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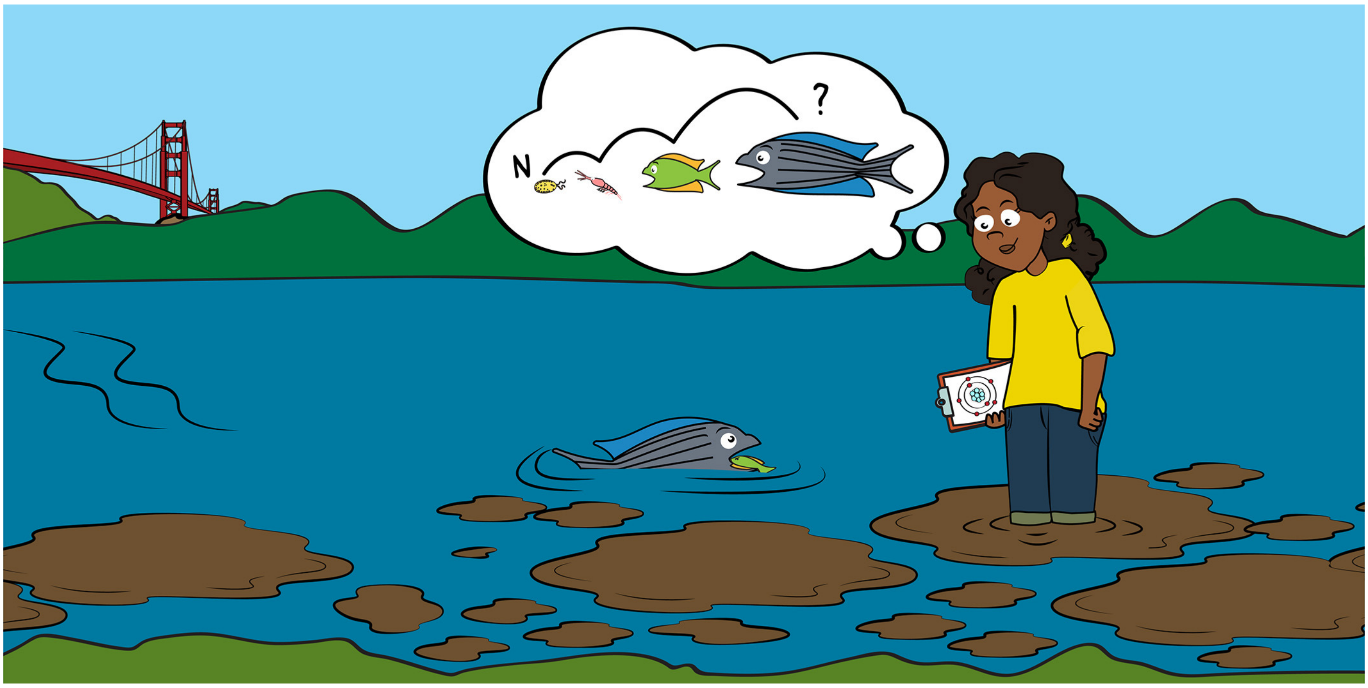

UNTANGLING THE FOOD WEB OF SUISUN MARSH USING ISOTOPES

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YOUNG REVIEWERS:

ANSHUL
AGE: 10

J. W.
AGE: 10

LUVENA
AGE: 12

MATTHEW
AGE: 14

PRANATEE
AGE: 13

What goes on beneath the waters of a marsh? What are the critters below the surface eating? Scientists who study Suisun Marsh in California find out by using a new and powerful tool called isotope analysis. With this technique, scientists untangle the complex food web of Suisun Marsh. This knowledge helps us understand what the connections are between the different types of plants and animals in the Marsh, and how changes to the system may impact these species.

FOOD WEBS ARE DIFFICULT TO STUDY

Nestled in the upper San Francisco Estuary, where rivers meet ocean waters, is California's largest tidal wetland: Suisun Marsh (pronounced "suh-soon") (Figure 1). If you were to dive beneath the water's surface there, you would be amazed by all the activity you find. Over 50 fish species and countless **invertebrates** inhabit the marsh [1].

