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MURKY MYSTERIES OF YOUNG LAMPREY IN THE SAN FRANCISCO ESTUARY

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YOUNG REVIEWERS:

SAMEEN
AGE: 15

ZAINAB
AGE: 12

Early one morning, a scientist collecting fish in the San Francisco Estuary was surprised to find a young lamprey. She knew lamprey were ancient fish without jaws, bones, or scales, and she wondered to herself: Where else are young lamprey in the estuary? She discovered that although lamprey existed long before dinosaurs, little is known about their lives in estuaries. She and her team decided to gather data from scientists who accidentally caught lamprey while studying other animals. This process of reusing data from unrelated studies, called data synthesis, is an important tool for answering unsolved mysteries. The team uncovered differences in where young lamprey live and that three species live in the San Francisco Estuary, including two species that live half of their lives in the ocean and the other half in freshwater. Knowing where young lamprey live can help scientists protect the habitats lamprey need to develop.

Figure 1

Figure 1

Our discovery of a larval lamprey in the freshwater part of the San Francisco Estuary, or Delta (Illustration by N. Aha Kwan).

LAMPREY IN THE SAN FRANCISCO ESTUARY

With the light from headlamps guiding my way, I set out on a boat with a group of scientists to study predatory fish in the freshwater part of the San Francisco Estuary, also called the Delta. Gathering data for the study required us to stretch a net across the channel to capture large fish (Figure 1). As I pulled up the anchor used to secure the net to the muddy channel bottom, I noticed something wriggling in the mud left on my hand. I called to the other scientists on the boat, and together we identified the wriggling creature as a larval, or immature, **lamprey**. After carefully returning the young fish to the water, I wondered to myself, "What is a larval lamprey doing in the Estuary?"

LAMPREY

An ancient lineage of jawless and scaleless fish in the family Petromyzontidae.

Before finding the larval lamprey in the Estuary mud that morning, I did not know that lamprey could live in the Estuary when they were that young. Everything I read about these ancient fish indicated that they are **anadromous** and are only found in the Estuary when traveling between rivers and the ocean. Anadromous species use river networks to complete their lifecycles, which requires traveling great distances. When rain falls, it collects in creeks and rivers, which connect to each other and drain into the estuary and then the ocean. Anadromous lamprey also travel from the creeks and rivers where they are born, downstream to estuaries, and ultimately to the ocean. While in freshwater, larval lamprey burrow their eyeless bodies tail-first into mud or sand and **filter feed** by sucking in water and filtering out tiny organisms and decaying matter to eat. Larval lamprey are

ANADROMOUS

A large-scale migration, where adult fish travel from the ocean upstream to freshwater, to reproduce.

FILTER FEEDER

Feeding by straining suspended food particles from water. Many animals suspension feed, such as clams, krill, whales, sharks, ducks, and flamingos.

thought to remain upstream in freshwater up to 12 years, after which they begin metamorphosis, which is a physical transformation from one distinct life stage to the next. For lamprey, this transformation from the larval to juvenile stage is where their eyes fully emerge, and they develop complex sucking mouthparts. Juvenile lamprey also become free-swimming, which allows them to migrate to the ocean and **parasitize** larger fish by attaching to the sides of their bodies and feeding off their blood. When lamprey have grown large enough, they return to creeks and rivers, where they build gravel nests and spawn, releasing eggs and sperm into the water and gravel to create the next generation of lamprey [1].

PARASITIZE

A type of relationship where one organism, called the parasite, benefits from another organism, called the host, who is harmed. For lamprey, the hosts are other migratory fish, like salmon and sturgeon.

This understanding of the lamprey's anadromous lifecycle conflicted with my experience finding a larval lamprey, rather than migrating juvenile or adult lamprey, in the San Francisco Estuary, so I decided to investigate it further. If the larval lamprey I discovered in the Estuary was there by mistake, then there would be little evidence of other larval lamprey collected in the Estuary. I began speaking with other scientists studying **benthic** habitats in the Estuary where larval lamprey might be found. I discovered that other scientists were also accidentally collecting larval lamprey in the Estuary, but no one thought to look at all the lamprey catch data together.

BENTHIC

Anything associated with or occurring on the bottom of a body of water.

