The Microscopic World of Plankton

Exploring Aquatic Food Webs and Marine Ecosystem Processes

BY ANUSCHKA FAUCCI, JOANNA PHILIPPOFF, AND CRISTINA VERESAN

Plankton are some of the most diverse and numerous organisms on Earth. They reside in all bodies of water, including the ocean, lakes, ponds, and estuaries. The term plankton comes from the Greek word *planktos*, meaning wanderer or drifter. Hence, plankton cannot swim against major currents. They are also tiny—over one million plant-like phytoplankton can fit in a teaspoon of water. Viewing marine plankton under a microscope reveals spikes, coiled shells, jointed appendages, and delicately woven chains.

Focusing on plankton is an excellent way to introduce students to aquatic food webs and marine ecosystem processes, which are often neglected, even though understanding these processes is essential to understanding the more than 70% of our Earth that is covered in water. In this series of lessons, students create a plankton net to collect live specimens for observation with a microscope. Then, students construct a food web model to better understand how populations of plankton (despite their small size) affect aquatic ecosystems around the world. The lessons align with the *Next Generation Science Standards* (see *NGSS* box, p. XX).

CONTENT AREA

Life sciences, engineering

GRADE LEVEL

6–8

BIG IDEA/UNIT

Plankton are the basis of the aquatic food web and reflect the physical and chemical components of the surrounding ecosystem.

ESSENTIAL PRE-EXISTING KNOWLEDGE

Food webs are composed of producers, consumers, and decomposers. Most producers convert water and carbon dioxide into food and oxygen using light energy from the Sun through the process of photosynthesis. Many organisms in the food web have unique and diverse life cycles.

TIME REQUIRED

Approximately 4–8 50-minute classes (not including optional field trip to collect plankton)

COST

Approximately $25/class (not including transportation for optional field trip to collect plankton)

SAFETY

See the Safety Note on p. XX

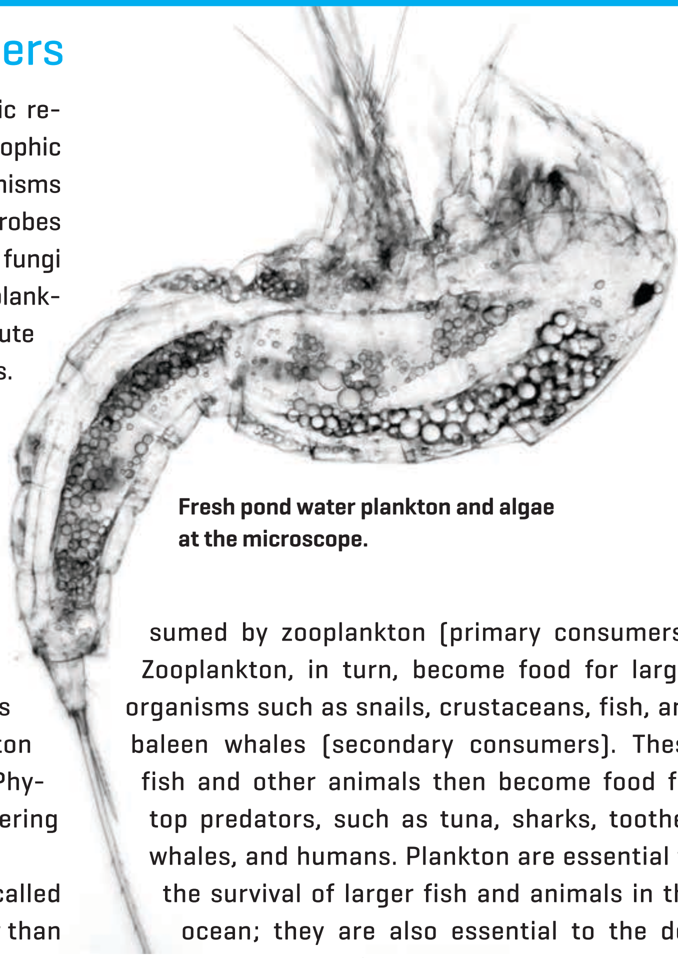
Plankton primer for teachers

Plankton can be classified by size, taxonomic relationships, or trophic group. Traditional trophic groups of plankton include plant-like organisms (phytoplankton), animals (zooplankton), microbes (bacteria and archaea: bacterioplankton), and fungi (mycoplankton). Fungi and many microbial plankton are important decomposers that contribute to the cycling of matter in aquatic ecosystems. Student-collected plankton mostly include phytoplankton and zooplankton.