INVERTEBRATES

Invertebrates are animals without a backbone.

Figure 1

Figure 1

Suisun Marsh is located in the northern region of the San Francisco Estuary in California (United States of America). The call-out box that says "Sampling Location" shows where we sampled in 2011 for the food web isotope study.

The combination of fishes, invertebrates, and their foods makes up what scientists call a food web. Food webs help scientists describe what animals are eating in a place. Food webs organize what animals are eating by splitting them up into **trophic levels**. Trophic levels indicate what a plant or animal eats and what it gets eaten by. The number of trophic levels in a place depends on the number and diversity of species that live there.

In a typical marsh, there are four to five trophic levels. The first level includes organisms that make their own food. These are called primary producers. **Primary producers** in a marsh are typically plants and phytoplankton. They get energy from the sun to produce their own food with the nutrients from the soil, water, and air. The animals that eat the primary producers are the **primary consumers** (usually tiny organisms such as bacteria). **Secondary consumers** (such as mysid shrimp) eat primary producers and primary consumers. The next level up is tertiary consumers. **Tertiary consumers** eat lower-level consumers. A fish that eats mysid shrimp is a tertiary consumer.

How do we figure out what a food web looks like? How do we know what these animals eat and what trophic level they are in? Scientists identify food in animal stomachs to understand food webs. However, because so many animals are small, it is hard to identify the exact foods in their stomachs. This has made it hard for scientists to get a complete picture of a food web. Luckily, a new tool called "isotope analysis" gives scientists a way to map food webs more completely.

TROPHIC LEVEL

Describes the overall categories of a food web. Primary producer, primary consumer, secondary consumer, and tertiary consumer are all different trophic levels.

PRIMARY PRODUCER

Organisms that produce their own food. Plants are primary producers.

PRIMARY CONSUMER

Organisms that only eat primary producers. Zooplankton can be primary consumers.

SECONDARY CONSUMER

Organisms that eat primary consumers and primary producers. Amphipods are an example of a secondary consumer because they eat bacteria and aquatic vegetation.

TERTIARY CONSUMER

Organisms that eat secondary and primary consumers. Striped bass are tertiary consumers that eat amphipods (secondary consumers).

USING ISOTOPES TO STUDY FOOD WEBS

Isotopes are different versions of the same element. To understand what isotopes and elements are, we first need to define what atoms are. Everything around you is made up of tiny building blocks called **atoms**. Atoms are made up of even tinier pieces called protons, neutrons, and electrons (Figure 2A). Different atoms have different numbers of protons, neutrons, and electrons.

ATOM

A tiny building block of our universe, made up of electrons, protons, and neutrons.