For some fish species, estuaries are nurseries for young fish to grow before traveling to the ocean [2]. Swimming to the ocean can be dangerous for young fish because the larger fish, birds, and mammals they encounter in the ocean may eat them. Taking time to grow larger while in an estuary can be very important for the survival of young fish. After talking with some colleagues, I assembled a team of researchers interested in understanding where larval lamprey were found in the San Francisco Estuary and why they were there. Together, we developed a two-part hypothesis: if young lamprey use the Estuary as a nursery then: (1) they will be found in the Estuary often; and (2) they will be found in places within the Estuary best suited for their development.

SOLVING THE MYSTERY WITH DATA SYNTHESIS

To test our hypothesis, we pulled together existing data on lamprey catch and habitat conditions collected by other scientists in the Estuary. The process of compiling data from multiple scientists is called **data synthesis**. We found that lamprey were caught by all the scientists whose data we collected and across all areas of the Estuary. This meant that the first part of our hypothesis was correct! As we searched through the data, we noticed there were gaps and differences in the way data were collected. The studies shared with us were not designed to collect data specifically on lamprey, and not all the scientists conducting the studies were trained to identify lamprey. Having imperfect data is a common issue with data synthesis;

DATA SYNTHESIS

A process of bringing together and studying data from multiple projects, with an aim to draw new conclusions or identify similarities to solve scientific questions.

however, there are still many benefits to conducting a data synthesis. For example, data synthesis allows scientists to use data that are freely shared and can include data gathered over many years and across a broad geographic area.

Although there were gaps in the data, our data synthesis taught us that there are three different species of lamprey in the Estuary. Two of those species, Pacific lamprey and western river lamprey, are anadromous and parasitize larger host fish while living in estuaries and the ocean. The third species, western brook lamprey, is not anadromous or parasitic [1]. Instead, this species lives only in freshwater. Freshwater lamprey that are not parasitic spend most of their lives as filter feeders. As adults, western brook lamprey do not parasitize other fish; in fact, the adults do not feed at all. Instead, they live off the energy stored up in their bodies during the filter feeding stage of their life. This life strategy allows lamprey to live in small streams, from which swimming to the ocean may not be possible.

Once we discovered that several species of lamprey lived in the Estuary, we examined our second hypothesis: that young lamprey prefer certain areas of the Estuary. Our team used math to determine the **probability** of young lamprey presence in different areas of the Estuary. This revealed that young lamprey were found in some places more than others. In fact, there was a greater chance that young lamprey would be found in the lower Sacramento River and the **confluence** of the Sacramento and San Joaquin rivers (Figure 2). Our team also discovered that the probability of young lamprey living in the San Francisco Bay and lower San Joaquin River was very low, indicating that lamprey may require specific habitat conditions to thrive. The lower San Joaquin River is known to have higher water temperatures and poor water quality [3], which may be harmful to young lamprey

PROBABILITY

How likely an event is to occur. The value of a probability is a number between zero and one, where zero is impossible and one is certain.

CONFLUENCE

An area where two rivers meet and combine into one. In the San Francisco Estuary, the confluence is the area where the Sacramento and San Joaquin rivers meet.

