ECOLOGICAL FORECASTING LESSON PLAN
The Stinging Sea

Theme
Predicting the presence of sea nettles in the Chesapeake Bay.

Links to Overview Essays and Resources Needed for Student Research
http://oceanservice.noaa.gov/topics/coasts/ecoforecasting/
http://coastwatch.noaa.gov/seanettles/

Subject Area
Life Science

Grade Level
9-12

Focus Question
How can the impacts of changes in coastal ecosystems be predicted to help prepare for potential impacts on natural resources and human communities?

Learning Objectives
• Students will define ecological forecasting, and be able to describe three examples of this process.

• Students will explain how the life cycle and ecological preferences of sea nettles help make them unusually abundant in the Chesapeake Bay.

• Students will describe the economic and ecological impacts associated with large numbers of sea nettles in the Chesapeake Bay, and how ecological forecasting may help reduce these impacts.

• Students will define "limiting factors," explain how physical factors can be used to forecast sea nettle "outbreaks," and describe the limitations of these forecasts.

Materials Needed

- (optional) Computers with internet access; if students do not have access to the internet, download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student or student group

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Classroom style or groups of 3 – 4 students

Maximum Number of Students

30

Key Words

Sea nettle
Chrysaora quinquecirrha
Cnidaria
Medusa
Polyp
Jellyfish
Ecological forecasting
Limiting factors
AVHRR
Chesapeake Bay
Nematocyst

Background Information

Coastal ecosystems are constantly changing environments. Some changes are barely detectable (such as a gradual build-up of sediment over a period of twenty years), while others can have major impacts on natural resources and human communities (such as hurricanes or chemical spills). NOAA's National Ocean Service (NOS) has developed a series of ecological forecasting projects to predict these impacts and help prepare for them. The goals of ecological forecasting are to

- Provide information needed to make effective decisions

about how best to maintain benefits from coastal ecosystems (such as whether or not to prohibit harvest of certain species during reproductive seasons or limiting the number of certain species that can be harvested by humans);
- Reduce the negative impacts from extreme natural events and human activities (for example, by protecting wetlands from development to maintain the ability of these systems to buffer the effects of severe storms or floods);
- Apply scientific knowledge and technical capabilities to improve the use of coastal resources; and
- Identify ways that scientific research and monitoring can contribute to more accurate ecological forecasts.

Ecological forecasts vary in time and spatial scales that range from hours to decades and local to global. Current ecological forecasting projects include:
- Predicting the presence of sea nettles in the Chesapeake Bay (short-term, local scale);
- Predicting the movement and behavior of spilled oil or chemicals and evaluating the risk to resources (short-term, local scale);
- Predicting the abundance of pink shrimp in North Carolina in the spring and summer (short-term, local scale);
- Predicting the development, persistence, movement and landfall of harmful algal blooms off coastal Florida and in the Gulf of Maine (short-term, regional scale);
- Predicting the effectiveness of seagrass restoration efforts in North Carolina coastal waters (long-term, local scale);
- Predicting oyster abundance in Florida's Apalachicola Bay based on variable freshwater inflow scenarios (long-term, regional scale);
- Predicting changes in the size of the Gulf of Mexico Dead Zone (long-term, national scale);
- Predicting the potential population of cod and haddock on Georges Bank based on predator/prey relationships and environmental variability (long-term, regional scale); and
- Predicting shellfish bed closures based on freshwater input and large coastal storms(long-term, regional scale).

Ecological forecasting of sea nettle abundance in Chesapeake Bay is a good example of how physical and chemical environmental factors can be used to make predictions about biologi-

cal organisms. Sea nettles in Chesapeake Bay belong to the species *Chrysaora quinquecirrha*, and are members of the phylum Cnidaria which also includes hydroids, anemones, corals, and other jellyfish. Like all jellyfish, sea nettles have an umbrella shaped body called a bell. Several dozen yellow tentacles and four long, frilly, white feeding arms hang down from the bell. The tentacles are equipped with rows of stinging cells called nematocysts. These cells are used to capture and immobilize prey, which can be almost any small creature that blunders into the tentacles. Small fish, microscopic crustaceans, larvae of many species, and comb jellies (another Cnidarian) are typi- cal food. Studies in Chesapeake Bay tributaries have shown that in one day sea nettles are able to consume as much as 40% of bay anchovy eggs and 94% of the copepods present, demonstrating that sea nettles can have a significant impact on individual species and possibly on other organisms that use these species for food. While they are generally regarded as a nuisance or worse, sea nettles may actually benefit the oyster industry since they consume large quantities of comb jellies which are a major predator on oyster larvae. Nematocysts can also deliver a painful sting to humans, and in large numbers can pose a serious danger to people in the water. Knowing where and when to expect sea nettle "outbreaks" can help swimmers and fishermen avoid this risk.