Each plant-like phytoplankton is usually a single cell or a chain of cells. Phytoplankton lack roots, stems, and leaves, but like land plants, they use water, carbon dioxide, and energy from the Sun to make food in the form of sugars, while generating oxygen as a byproduct. Through this process, called photosynthesis, phytoplankton produce over 50% of the oxygen on Earth! Phytoplankton are extremely productive considering their small size.

The animals that drift in the ocean are called zooplankton. Zooplankton are usually larger than phytoplankton and can range in size from microscopic to sea jellies that can grow several meters in length. There are two types of zooplankton: temporary and permanent. The temporary zooplankton—meroplankton—only spend part of their life cycle as plankton. Meroplankton are plankton only when they are young larvae. When they grow up, they transform into completely different forms such as crabs or fish. Most marine organisms that live along the coasts or on the bottom floor of the ocean have a planktonic larval stage. In contrast, the permanent zooplankton—called holoplankton—spend their whole life as plankton (e.g., copepods).

In addition to supplying oxygen, plankton serve as the nutritional basis for many of the animals that live in our ocean. Phytoplankton are primary producers within marine food webs, and are consumed by zooplankton (primary consumers). Zooplankton, in turn, become food for larger organisms such as snails, crustaceans, fish, and baleen whales (secondary consumers). These fish and other animals then become food for top predators, such as tuna, sharks, toothed whales, and humans. Plankton are essential to the survival of larger fish and animals in the ocean; they are also essential to the decomposition of ocean organisms. Plankton are critical to matter cycling in aquatic food webs; without plankton, marine food webs would collapse.



Fresh pond water plankton and algae at the microscope.

Just like plants on land, phytoplankton require nutrients to grow. Therefore, places with more nutrients in the water have larger densities of plankton. Phytoplankton densities are also dependent on light availability from the Sun. Therefore, plankton densities have predictable seasonal variation. For example, nutrient-rich polar areas in the summer have some of the highest plankton densities. Disturbing this natural balance (e.g., by pollution or global climate change) can have drastic effects on the plankton community and consequently affect fish populations (Moore 2018). (See Online Supplemental Materials for a plankton primer for students.)

Before engaging in the activities, make sure students have had some prior knowledge of energy flow and matter cycling, perhaps through previous explorations of photosynthesis and food webs. For background information about plankton, see Plankton Primer for Teachers, p. XX.

Lesson implementation

This series of lessons will take four to eight 50-minute class periods to cover all the material. Specifically, this requires one or two classes for the preassessment, plankton activity card sort, and introduction to plankton; one or two classes for plankton net construction and plankton collection; one class period for plankton observation; and one to three class periods for the summative project and postassessment. Students who need additional support will find comfort in the collaborative work, content scaffolding, and teacher modeling featured in these lessons. We provide some specific modifications for differentiating the lessons, but you can adapt all aspects of the lessons to meet the abilities of your students.

Gauging students' prior knowledge

Most students are unfamiliar with plankton; as such, they rarely have preconceptions about these organisms. However, students do hold misconceptions about plankton. For example, students may think that there is just one type of plankton or that plankton are not important because of their small size. As a preassessment, gauge your students' prior knowledge of plankton by asking them the following questions, either as science journal writing prompts or in small-group or whole-class discussions.

- What are plankton?
- How can we collect and observe plankton?
- How big are plankton?
- What are the different types of plankton?
- What do plankton eat? What eats plankton?
- How are plankton related to matter cycling in aquatic ecosystems?
- How do changes in plankton populations affect aquatic food webs?
- How does pollution affect plankton and aquatic food webs?

