from the land mixes with saltwater from the ocean, which is pushed inland by the tides. This mixing creates diverse habitats that support a variety of specially adapted species. In estuaries with Mediterranean climates (similar to that of the Mediterranean region in Europe), winters are wet and summers are dry. Some winters have lots of rain, others have almost none. The animals and plants of California's San Francisco Estuary have adapted to these variable conditions. But humans have changed how and when the water flows through the Estuary, making it tough for some species to survive. Climate change is likely to bring hotter air and water temperatures, more extreme floods and droughts, and rising sea levels, further complicating species survival. In this article, we discuss how ecosystem restoration and water management can help species survive in a changing climate.

Figure 1

The San Francisco Estuary. The waterways are in blue, the area of the inland delta is in green. The Sacramento River in the north and the San Joaquin River in the south meet in the Delta, then flow through Suisun, San Pablo, and San Francisco Bays into the Pacific Ocean. Sacramento, the capital of California, is located on the Sacramento River. The water-pumping plants pump water from the Estuary all the way to southern California.

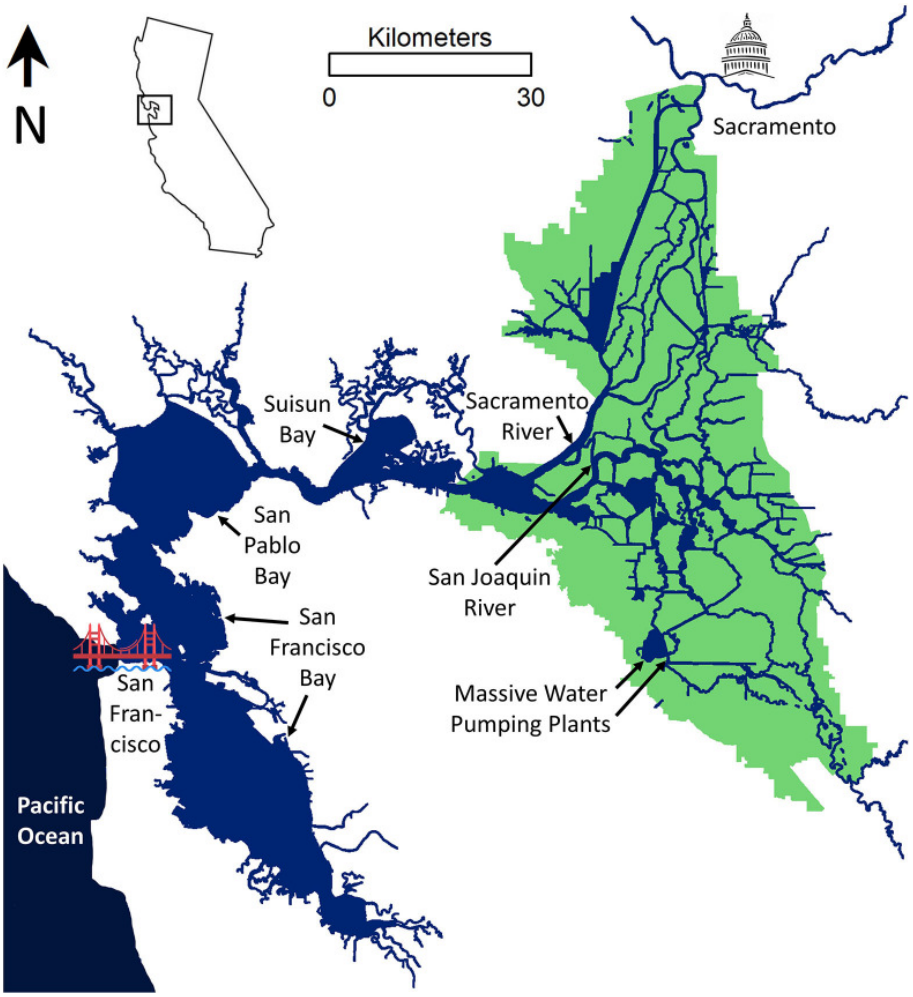

Figure 1

THE SAN FRANCISCO ESTUARY

What do people who live in Los Angeles, the almonds in your trail mix, and salmon have in common? They all depend on water from the San Francisco Estuary! **Estuaries** form where rivers meet the ocean. The San Francisco Estuary is located near the city of San Francisco in northern California, USA (Figure 1). It is a special estuary, in part because much of its water is pumped out and transported over hundreds of kilometers in concrete channels, to provide water to over 25 million Californians and over 12,000 km^2 of agricultural crops. Another thing that makes the San Francisco Estuary special is its wild and crazy climate. In the summer, it does not rain for months on end, but winters are wet. Well, some winters. During **drought** years, it may not rain at all. And during very wet winters, large areas of the Estuary can flood. There is no such thing as a "normal" year for the San Francisco Estuary [1]. However, this climate variability *is* normal for places like California, which has a Mediterranean climate—like that of the area surrounding the Mediterranean Sea in Europe.

