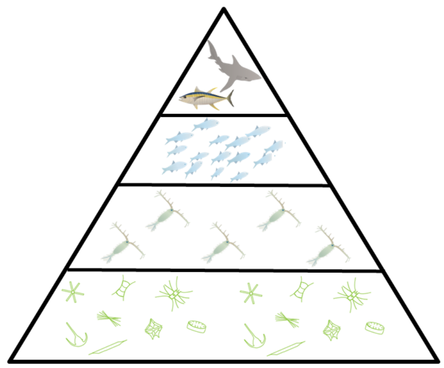
Aquatic Model Mania

Scientists often use models to study naturally occurring systems that may be too complex to bring into the laboratory. Models are of central importance in many scientific contexts. Scientists spend a great deal of time building, testing, comparing and revising models, as they are one of the principal instruments of modern science. Marine biologists can't always study aquatic food webs in their natural environment so a model simulating the environmental conditions of an aquatic food web allows scientists to study this system and all its variables.



To examine the trophic interactions in an aquatic food chain, it is best to consider that the biomass of all trophic levels depends on the limiting resources of the habitat. The limiting resources to plants, for example, are nutrients such as phosphorus and nitrogen, which limit how much the plants can grow. Organisms use nutrients to build tissue and to convert inorganic matter into carbohydrates. These carbohydrates provide the energy for the upper trophic levels.

If nutrients are present, then a system can sustain phytoplankton, which are the first level of most aquatic food webs. Phytoplankton are primary producers because they make their own food, followed by zooplankton, a consumer, because they feed on phytoplankton. Zooplankton are then eaten by small fish and other crustaceans, which, in turn, are eaten by larger fish. This chain of feeding is known as a food chain.

Another major component in an aquatic food system is detritus, which is organic debris formed from decaying organisms as well as their fecal matter. Bacteria colonize within this organic material and recycle the nutrients back into the system for phytoplankton to reuse.

In order for a marine food web to maintain a healthy existence, many variables must remain constant, particularly the availability of nutrients to support phytoplankton growth. Without phytoplankton, zooplankton would not have food and would die. Without zooplankton, smaller fish and other crustaceans would have nothing to eat and they would die. All aquatic animals depend on nutrient availability and in turn, phytoplankton for survival. The model we use in this activity illustrates the trophic interactions occurring in an aquatic food chain as well as how changes in nutrient concentration and organism behavior impacts an entire food chain.

Background questions

1. Phytoplankton are producers, meaning they make their own food using sunlight and CO_2 to make ______________________. This process is known as ______________________________________.
2. Zooplankton that eat phytoplankton are herbivores/carnivores (circle one). Therefore zooplankton that eat phytoplankton are known as a primary/secondary (circle one) consumers.
3. How do the zooplankton obtain nutrients (nitrogen and phosphorus) from the ecosystem?

4. Type the address http://www.hpl.umces.edu/~jpierson/applet/ into the URL space.

The NPZD model represents a simplified version of the various components of an aquatic food web. These components are nutrients (N), phytoplankton (P), zooplankton (Z), and detritus (D). The model also includes rate factors that affect the aquatic food system, listed in the sliding bars on the right side of the model. Rate factors include the amount of nutrients added to the system per unit time, the growth rate of phytoplankton (based on how quickly they reproduce), zooplankton mortality (the quantity of zooplankton that die per unit time), detritus conversion (how quickly bacteria convert detritus back to nutrients in a form that phytoplankton can use), and detritus sinking rate (how quickly detritus falls out of the system).

5. Without clicking on anything observe the changing sizes of each component of the aquatic food web. Hit the REW button in the top left hand corner to watch the system in action again.

6. Locate the Model Speed slider beside the REW button. How fast is the model running (in days/second)?

Slide the marker to the left so it is as close to 0.30 d/sec. If it's not exactly on 0.30, that's okay. Click on the REW button to the left and observe the direction of the arrows.

7. When the phytoplankton cycle begins what variable (N, P, Z, or D) is the most abundant?

8. There is an arrow going from the nutrients (N) to the phytoplankton (P). What does the direction of this arrow indicate?

9. Hit the REW button again and observe the two arrows going away from the P. What do each of these arrows indicate?

   P → Z:

   P → D:

10. The arrow leaving the detritus (D), points downwards. What does this arrow represent?

11. Select the “available nutrients” slider and move it towards a zero value. Describe what happens to the P, Z, and D amounts.

    Phytoplankton (P):

    Zooplankton (Z):

    Detritus (D):

Nutrient enrichment, particularly nitrogen and phosphorous generally increases the production of phytoplankton, which would seem positive for a food web because more food would be available for the zooplankton. However excess nutrients actually have a negative effect. Algal blooms reduce water clarity, and thus light penetration. Dissolved oxygen in the bloom area is also depleted (hypoxia), which alters the quality as well as the quantity of food for secondary consumers. Nutrient overloading and algal blooms leads to eutrophication, which is an increase in the rate of supply of organic matter in an ecosystem. Increased primary production by the phytoplankton as well as qualitative changes in the producers (e.g. the quality of food for primary consumers may not be as good) have consequences throughout the food chain, leading to diminished survival of fish larvae, and increased production of jellyfish.

12. Repeat step 11 but set the “available nutrients” slider to 2.0. Describe the effects on the P, Z, and D.

    Phytoplankton (P):

    Zooplankton (Z):

    Detritus (D):

13. Why didn’t the zooplankton population increase very much? Name two things that could contribute to zooplankton mortality.

14. Play around with the rate sliders (the sliders to the right of the model). Try to get a feel for how change in each rate factor influences the N, P, Z, and D pools (this will help you with Question 15).

    Try to make P as large as possible. What did you have to do to maximize P?

    Try to make Z as large as possible. What did you have to do to maximize Z?

15. Sometimes we use models to make predictions. Using what you observed from the behavior of the model, make 2 if-then statements predicting how changes in a rate factor will impact the ecosystem (e.g., **if** ____ increases/decreases, **then** ____will happen to N, P, Z, and D).

   1)

   2)

Extra credit: Try to think of a real world situation that would cause one of your if-then statements to occur. Describe with words and/or draw a diagram illustrating the situation below.