Large numbers of sea nettles are associated with a specific range of salinity and temperature. This association is the basis for an ecological forecasting project that uses information on salinity and temperature in the Chesapeake Bay to create maps that describe the probable distribution patterns of sea nettle populations. A mathematical model of the Chesapeake Bay (the Chesapeake 3-D Physical Oceanographic Model, or C3PO) as well as satellite imagery are used to predict salinity and temperature conditions in the Bay. Every Friday, maps of prob- able sea nettle presence are created based on locations where current environmental conditions are favorable to sea nettles. In addition, the sea nettle forecasting project uses volunteer observers (such as high school and college students, boaters, fishermen, mariners, and individuals from organizations that use the Bay) to confirm or reject these predictions by reporting the presence or absence of sea nettles in all regions of the Bay.

The mathematical model to predict the probability of encountering sea nettles from estimations of sea-surface temperature and salinity was developed from data on *Chrysaora quinquecirrha* abundance collected between 1987-2000. Temperature, salinity, and depth were also measured at the sites where abundance data were collected, and a statistically significant correlation was found between these factors and *Chrysaora quinquecirrha* abundance. In this lesson, students will seek a correlation between abundance and physical factors, and make inferences about conditions that are most likely to be associated with large populations of sea nettles. In addition to acquainting students with the basis for ecological forecasting of sea nettle outbreaks, this lesson also provides an introduction to some of the data sources that can be useful for this type of project.

Learning Procedure

1.

To prepare for this lesson:
- Review introductory information at
  http://oceanservice.noaa.gov/topics/coasts/ecoforecasting/ and
  http://coastwatch.noaa.gov/seanettles/;
- Make copies of descriptions of ecological forecasting projects, unless you plan to have students review these online; and
- Copy Appendix A ("Jellyfish in Chesapeake Bay and Nearby Waters" by Dr. Jennifer E. Purcell), one copy for each student or student group.

2.

Introduce the concept of ecological forecasting, describe some examples of ecological forecasting projects, and discuss the kinds of benefits that result from the ability to make accurate ecological forecasts. Briefly review the biology of cnidarians and jellyfish in particular. Be sure students understand the distinction between medusoid and polypoid forms, and that many cnidarians resemble both forms at some stage in their life cycle. Discuss the hazards posed by cnidarians, and introduce the problems associated with sea nettles in the Chesapeake Bay.

3.

Provide each student or student group with a copy of "Jellyfish in Chesapeake Bay and Nearby Waters," or direct

students to this material online. After students have reviewed this article, provide each student or student group with a copy of "Ecological Forecasting of Sea Nettle Abundance Worksheet." Direct students to answer questions in Part I, and complete the assignment described in Part II. Depending upon your students' research skills, you may want to:

- Complete Part II as a class exercise; or
- Walk through the steps before students begin this part of the lesson; or
- Allow students to work through these steps on their own.

4.
Lead a discussion of students' answers to questions on the worksheet. The following points should emerge:

Part I

1. The greatest numbers of sea nettles are found in the Chesapeake Bay, particularly the Middle Bay area.

2. The sting of the moon jelly, *Aurelia aurita*, is much less severe to humans than that of the sea nettle.

3. Sea nettle stings can be prevented by wearing light-weight protective clothing, or by spreading a layer of petroleum jelly (Vaseline™) on exposed skin. Jellyfish stings should be treated by liberally sprinkling meat tenderizer or baking soda on the area of affected skin. Vinegar, lemon juice or other dilute acids can also be effective in treating stings from Portuguese man-of-war (*Physalia physalis*).

4. During the summer, male and female sea nettles release eggs and sperm into the water. Fertilized eggs form larvae which attach to hard surfaces and grow into tiny polyps. These polyps are dormant during the winter. From May through August, the polyps bud off tiny medusae (jelly-fish) that grow rapidly into visible sea nettles.

5. Sea nettles eat a variety of zooplankton, including juve-nile fishes, fish eggs, worms, mosquito larvae, and comb jellies. Their primary food is copepods.

6. Sea nettles capture their food with tentacles that trail behind the swimming bell. Microscopic stinging cells stun or kill prey animals, which are transported by central tentacles to gastric pouches in the swimming bell where digestion occurs.