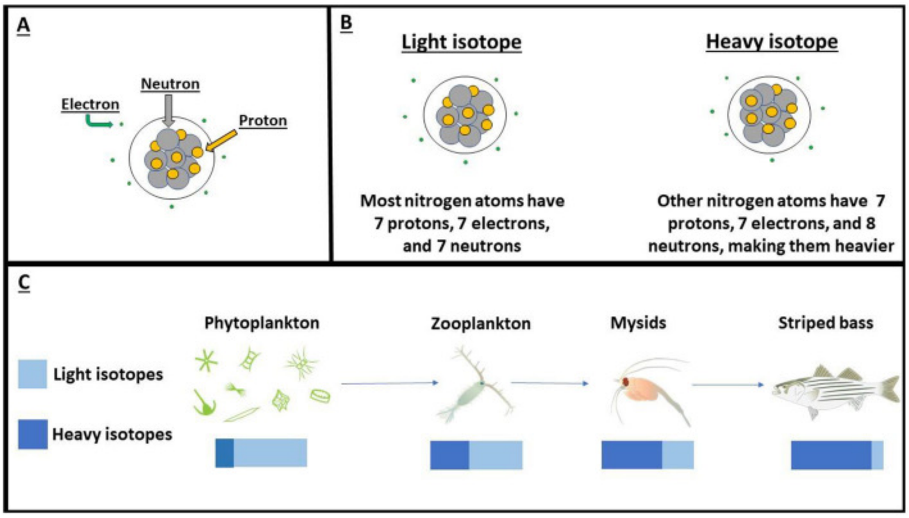

Figure 2

Figure 2

(A) Using nitrogen as an example, you can see that atoms are made up of protons, neutrons, and electrons. The number of protons determines which element the atom belongs to. **(B)** Two isotopes of the element nitrogen. The different number of neutrons gives isotopes different weights, which causes them to behave differently. **(C)** As nitrogen isotopes get passed along the food web, each time an animal eats another they gain more heavy nitrogen. The most amount of light nitrogen is found in the phytoplankton and the most amount of heavy nitrogen is found in the striped bass.

We organize atoms by the number of protons they have and define them as **elements**. For example, nitrogen is an element whose atoms have seven protons. When atoms of the same element have different numbers of neutrons, however, they are called **isotopes** of that element. For example, the element nitrogen has two isotopes. Isotopes with more neutrons are heavier than isotopes with less neutrons (Figure 2B).

ELEMENT

The type of atom, based upon the number of protons the atom has. For example, the element carbon has 6 protons in each of its atoms.

To know what trophic level an organism is in, scientists use nitrogen isotope analysis. The difference in isotope weights is the key to nitrogen isotope analysis. Organisms process heavy nitrogen isotopes more slowly than light nitrogen isotopes. This means that when they eat stuff with nitrogen in it, they will keep more of the heavy isotopes which are slow and hang around in the gut. Meanwhile the light nitrogen isotopes rush through and leave the body.

ISOTOPE

An isotope of an element depends on the number of neutrons it has. Different isotopes of the same element have different behaviors based upon the number of neutrons they have.

Phytoplankton (primary producers) have less heavy nitrogen isotopes than zooplankton (primary consumers). Mysid shrimp (secondary consumers) have less heavy nitrogen isotopes than a striped bass (tertiary consumer) (Figure 2C). This process is very predictable, so looking at nitrogen isotopes allows scientists to figure out how many trophic levels exist in a food web.

To know what animals are eating, scientists use carbon isotope analysis. Carbon is an element whose atoms have six protons. Heavy carbon isotopes have seven neutrons while light carbon isotopes have six. Some primary producers take up more heavy carbon when they photosynthesize sunlight, while others keep more light carbon isotopes.

Once scientists understand which primary producers keep more light carbon and which keep more heavy carbon, they can connect them to animals with similar types of carbon isotopes. So, a plant that has more heavy carbon will pass on more heavy carbon to a primary consumer than a light-carbon plant does for its own primary consumer (Figure 3). By understanding isotopes, scientists can use nitrogen to figure out how many levels there are in a food web and carbon to understand the connections between those levels. Pretty neat stuff!

THE SUISUN MARSH FOOD WEB

In autumn 2011, scientists from the University of California, Davis, wanted to understand the food web of Suisun Marsh in the San Francisco Estuary. To untangle the food web of Suisun Marsh (Figure 1), they collected samples of algae and plants (the suspected primary