ESTUARY

A coastal area, enclosed by land, where fresh river water mixes with salt water from the ocean.

DROUGHT

A period of time when a place gets less than normal precipitation (rain or snow).

ADAPTATIONS TO A CRAZY CLIMATE

Plants and animals that live in estuaries located in Mediterranean climates are well-adapted to both raging floods and long droughts. They have developed various physical and behavioral mechanisms to help them survive all the different, crazy weather events. Wetlands are critical habitats for many fish and bird species [2] and, in the San Francisco Estuary, over 80% of the wetland species have been lost since the 1800s [3]. Wetland plants have developed certain adaptations to tolerate the changes in **salinity** that accompany both floods and droughts [4]. Migratory bird species evolved to follow the water, taking advantage of **seasonal habitat** across the region [5]. These adaptations have allowed species to shift and change over time, in response to climate conditions. You can read more about the strategies of a specially adapted fish species in Fichman et al. [6].

SALINITY

Varies with the amount of mineral salt dissolved in water. Oceans have high salinity due to high salt content, rivers have low salinity, due to low salt content.

SEASONAL HABITAT

Habitat used by a migrating species for only specified season(s) of the year.

AN ALTERED LANDSCAPE

You might think that the unique species of the San Francisco Estuary would be prepared for climate change—after all, they are adapted to survive crazy weather! And that might be true if it was not for one other "little" issue. In many estuaries, including the San Francisco Estuary, important habitats such as wetlands, stream channels, and **floodplains** have been turned into agricultural fields, cities, and towns. People have changed the Estuary by filling in some channels, deepening and straightening others, and building **levees** to keep fields and houses from flooding (Figure 2). In addition, lots of water that would naturally flow through the San Francisco Estuary to the ocean is being diverted from the Estuary for humans to drink and for watering crops. These changes have destroyed most fish and wildlife habitats and have greatly altered water flow patterns, making it harder for **native species** to cope with climate change [1, 7].

FLOODPLAIN

An area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding.

LEVEE

A wall that prevents water from going where we do not want it to go. Also called a dike or embankment. It can be either naturally or artificially constructed.

NATIVE SPECIES

Plants and animals that occur naturally in a particular region without human introduction.

HOW DOES CLIMATE CHANGE AFFECT THE SAN FRANCISCO ESTUARY?

Climate change threatens the San Francisco Estuary in a variety of ways.

Sea Level Rise

Sea level rise is caused by ocean water expanding as it gets warmer and ice sheets on land melting. The direct connection between the San Francisco Estuary and the ocean means that extreme sea level rise can permanently drown wetlands, which are a key habitat for many plants and animals. In the past, wetlands could move inland to higher elevations as tides got higher. But today, levees, roads, and cities prevent wetlands from shifting inland. Models predict that some wetlands may survive sea level rise, but others will probably drown over

Figure 2

The San Francisco Estuary today. People built levees on the sides of the rivers and channels to protect their farms and homes. There are few small channels or marshes for fish and wildlife to live in (Photograph credit: California Department of Water Resources).

time, which is particularly problematic because most wetlands have already been lost [4].

Levee Failure

A rising sea level combined with extreme floods may cause levees to fail. Levee failure would flood the areas that are behind the levees and now below sea level. To read more about levees and the risk of island flooding, please see Stern et al. [8]. Although this flooding would be disastrous in many ways, it may create more habitat for some aquatic plants and animals [1].

Rising Water Temperatures

Another threat comes from rising water temperatures. In the San Francisco Estuary, spring and summer water temperatures are likely to increase by 1–5.5°C (1.8–9.9°F) over the next few decades. This will be stressful for native species that are adapted to lower temperatures and will likely change the timing of important life events, such as reproduction. Lacking the many microhabitats that are common in a natural estuary, including deeper waters, water shaded by cottonwood or willow trees, fast-flowing water, and groundwater-fed cooler pools, native species will have a harder time persisting [7].

Higher water temperatures also affect salmon. For thousands of years, these amazing fish have laid their eggs in small, cold streams upstream from the Estuary. Their babies hatch in streams and then migrate through the Estuary to the ocean, where they stay until they are grown and ready to return to their birth streams to lay their own eggs. Because dams block access to the clear mountain streams in which salmon used to reproduce, they now lay their eggs at much lower,

warmer elevations, but still return to their birthplace to reproduce [9]. If droughts become more frequent and water temperatures keep rising, salmon may disappear from this region, because of a lack of cool water that salmon eggs and young need to grow. People who operate dams can use cold water from the reservoirs to keep the streams below cold when the salmon need it for reproduction, but in years with little rain to fill the reservoirs, this is not an option [1].