7. Sea nettles can feed at night, since they do not have eyes and consequently are not dependent upon light for feeding.

8. Sea nettles require very little food for rapid growth because only about 0.2% of their live weight consists of organic materials.

9. Sea nettles are said to be "geared for high reproduction" because:
   - They begin producing eggs when the swimming bell is only about 1 1/2 inches in diameter;
   - They produce large numbers of eggs (a nettle 4 inches in diameter produces about 40,000 eggs per day);
   - The polyps that grow from fertilized eggs can bud to produce more polyps; and
   - Each polyp can produce up to 45 jellyfish each summer.

10. Sea nettles' preference for low salinity water is unusual among jellyfishes.

11. Sea Nettles' preference for low salinity waters eliminates competition from most other jellyfishes that require salinities closer to that of normal seawater. In addition, sea nettles eat comb jellies which are their most abundant potential competitors. Lower salinities also exclude many potential predators such as fishes and sea turtles.

12. While there is no direct evidence that human activities have increased the numbers of sea nettles in the Chesapeake Bay, there is ample evidence that the Bay has been enriched by organic materials (such as wastewater) and fertilizers from surrounding human communities. This kind of enrichment can enhance the growth of microscopic plants (phytoplankton), which are food for

microscopic grazing animals such as copepods. If enrich-
ment led to an increase in phytoplankton, which in turn
led to an increase in copepods, this series of events could
provide food for larger populations of animals that feed
on copepods – such as sea nettles. It has also been sug-
gested that depletion of oysters in the Bay by commercial
fishing could also increase phytoplankton which would
otherwise have been consumed by the oysters.

Part II

Students have several options for calculating average
January – June river discharge from monthly stream
flow data. The easiest is to import the relevant data into
a spreadsheet and perform the calculations with a simple
sum function divided by 6. Alternatively, the appropriate
data could be added using a calculator, or even paper and
pencil. A spreadsheet program could also be used to graph
the data, with appropriate adjustment to compensate for
scale differences in abundance, temperature, and discharge
values (see Appendix B).

Students should realize that years having the greatest
abundance were also years with the highest sea surface
temperatures (27°C – 29°C), and years in which January –
June discharge from the Susquehanna River averaged 1,594
– 3,637 ft³/sec. Students should note that the abundance of
was zero in 2000, even though the discharge rate was also
in this range, and should infer that the sea surface tempera-
ture of 24.5°C (the lowest recorded during the study) was
sufficiently low to outweigh potentially favorable salinity
conditions. Following discussion of students' results and
inferences, you may want to tell them that the technical
journal article on which this activity is based reports that
the majority of *Chrysaora quinquecirrha* are observed in shal-
low (< 15 m) surface waters with temperatures ranging
from 26 to 30°C and salinities ranging from 10 to 16 parts
per thousand.

Discuss the concept of "limiting factors." Be sure students
understand that the habitat of a species is defined by many
physical and biological parameters, and that one or more of
these limits the size that populations can attain. Point out

that while salinity and temperature are important physical factors that influence the presence of sea nettles, other factors (such as food availability) become limiting even when salinity and temperature are optimal.

The Bridge Connection

http://www.vims.edu/bridge/chesapeake.html – Link to the Bridge Chesapeake Bay Resource Page

The Me Connection

Have students write a brief essay describing how the concept of ecological forecasting might be applied to human populations, and what limiting factors might be used as the basis for a forecasting model. You may also want to ask them to speculate on what might happen when one or more of these limiting factors are removed.

Extensions

Visit *http://jellieszone.com/* for more information about jellyfishes, including the deadly cubomedusae of Australia, as well as how jellyfish can be kept in aquaria (with a lot of work!).

Resources

http://www.intercom.net/local/shore_journal/jp010716.html – "Jellyfish in Chesapeake Bay and Nearby Waters" by Dr. Jennifer E. Purcell

http://www.mdsg.umd.edu/MarineNotes/Jul-Aug94/side1.html – "Neither Jelly nor Fish" University of Maryland Sea Grant Maryland Marine Notes, vol 12, number 5, July-August 1994

J.E. Purcell and M.B. Decker. 2002. Effects of climate on relative predation by scyphomedusae and ctenophores on copepods in Chesapeake Bay during 1987-2000. Limnology and Oceanography 50(1):376-387 – The technical article on which this lesson is based; available online at *http://aslo.org/lo/toc/vol_50/issue_1/0376.pdf*

http://www.nodc.noaa.gov/dsdt/index.html – Interactive Data Access and Retrieval System Web site, including access to real-time and archival AVHRR data

http://nwis.waterdata.usgs.gov/nwis – U.S. Geological Survey
National Water Information System Web site

National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Interdependence of organisms
- Behavior of organisms

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H1 – Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually results in a system similar to the original one.