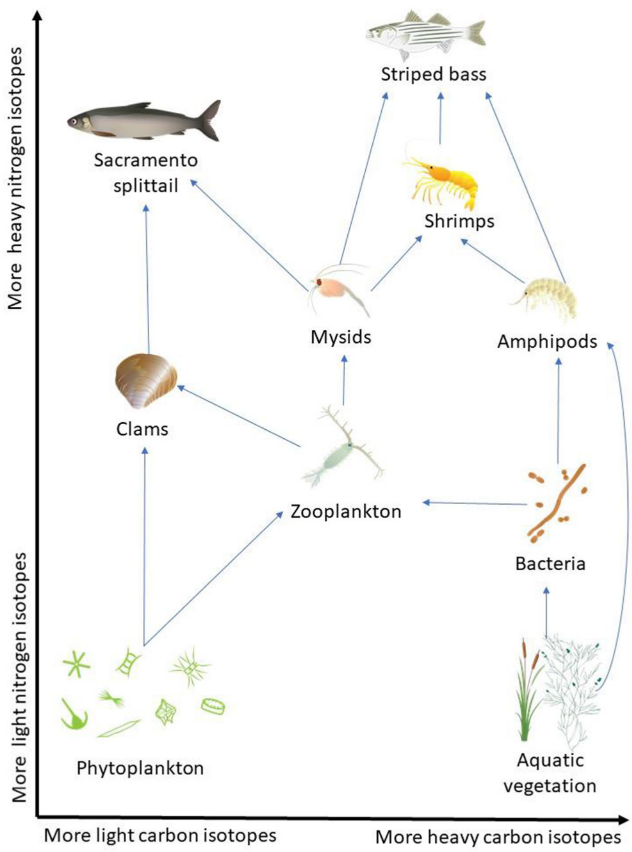

Figure 3

Figure 3

Analysis of isotopes, combined with knowledge from other diet studies, helps scientists understand Suisun Marsh's food web. The primary producers shown here are phytoplankton and aquatic vegetation. The arrows show the path carbon and nitrogen isotopes take as plants and animals get eaten. Diagram does not have every organism in Suisun Marsh but does show how some pieces of the food web fit together [2]. Images in diagram acquired from Integration and Application Network (ian.umces.edu/media-library).

producers). They also collected consumers such as zooplankton, clams, shrimps, and fish—anything they suspected could be in the food web. Then, samples were taken to the lab to look at the nitrogen and carbon isotopes each species had.

The results from the nitrogen isotopes showed scientists that Suisun Marsh's aquatic food web had four trophic levels: primary producers, primary consumers, secondary consumers, and tertiary consumers. Nitrogen isotope analysis confirmed that plants and algae were the primary producers in the marsh. Nitrogen showed only one primary consumer in the marsh – small pileworms. The pileworms had relatively little heavy nitrogen. Secondary consumers had more heavy nitrogen. The secondary consumers were amphipods and mysid shrimp. Striped bass had even more heavy nitrogen, so it was a tertiary consumer (Figure 3).

The results showed large gaps in the food web. Curiously, no primary consumers other than pileworms were found. This likely means we missed other small primary consumers in the marsh (bacteria, for example) because we did not sample them. There were other gaps as well. We know of other fish and invertebrates in the marsh's waters that we did not sample. For example, even though we did not sample Sacramento splittail, we know from other studies that they eat clams. Since it is so hard to study aquatic environments, sometimes it takes putting together information from multiple studies to get a complete answer to our questions (Figure 3).

The data the scientists got from carbon isotopes showed how the different trophic levels were connected. In Suisun Marsh, more heavy carbon belonged to phytobenthos and submersed aquatic vegetation. Phytobenthos are algae that live underwater on the marsh mud. Submersed aquatic vegetation are plants that grow entirely under water (Figure 3). Brazilian waterweed is an example of submerged aquatic vegetation.

More light carbon was found in terrestrial vegetation, emergent aquatic vegetation, and phytoplankton. Plants that grow only on land are called terrestrial vegetation. Bushes, trees, and grass are examples of terrestrial vegetation. Emergent aquatic vegetation are plants that start growing below water and emerge into the air as they grow. Tules are a member of this group. Phytoplankton are microscopic algae that float around in the water and turn nutrients and carbon dioxide into food.

Once the scientists understood the different carbon types of the primary producers, they looked at the consumers in the food web to see which producers they were getting their carbon from. Following the path of light and heavy carbon isotopes, scientists could trace what the consumers were eating. Many invertebrates (such as zooplankton and clams) ate a lot of phytoplankton, decaying emergent vegetation, and decaying terrestrial vegetation. Other invertebrates (such as amphipods) had more of the heavy carbon isotopes, which connected them to submersed aquatic vegetation and phytobenthos.

Higher-level consumers used all of the carbon sources. Most secondary consumers had more light carbon isotopes. This was true for Black Sea jellyfish, yellowfin gobies, and prickly sculpin. Shrimp, on the other hand, had more of the heavy carbon isotopes. Striped bass, one of the most important fishes in the marsh, fell practically in the middle of the carbon spectrum. This means that striped bass ate a large range of other consumers (Figure 3) [2].