As a postassessment, students can revisit these questions and write individual responses in their science journals. Students could also address the questions in a creative format such as a blog, children's book, animation, or game. You can differentiate the product by providing options from which to choose

FIGURE 1: Plankton activity card with description

Common name: *Cyanobacteria puff*

Taxonomic designation: Bacteria – Eubacteria – Cyanobacteria – *Trichodesmium*

Description: This little puff is a colony of cyanobacteria, probably in the genus Trichodesmium, commonly found in tropical and subtropical shallow waters low in nutrients. Cyanobacteria obtain their energy through photosynthesis. These puffs are little floating oases providing habitat for many marine organisms including other bacteria, diatoms, protozoans, and copepods. Copepods are its primary predator.

Habitat: Tropical and subtropical shallow waters; holoplankton

Position in food web: Producers/autotrophs (photosynthesis)

FIGURE 2: Students using the plankton activity cards

from to demonstrate understanding.

Introducing plankton

To engage students in the lesson series, we first provide them with plankton activity cards (Online Supplemental Materials). The cards include 25 high-resolution photographs of diverse marine planktonic organisms and information on the organisms' taxonomy, biology, ecology, and life history (Figure 1). Although the images on the cards display species found in Hawaii, the taxonomic groups occur worldwide. Unlike diagrams, the images reveal the color (or lack of color) of plankton and such structures as appendages and sensory organs. You can also print, cut, and laminate the cards for repeated classroom use.

A plankton card sort not only introduces students to plankton, but also helps them practice observation and reasoning skills. To begin, arrange students in small groups of two to four and provide each group with a set of plankton activity cards. Next, instruct students to look for patterns and then sort the plankton according to shared characteristics such as morphology, taxonomy, position in a food web, or life history. Allow each student group to explain the reasoning behind their choices to the class. Finally, provide student groups with the descriptions of the organisms and give students the opportunity to revise their categories.

There are many other uses of the plankton activity cards. The following list describes just a few ideas:

- **Assigning groups:** Give each student a plankton card and have them find other students with the same organism.
- **Memory game:** Give each student group two sets of cards to play a memory-style matching game (Figure 2). Students spread out cards picture side down on the table. One student selects and turns over two cards. If the cards match (e.g., two copepods) the student keeps the pair and takes another turn. If not, the student flips the cards back over. Students in the group rotate turns until all the cards have been matched, and the student with the most pairs wins.
- **Reviewing adaptations:** Students can identify plankton structures (e.g., eyes, legs, antennae, spines) and research their functions. Students could also discuss advantages of certain sensory organs or other appendages (e.g., large compound eyes

FIGURE 3: Student-constructed plankton nets (top two purple nets) and a commercially available net (bottom white net).

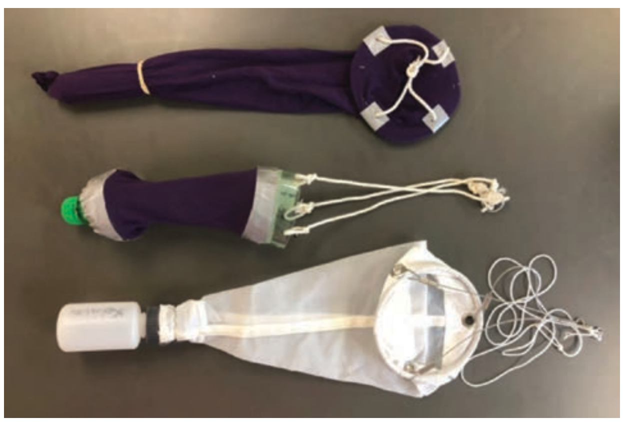
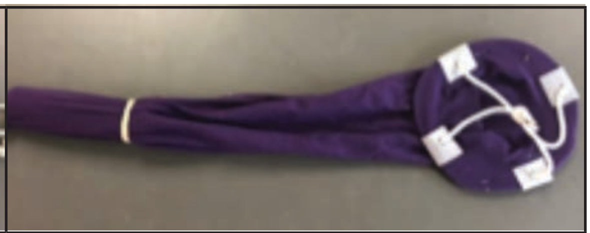