5D/H3 – Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

ECOLOGICAL FORECASTING WORKSHEET

Ecological Forecasting of Sea Nettle Abundance

Part I – Subject Review

Answer the following questions after reading "Jellyfish in Chesapeake Bay and Nearby Waters" by Dr. Jennifer E. Purcell:

1. Where are the greatest numbers of sea nettles found?

2. The moon jelly, *Aurelia aurita*, is also common in the Chesapeake Bay during the summer. Does this species poses a stinging threat to humans similar to that of the sea nettle?

3. How can sea nettle stings be prevented? How should they be treated?

4. Where do sea nettles go during the winter?

5. What do sea nettles eat?

6. How do sea nettles capture their food?

7. Can sea nettles feed at night?

8. Sea nettles can grow rapidly with very little food. Why?

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9. What are three aspects of sea nettles' life history that makes this species "geared for high reproduction"?

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10. What ecological preference of sea nettles is unusual when compared to most other jellyfishes?

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11. How do sea nettles deal with competition and predation from other species?

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12. How may human activities have increased the numbers of sea nettles in the Chesapeake Bay?

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13. Review examples of ecological forecasting projects at *http://oceanservice.noaa.gov/topics/coasts/ecoforecasting*, and describe three of these projects.

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Part II – The Foundation for Ecological Forecasts of Sea Nettle Abundance

The mathematical model that is used to make ecological forecasts of sea nettle abundance in Chesapeake Bay was developed from data collected during 1987-2000 on *Chrysaora quinquecirrha* abundance, temperature, salinity, and depth. Forecasters use satellite data to obtain real-time estimates of sea surface temperature. Another mathematical model that describes water circulation in the Chesapeake Bay is used to estimate salinity distribution in various parts of the Bay. Because salinity is strongly influenced by freshwater input from major rivers, variations in the discharge rates of these rivers correlate closely with salinity changes in the Bay. In this exercise, you will use online databases to obtain information on sea surface temperature and river discharge for comparison with data on abundance in samples collected during summer months from 1987 – 2000.

Abundance data were obtained by towing plankton nets (1 m diameter, 1.6 mm mesh) equipped with a flowmeter. The volume of water filtered by the nets ranged from 60 m^3 to 160 m^3. Captured jellyfish were separated and counted by hand. Table 1 summarizes *Chrysaora quinquecirrha* abundances determined by this method.

Table 1. *Chrysaora quinquecirrha* Abundance in Chesapeake Bay 1987 – 2000

Date	*Chrysaora quinquecirrha* Abundance (Individuals/m^3)	Average Temperature for Sample Month (°C)	Susquehanna River Average Monthly Discharge, Jan - Jun (ft^3/sec)
7 Jul, 1987	0.10	27	
28 Jul, 1988	0.05	27	
28 Jun, 1989	0.04	26.5	
15 Aug, 1990	0.13	27	
27 Jul, 1995	0.045		
20 Jul, 1996	0.005		
11-13 Jul,1997	0.02		
11 Aug, 1998	0.01		
29 Jun,1999	0.007		
28 Jul, 2000	0.000		

Sea surface temperature (SST) is measured by satellites carrying the Advanced Very High Resolution Radiometer (AVHRR), which measures infrared radiation from Earth's surface in six spectral ranges. These data can be accessed on the Interactive Data Access and Retrieval System (IDARS):

1. Point your browser to *http://www.nodc.noaa.gov/dsdt/index.html* to open the the IDARS index page. From the "ONLINE DATA" pulldown menu, select "NOAA CoastWatch Retrospective AVHRR SST Images" to open the "Retrospective AVHRR Data" page.

2. Scroll down to "Produce Composite AVHRR SST Images," and click the button next to "North East Region." In the box next to "Starting Date" enter "1995 July 1" and in the box next to "Ending Date" enter "1995 July 31." Leave the rest of the buttons at their default settings and click "Produce image." Shortly a map will appear showing sea surface temperatures along the U.S. east coast for the specified date interval. Notice that temperatures in the Chesapeake Bay were around 30°C during this period.

3. Go back to the "Retrospective AVHRR Data" page. Enter settings as in step 2, but this time also enter a minimum and maximum temperature range. Set the minimum temperature at 25°C and the maximum temperature at 35°C. Click "Produce image." By narrowing the scale from 0°C to 30°C, the map shows temperature much more precisely. This map indicates that average sea surface temperatures were close to 29°C for the month of July 1995.