FUTURE RESEARCH

Untangling food webs is tricky, but using isotope analysis gets us closer to understanding the mysteries of who eats whom. The knowledge gained from these studies helps scientists predict how climate change and development projects near Suisun Marsh may impact species in the San Francisco Estuary. If these changes wiped out any one species in the food web, everything could change. Predicting how wetland species will react to changes is crucial for management and conservation of these species. Much more work needs to be done to deepen our understanding of how all the plants and animals in this important area are connected so that we can better protect them.

ORIGINAL SOURCE ARTICLE

Schroeter, R. E., O'Rear, T. A., Young, M. J., and Moyle, P. B. 2015. The aquatic trophic ecology of Suisun marsh, San Francisco estuary, California, during autumn in a wet year. *San Franc. Estuary Watershed Sci.* 13:3. doi: 10.15447/sfews.2015v13iss3art6

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2. Schroeter, R. E., O'Rear, T. A., Young, M. J., and Moyle, P. B. 2015. The aquatic trophic ecology of Suisun marsh, San Francisco estuary, California, during autumn in a wet year. *San Franc. Estuary Watershed Sci*. 13:3. doi: 10.15447/sfews.2015v13iss3art6

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ANSHUL, AGE: 10

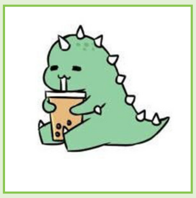
Hello! My name is Anshul and I am a fifth grader in North Wales, Pennsylvania, which is close to Philadelphia. I am very interested in Biology and Entomology. I am an active member for the Johns Hopkins CTY program, and my favorite hobby is to read.

J. W., AGE: 10

My name is J. W. and I live on a ranch. I love to pet cows and play with my dogs. I also like whittling wood to make stuff and riding my 4 wheeler.

LUVENA, AGE: 12

Hi, my name is Luvena! I love music, sports, and food. My favorite subjects in school are math and language arts. In my spare time, I enjoy playing piano and reading books with my sister. When I grow up, I would like to be a neurosurgeon.



MATTHEW, AGE: 14

Outside of school, Matthew spends lots of time wrestling, building elaborate Lego structures, and eating chocolate chip cookies. He wishes he had spent less time battling his 3D printer.

PRANATEE, AGE: 13

Hello! I love to bake, especially tarts and pies. In school, my favorite subjects are science, lunch, and recess. I like spending time outdoors and going hiking. I also love going to the beach and have an interest in photography. Watching my favorite TV shows, painting, listening to music, singing, and hanging out with friends are my favorite things to do in my free time. In the future, I would like to either like to be a scientist, or a singer/songwriter and actress.

AUTHORS

CAROLINE L. NEWELL

Caroline L. Newell is a research biologist at the University of California, Davis. She studies fish and food-web dynamics in the Suisun Marsh and upper San Francisco Estuary. She received her bachelor's degree from U.C. Davis with a major in wildlife fish and conservation biology, and minors in statistics and geographic information systems. She loves getting muddy and fishy out in the field and doing science that helps conserve habitat for her beloved aquatic critters. In her spare time, she loves playing soccer. *clsnewell@ucdavis.edu

TEEJAY A. O'REAR

Teejay A. O'Rear is the supervising field biologist for several fisheries projects conducted by U.C. Davis. His primary interest is the relationships among native and non-native aquatic species through time in the San Francisco Estuary watershed. Additionally, his work focuses on rethinking dogmatic ideas such as *native*, *wild*, *non-native*, and *watershed*. In his spare time, he bashes on a guitar and a computer keyboard, and roams all over the wild areas of California.

JOHN R. DURAND

John R. Durand studies the ecology of foodwebs and fish in estuaries. He is particularly interested in how restored and managed wetlands create food and habitat for fishes and other animals, and the effects of climate change on these habitats. Dr. Durand got interested in wetlands and estuaries because he spent a lot of time kayaking in them and had a lot of questions, which eventually led him to get a Ph.D., in ecology at University of California, Davis, where he still works as a research scientist.