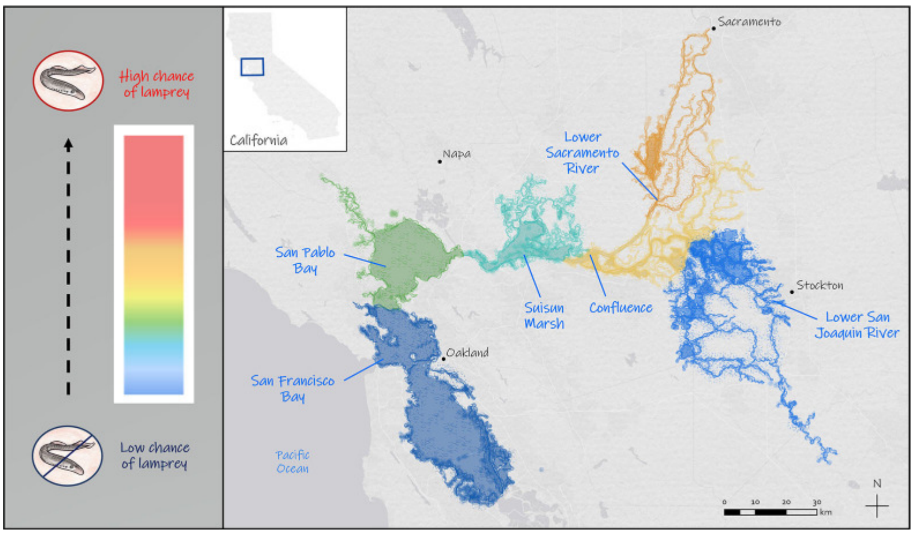

Figure 2

Figure 2

The probability that young lamprey are present in different areas of the San Francisco Estuary. Warmer colors indicate places with the highest chance of lamprey and cooler colors indicate that lamprey are not likely to be found in that area. For example, green in the San Pablo Bay means that there is a 25% chance (1 out of 4) of capturing a young lamprey. Notice that there is no red on this map, which means that no area in the Estuary has a very high chance of finding lamprey.

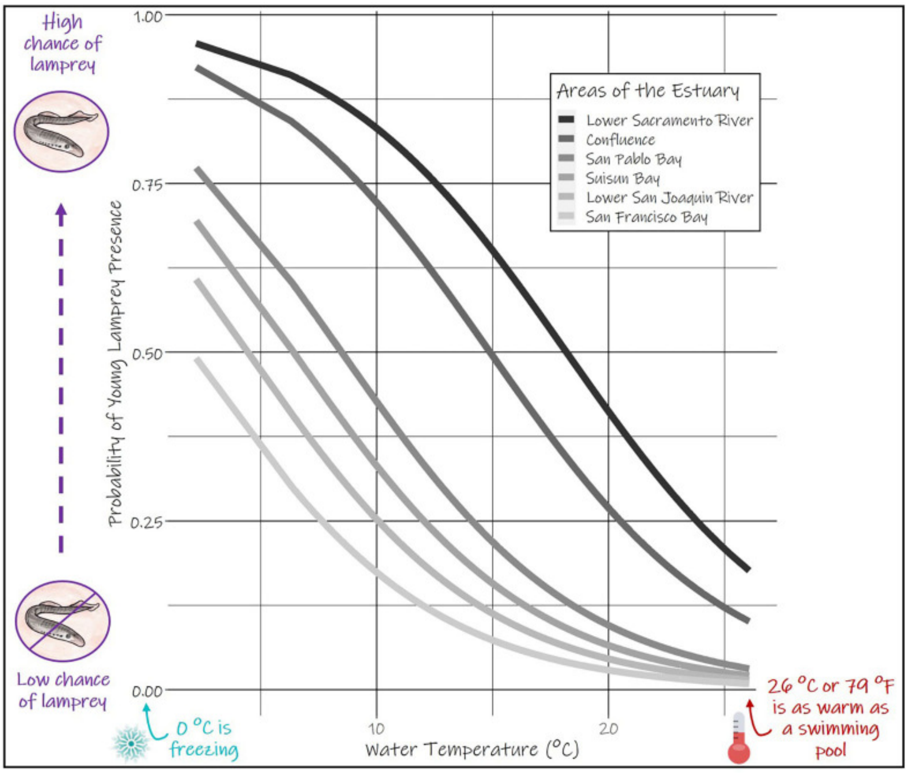

Figure 3

Figure 3

The probability that young lamprey are present at different water temperatures (in degrees Celsius) and areas of the San Francisco Estuary. Notice that in every area of the Estuary, or every line in this figure, there is a higher chance of capturing lamprey at colder water temperatures than at warmer water temperatures. For example, the horizontal line at 0.75 is a probability of 0.75, or a 75% chance (3 out of 4) of capturing a young lamprey in that area and at that temperature. As the temperature increases, the chance of capturing a lamprey decreases.

that filter feed. This is because filter feeding exposes the larval lamprey to chemicals and pollution that may build up in the mud or sand where they feed [4].

The analysis also taught us that young lamprey were more likely to be found where water temperatures were cooler (Figure 3). Like many fish species, the energy required for a lamprey to survive is controlled by temperature. Warmer water temperatures that sometimes occur in the Estuary may stress or harm lamprey [5]. If young lamprey use the Estuary as a nursery, then Figure 3 shows that the cooler temperatures in the lower Sacramento River and the confluence of the Sacramento and San Joaquin rivers may be important places for lamprey to develop.