FIGURE 4: Instructions for making two types of plankton nets

		
Materials (per group of 3–5 students)	• one plastic soda bottle (any size) with cap • one piece of nylon stocking that is as long as the bottle • nylon or other heavy-duty string: about 9 feet for net, about 6 feet for tow line • 1 inch key ring • duct tape • scissors • hole puncher • small collection container with lid **Total cost:** about $10 for six nets	• metal wire (about 20 inches long) • one piece of nylon stocking (about 1 foot long) • two pieces (about 20 inches long) of nylon or other heavy-duty string; two pieces of tow line (about 6 feet long) • 1 inch key ring • rubber band • duct tape • scissors • stapler • hole puncher • small collection container with lid **Total cost:** about $15 for six nets
Instructions	1. Cut the nylon stocking to about the length of the plastic bottle. 2. Cut the bottle into three equal parts. Leave the cap on. Discard the bottom part of the bottle. 3. Attach the nylon stocking with duct tape to the bottle parts (see diagram). 4. Punch three holes, evenly spaced apart, around the open end of the bottle. 5. Cut string into three 3-foot pieces. Attach each string to one of the holes and tie them together with a key ring. 6. Attach a tow line to the key ring. 7. Collect plankton. Remove bottle cap to pour water with collected plankton into collection container.	1. Bend the metal wire into a circle (about 4 inches in diameter). Overlap the loose ends and use duct tape to fasten them together. 2. Put one end of the nylon stocking on the wire ring. Secure the stocking to the ring by using staples. 3. Tie a knot in the bottom of the stocking and put the collection jar without the lid inside. 4. Secure the stocking around the rim of the jar with the rubber band. 5. Cut four pieces of duct tape and place them evenly around the wire ring at the top of the net. Punch a hole in each piece of duct tape. 6. Tie the key ring to the middle of each of the two pieces of string. Thread each end of the strings through one of the four duct tape holes and secure with a knot. 7. Attach the tow line to the key ring so you can collect plankton. Put the lid on the collection container to transport your plankton.

belonging to visual predators and long spines and appendages help with buoyancy and can prevent predation).

Creating plankton nets

Although commercial plankton nets are available for purchase, students can construct a simple plankton net using a few everyday materials (Figure 3). Homemade plankton nets usually consist of a stocking for the net. The opening of the net is framed by a ring of wire or plastic, and a container is attached at the end to collect the plankton. The size of the net's mesh will determine the size of plankton collected. For example, student-made nets using fine-mesh stocking will collect mostly zooplankton. (See Figure 4 for basic instructions for constructing two types of plankton nets.) Students can select one net, or both, to construct and test. Students may also choose to combine features of these nets to make their own improved design.

If you decide to pose plankton collection as an engineering design challenge, students can define the problem, develop possible solutions, and improve their designs. For the design challenge, have students work in collaborative teams of three to four and document the process in their science journals with sketches, notes, and reflections. Alternatively, students can use the design process worksheets developed by NASA for documentation; the included rubric can be used for student or teacher assessment of the plankton net design (see NASA Design Packet under Resources). While students are constructing their nets, circulate the room to monitor student behavior and safety. (*Safety note*: Review safety procedures for using hot glue guns and sharp blades. Students should also wear impact safety goggles when assembling the plankton net and indirectly vented chemical splash safety goggles when collecting samples.)

Make sure to allow time for student groups to iteratively test and modify their plankton net designs for optimum results. For example, a plankton net made mostly of plastic might float rather than sink below the water. Students could modify their nets by adding small weights to the frame or collection jar. If testing designs in the field is not possible, students can test them in a sink, tub, or small plastic or inflatable pool filled with water. Although you may use glitter to simulate plankton, filter all of the glitter from the water before disposal to avoid clogging your drain.

FIGURE 5: Students collecting plankton along a harbor

Collecting plankton

Because plankton live in all aquatic environments, including streams and lakes, you do not have to live near the ocean to collect them. Collecting plankton is easiest, and safest, in places that do not require students to enter the water, such as along piers and harbors (see Figure 5), though collecting plankton in knee-deep water along a shoreline is also effective.

Each shoreline and body of water presents their own set of potential hazards. If you are not comfortable determining a safe and appropriate location for plankton collection, contact local experts, perhaps from a nearby marine or aquatic science center or college science department. Remember to follow all field trip safety guidelines required

Plankton prep instructions

Safety note

There is minimal risk involved with collecting plankton yourself or with students, but you need to consider every potential hazard in order to stay safe. The following lists provide some general and specific precautions to collecting plankton with students.