Droughts

Droughts cause warmer water temperatures and keep seasonal floodplains dry. Extended droughts are hard on native fishes, because some fish are sensitive to warm water temperatures and many use floodplains for spawning and for feeding. Floodplains only fill with water in rainy winters, or when a lot of snow melts in the mountains [1]. Before levee construction, floodplains were common along the streams in the upper Estuary. Wet floodplains produce lots of fish food, provide habitat for young native fish, and shelter those young fish from predators [1].

Salty or Fresh Water

In estuaries, the salinity of the water increases the closer you get to the ocean. Water salinity in certain locations changes throughout the month, the year, and between years. High tides push the salty water further up into the Estuary; melting snow in the mountains brings fresh water down the rivers and makes the Estuary less salty. In dry years, the salty water can travel further into the Estuary than in wet years. Animals and plants living in estuaries are used to these changing conditions and can handle them if habitat is available along the whole stretch of the Estuary [1].

Because water from the San Francisco Estuary is pumped out for drinking water and for watering almonds, fruits, and vegetables, water managers keep the salty water from coming far up the Estuary. They catch water in upstream reservoirs in the wet season and release this water in the dry season. These management actions result in less salty but also less variable conditions, which are better for non-native or **invasive species** that are not adapted to the normal, varying conditions and can outcompete the native species [1]. To read more about the effect of invasive species see Morais et al. [10].

INVASIVE SPECIES

Species not originally from an area; "non-native," which when introduced displace and make habitats unsuitable for native species.

WHAT CAN WE DO?

Each species responds in its own unique way to changes brought about by climate change. While we expect the effects of climate change on an estuary to be profound, predicting exactly how species and ecosystems will respond is nearly impossible.

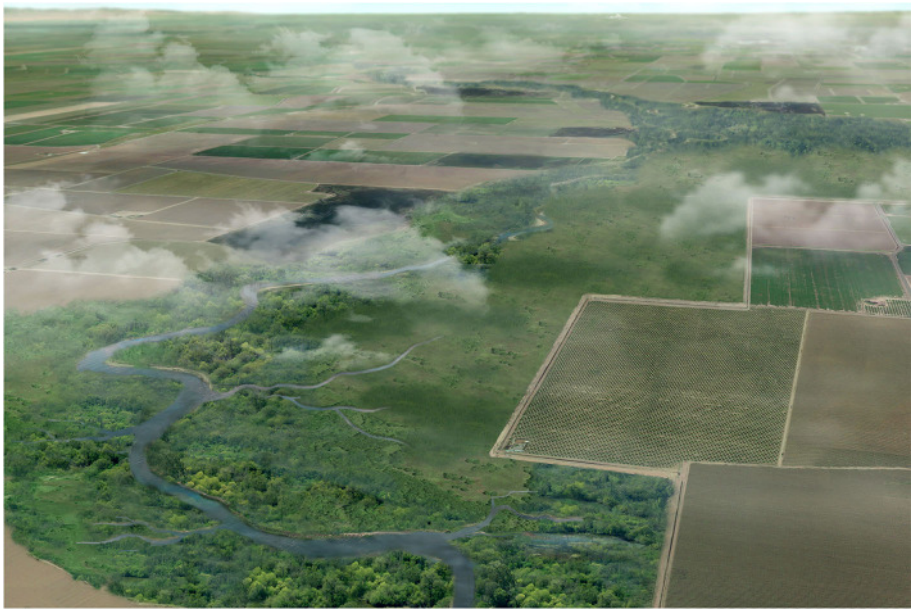

Figure 3

A vision of the San Francisco Estuary in which nature-filled landscapes surround the rivers, offering space for fish and wildlife to thrive and for people to enjoy (Image credit: Yiping Lu, San Francisco Estuary Institute).

There are three approaches to making an estuary more resilient to climate change. First, we must continue monitoring and researching fish and wildlife, salinity, water temperature, and other factors. The more we know about how the ecosystem works and responds to changes, the more effectively we can manage it. Second, it is important to restore the different ecosystems of the Estuary, particularly wetlands and floodplains, to create more habitat. A large amount of intact natural areas will offer a diversity of microhabitats, allowing fish and wildlife to move to where conditions are best for their survival (Figure 3). Finally, we should try to manage the water flowing through the Estuary, to create suitable and varying conditions for native animals and plants. In the San Francisco Estuary, this may present the greatest challenge because of the importance of the Estuary for providing water for humans.

Scientists are sure that human activity is responsible for the climate change we see today; the good news is that it means we can do something about it. In the Estuary and around the world, people are working together to understand and address the impacts of climate change. Articles like this one explaining the science of climate change can help us identify what solutions are available and move them forward.

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This group of international and hungry minds took the opportunity to engage in this new scientific activity and managed to make the difference by working wonderfully together!

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