Like most studies, there are questions left unanswered and new questions asked. Although we discovered where young lamprey are most likely to be within the Estuary, it is still not clear what young lamprey are doing there. The data we compiled were missing details on the developmental stage of each lamprey collected. It may be that larval lamprey feed and grow in the Estuary, whereas metamorphosed juvenile lamprey may only enter the Estuary on their way to the ocean. We cannot know for certain that the young lamprey found in the Estuary were using the Estuary as a nursery or if they were simply traveling to the ocean. However, our data synthesis taught us a valuable lesson—several species of lamprey live in the San

Francisco Estuary and water temperature impacts where we find them. Now, scientists can continue to investigate the remaining unanswered questions by collecting more consistent data to determine which habitats lamprey prefer during each life stage.

HOW WE SHARE WATER RESOURCES WITH FISH

With this new information, we can focus our efforts to protect these areas for future lamprey. California lamprey populations are thought to be declining [1]. Habitat changes and destruction have already restricted known populations to limited areas with less-than-ideal habitat. Understanding how young lamprey respond to warm water temperatures may be critical for protecting these species. As we learn more about lamprey habitat use, more information will be available to help us to improve and expand existing habitat. This is important because lamprey provide many benefits to the environment. For example, larval lamprey feed by filtering tiny organisms and decaying matter out of the water, which helps keep waters clear. Lamprey are also food for other animals, including humans! Protecting lamprey not only keeps them around for us to study, but it also helps preserve the ecosystems that rely on their services.

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ORIGINAL SOURCE ARTICLE

Goertler, P. A., Shakya, A. W., Seesholtz, A. M., Schreier, B. M., Matica, S. Z., and Holley, K. S. 2019. Lamprey (*Entosphenus* sp. and *Lampetra* sp.) estuarine occupancy is regionally variable and constrained by temperature. *J. Fish Biol*. 96:527–32. doi: 10.1111/jfb.14143

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YOUNG REVIEWERS

SAMEEN, AGE: 15

Hello, I am Sameen from and I have a strong interest in science subjects, but I like studying biology more. I love to explore natural processes, particularly in aquatic ecosystems. I love to read science articles in the newspaper and learn new languages. Besides, I wish to participate in environmental clubs and field trips. I want to study freshwater ecosystems and molecular biology when I grow up.

ZAINAB, AGE: 12

Hi, My name is Zainab, and I live in a small village. I am excited about species relationships and environmental changes, perhaps why I love knowing about species and ecosystem biology. Apart from that, I want to learn about the history of species and their environment. I like to go to the countryside and see the variety of land plants and animal species. I am also willing for online learning activities related to biology and ecosystems.

AUTHORS

PASCALE AVA LAKE GOERTLER

I am an ecologist who works with fish that travel great distances and are eaten by people. In California, where I live and work, we share the rivers, estuaries, and ocean with the three native groups of fish that I study most often: salmon, sturgeon, and lamprey. My research aims to better understand how to balance the needs of humans and fish for the environment, particularly in estuaries. I am also very interested in data and statistics, and work with other scientists to combine data for a more comprehensive perspective on these fish. *pascale.goertler@deltacouncil.ca.gov

KIMBERLY SHEENA HOLLEY

I am a regulatory biologist with the California Department of Fish and Wildlife. My work is focused on protecting threatened and endangered species that are impacted by long-term changes in their habitats. I work with other fisheries and terrestrial biologists to promote improvements in science and monitoring efforts. New science and collaboration helps me develop management actions that will improve habitat for species in decline. Outside of work, I enjoy exploring the outdoors and all things related to crafting.

NICOLE AHA KWAN

I am a fisheries ecologist with the California Department of Water Resources. I am passionate about advancing fisheries science, to help native species in decline. In my job, I often put on waders and head out into the field to sample fish in river and floodplain habitats. The data from these sampling projects is an important part of monitoring native and endangered species and informing actions to improve their populations. In my free, time I enjoy running with my dog, doing DIY projects, and traveling.