General precautions

- Research potential dangerous currents and other hazardous conditions before conducting a plankton tow.
- Consult a local aquatic expert about possible water quality concerns in your area. Avoid
- collecting near industrial runoff sites or in areas that have toxic organisms (e.g., toxic algal blooms, red tides).
- Always check the current weather and tidal conditions before heading into the field (e.g., *https://tidesandcurrents.noaa.gov*, *www.windy.com*). Have a plan in place for changing weather conditions that includes procedures for evacuating students and seeking shelter if weather becomes unsafe, as well as alternative classroom activities should the field trip need to be canceled.
- Have a plan in place in case your equipment or a person falls into the water. Depending
- on the location, this might require access and availability of specific rescue equipment.

Precautions for plankton collection

- Consult with your school and school district about field trip policies and possible safety limitations and required chaperone-to-student ratios.
- Ask parents or other adults to serve as chaperones.
- Secure signed parent or guardian consent forms for each student.
- Visit the location you have in mind ahead of time. Try to find a spot with unobstructed access to the water, such as a shoreline, a pier, or the bank of a stream, so that students will not have to go into the water. These locations allow students to simply lower their net into the water and tow it just below the water's surface.
- Do a test run to ensure you are comfortable with the equipment and you can successfully collect plankton. Avoid scraping the net along the bottom, the pier, or along shoreline rocks to minimize damage to the net.
- Instruct students to wear sunscreen, comfortable clothing, and shoes appropriate for the location and weather conditions.
- Be aware of any hazardous conditions such as slippery rocks or debris.
- Inform students and chaperones of safety rules ahead of time, as well as when arriving at the site the day of your field trip.
- Demonstrate how to safely use the plankton net for collecting samples.

How to collect plankton

Materials: plankton net, small jar(s) with a lid to transport the plankton

- Plankton rarely stay alive 24 hours after collection. It is best to examine plankton within one to four hours after collecting them. Always keep collected plankton cool and out of the Sun to prolong their life. If you need to collect plankton the day prior to viewing, you can extend their life by placing them in a bucket or big bowl filled with water from the collection site and place it in a fridge or cooler with a sealed bag of ice.
- Before starting your plankton tow, make sure the line and the collection container are securely attached to the plankton net.
- Walk back and forth along a pier or the shore, carefully towing the plankton net just below the

surface of the water. The amount of plankton at your collection site will determine how many passes you have to take with your net. An indicator of plankton density is the clarity of the water—the clearer the water, the less dense the plankton, and the longer you will have to tow.

- Try to keep your net away from the bottom of the body of water to avoid damaging it and to avoid stirring up sediment. If you collect sediment along with your plankton, they will be harder to view.
- When finished towing, remove the container at the end of the net that contains the plankton.
- Transfer the plankton to a jar (see photo at right). Add additional water to fill the jar and close the lid tightly for transport. If you use multiple nets for different groups of students, label each jar accordingly.
- Rinse the plankton net and the collecting container separately, ideally with fresh water, prior to storing it. Otherwise organisms stuck to the net will rot and stink.

How to make a plankton sieve

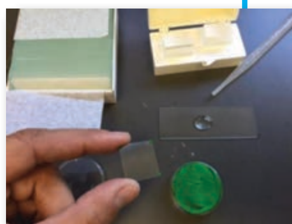
Materials: small plastic beaker, scissors, nylon 6 woven mesh, hot glue gun, and glue. Various sizes of nylon 6 woven mesh sheets are available online. For plankton, use mesh that is between 70 and 200 µm. The smallest size sheets you can buy are usually 12 x 12 inches and cost about $15. This size sheet should provide enough material for at least nine sieves.

1. Cut off the bottom of a small plastic beaker (or other small plastic container).
2. Cut a piece of the nylon mesh. The mesh should be slightly larger than the bottom of your beaker.
3. Lay the mesh over the bottom of the beaker and fold the extra mesh over on the edge to make sure the mesh adheres tight, so that there are no holes where plankton could escape.
4. Attach the mesh to the beaker with hot glue.

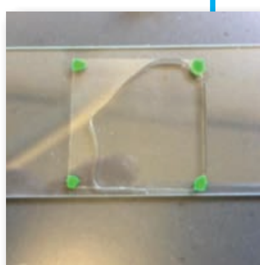
Observing plankton with a microscope

Materials: sieve, plastic transfer pipette, microscope slide, microscope cover glass, and clay.

- Check the containers you brought back from the field for sediment content. If there is a lot of sediment, wait for it to deposit at the bottom. The majority of the plankton will be swimming in the water above the sediment.



- Concentrate plankton with a fine mesh sieve. Pour some of the collected plankton through the sieve (avoid adding any sediment). Keep the sieve tilted so that the plankton accumulate on the side of the sieve and can be collected easily. You will see little dots stuck to the screen—these are your plankton! Collect the little dots with a plastic transfer pipette. Place two to three drops on the center of a microscope slide.
- Make a "plankton aquarium."



- Give a microscope cover glass little clay feet by passing each corner carefully over the clay (in green).
- Place the cover glass over the plankton drops on the microscope slide. The clay feet prevent the plankton from being crushed by the cover glass.

- Unless you would like to reuse your glassware, dispose of it according to your school's safety regulations. Plankton collected from nearby fresh or saltwater can usually be disposed of by pouring them down the drain. If you are unsure of the safest procedures to dispose of plankton in your area, contact a local aquatic science research center.

It might also lead students to conclude that when the substance is heated, the number of particles will be lessened. However, in total, the number of particles remains the same while the number of particles within the unit area will be lessened.

by your school. See Plankton Prep Instructions, p. XX, for detailed instructions on how to safely and successfully collect plankton. Sharing these procedures with students, as well as modeling how to effectively use the plankton net, will support all students.

If students cannot collect their own live plankton specimens due to time or budgetary constraints, the teacher may collect the plankton. The Plankton Prep Instructions detail how you can best collect and preserve live plankton until classroom observation. You can also arrange for a local college science instructor or graduate student to assist with plankton collection and identification. If no live plankton can be collected, students can observe the plankton activity cards and videos and photos (see Resources) as an alternative.

Real-time observations of plankton

It's best to observe plankton within a few hours after collecting them. Plankton can be viewed using a compound light microscope (consult the Plankton Prep Instructions for plankton viewing procedures). One trick is to make a "plankton aquarium" (see Plankton Prep Instructions) with a microscope slide, some clay, and a cover glass rather than use a depression slide, which can make it hard to focus on swimming plankton. Be sure to model this strategy for students. You can connect a microscope to a projector, smartphone, or tablet for the whole class to view or to support and guide students with special needs in conducting observations

To enhance their observation skills, students should sketch the plankton either in science journals or on the plankton worksheet (see Online Supplemental Materials). While your students are viewing the plankton, encourage them to locate specific structures such as cilia, appendages, spines, and eyes. Plankton can be identified by using the plankton activity card key, field guides, online references, or plankton apps (see Online Supplemental Materials and Resources). Students could generate a class list of plankton observed (to whatever taxonomic level is appropriate). If students cannot identify a plankton specimen, they can richly describe what they see.

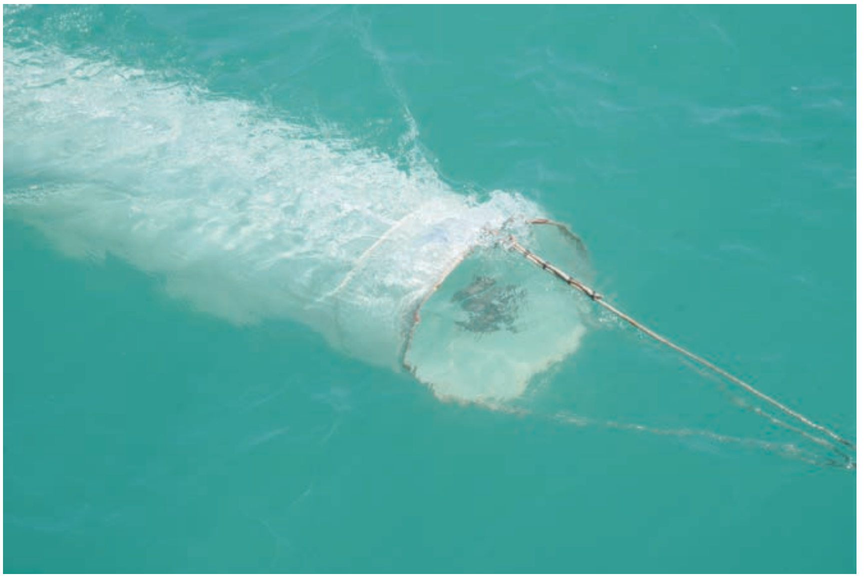
Optional extensions

In addition to collecting and observing plankton, students can collect water quality information (e.g., salinity, temperature, nutrient concentrations) at their field site. To compare water quality and plankton communities (e.g., diversity and quantity), students can collect plankton and water quality information from a different site or revisit the same site on a later date. When comparing plankton communities, it is best to sample similar volumes of water. For example, you would need to tow for the same distance or same amount of time, assuming the water current is the same.

You can also extend students' learning by having your students make a phytoplankton bloom (see Marrero and Stevens 2011).

Summative assessment

As a summative assessment, students construct a visual model describing the cycling of matter and flow of energy among living and nonliving components in an aquatic ecosystem. Instruct students to include an annotated aquatic food web depicting organisms, including plankton, that represent the diversity of trophic levels. Students also produce a narrative that explains matter cycling in their aquatic ecosystem, describe a scenario where a specific living or nonliving factor changes (e.g., an increase in nutrients, a decrease in a predator population), and make a prediction about how that factor affects ecosystem energy flow. To support students with special needs, this narrative could be an audio or video recording instead of a written document. You could further differentiate by providing a list of vetted resources for research, modifying the summative requirements (e.g., not requiring as many organisms depicted in the food web), or extending the work time. Detailed requirements for the summative project, along with sample scoring rubrics, are available in the Online Supplemental Materials. ●



A plankton net gathering specimens from the ocean.

REFERENCES

Marrero, M.E., and N. Stevens. 2011. Earth's most important producers: Meet the phytoplankton. *Science Scope* 34 (08): 25–31.

Moore, J.K. 2018. Climate change is bad news for plankton. Here is why you should care. World Economic Forum. *www.weforum.org/agenda/2018/04/climate-change-could-alter-ocean-food-chains-leading-to-far-fewer-fish-in-the-sea.*

NGSS Lead States. 2013. *Next generation science standards: For states, by states.* Washington, DC: National Academies Press.

RESOURCES

Additional plankton lessons—*http://stempreacademy.hawaii.edu/c-more/plankton*

Additional plankton lessons and marine science activities—*www.exploringourfluidearth.org*

Educational iPad app with plankton identification key—*https://itunes.apple.com/us/app/kahi-kai-plankton-guide-of-the-ocean/id1148336854?ls=1&mt=8*

NASA Design Packet—*www.nasa.gov/pdf/716281main_EDC_Design_Packet_6-12.pdf*

Videos and images on plankton—*www.planktonchronicles.com*

Video on plankton and marine food web—*ed.ted.com/lessons/the-secret-life-of-plankton*

ONLINE SUPPLEMENTAL MATERIALS

Plankton activity cards, plankton worksheet, plankton info sheet, plankton primer for students, and plankton assessment instructions and scoring guides—*www.nsta.org/Scope1901*

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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Standards

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics
www.nextgenscience.org/pe/ms-ls2-3-ecosystems-interactions-energy-and-dynamics

MS-ETS1 Engineering Design
www.nextgenscience.org/pe/ms-ets1-4-engineering-design

Performance Expectations

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practices	
Developing and Using Models	Students construct a visual model that synthesizes the important role of plankton in the cycling of matter and flow of energy among living and nonliving components of an aquatic ecosystem. Students use this model to make predictions about how changes to components might affect how the ecosystem functions.
Disciplinary Core Ideas	
LS2.B: Cycle of Matter and Energy Transfer in Ecosystems • Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem.	Students investigate how plankton serve multiple roles in aquatic ecosystems—as producers, consumers, and decomposers. By creating visual models, students demonstrate their understanding of how plankton contribute to the cycling of matter and transfer of energy in aquatic ecosystems.
ETS1.C: Optimizing the Design Solution • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	Students construct and iteratively test and improve their plankton nets.
Crosscutting Concepts	
Patterns	Students look for similarities and differences when observing and categorizing their plankton.
Structure and Function	Students examine the structure and function of collected plankton.