4. Use the same procedure to determine SST for the months in which abundance data were collected during 1996 - 2000, and enter these data in Worksheet Table 1. Data for 1987 – 1990 have been provided, since IDARS does not contain AVHRR data prior to 1995 (though AVHRR images dating from 1985 can be retrieved from NASA's Jet Propulsion Laboratory website at *http://podaac.jpl.nasa.gov/sst/*).

The U.S. Geological Survey provides access to water data from approximately 1.5 million sites throughout the United States through the National Water Information System (NWIS). To obtain water discharge data for the Susquehanna River:

1. Point your internet browser to NWIS Web page at *http://nwis.waterdata.usgs.gov/nwis* to open the "NWISWeb Data for the Nation" page. Click on the "Surface water" button under "Data Category" to open the "Surface-Water Data for the Nation" page.

2. Under "Statistics," click on "Monthly" which will open the Monthly Streamflow Statistics page. There are many ways to specify sites for which data are to be retrieved, but in this case it is simplest to use the number of the USGS monitoring station on the Susquehanna River at Conowingo, MD. Under "Site Selection Criteria," locate the "Site Identifier: column and click on the box next to "Site Number." Click "Submit." This will open the "Monthly Streamflow Statistics for the Nation" page.

3. Enter "01578310" in the box under "Site Number," click the button next to "Tab-separated data," then click "Submit." Data on the mean monthly water discharge (in cubic feet per second) from this portion of the Susquehanna River will be saved in a file named "monthly" on your desktop. This file contains all monthly streamflow records for the Conowingo monitoring station for the last 35 years or so. Compute the average monthly discharges from January through June for each of the sample years (1987 – 1990 and 1995 – 2000). Use these data to fill in the streamflow discharge column in Table 1. Refer to Appendix B for step-by-step instructions on how to process these data using Microsoft Excel®.

Plot the data in Table 1. You will have to use three different scales for the y-axis since values for abundance, temperature, and river discharge differ by several orders of magnitude. What conditions appear to correlate with higher abundance of *Chrysaora quinquecirrha*? Refer to Appendix B for step-by-step instructions on how to graph these data using Microsoft Excel®.

ECOLOGICAL FORECASTING LESSON PLAN APPENDIX A

Jellyfish in Chesapeake Bay and Nearby Waters

by Dr. Jennifer E. Purcell, PhD
Resident Scientist
Shannon Point Marine Center, Western Washington University

What types of jellyfish occur here?

In the summertime in ocean waters, for example, off Ocean City, two types of large jellyfish often occur. The Moon Jelly (*Aurelia aurita*) is a clear, flattened disk, with numerous small tentacles around the edge, and a pink four-leaf clover design in the middle. This species has a very mild sting and poses no threat to swimmers. The Lion's Mane jellyfish (*Cyanea capillata*) is brown in color, and has longer tentacles hanging from the edge of its swimming disk and from the middle. This species has a potent sting, and while it is not dangerous to swimmers, it is very unpleasant to encounter. Some other jellyfish are seen less often in the coastal waters. In the autumn, the Mushroom Cap Jellyfish (*Rhopilema verrilli*) may enter the Bay. It has a deep swimming bell without tentacles, and is creamy white with darker markings on the sturdy central tentacle structures. The Cabbage Head or Cannonball Jellyfish (*Stomolophus meleaqris*) is like a white softball, or larger, and has a short, hard tentacle structure in the middle. Neither of these jellyfish sting swimmers. The Portuguese man of war (*Physalia physalis*) very seldom is seen off beaches north of Cape Hatteras. It is a relative of jellyfish that floats at the water's surface by means of a gas-filled blue float. Beneath the float are extremely long tentacles which have a powerful sting. They should be avoided by swimmers, because a serious sting would cause extreme pain, and could result in hospitalization. The Moon Jelly also occurs in southern Chesapeake Bay during the summer. The Lion's Mane, or Winter Jellyfish, is found in Chesapeake Bay during the winter (January - April). The jellyfish for which Chesapeake Bay is widely known in the summer is the Sea Nettle (*Chrysaora quinquecirrha*). It occurs from Cape Cod south along the U.S. East Coast, Caribbean and Gulf of Mexico, yet it abounds in Chesapeake Bay in numbers unequaled elsewhere. It occurs most abundantly in the

tributaries of the middle Bay (salinities 10 - 20 ppt), where it is white in color. In the southern Bay, it often has red/maroon markings on the long central tentacles and on the swimming bell. It has an annoying sting, but is not dangerous to swimmers.

Jellyfish stings: How to prevent them and how to treat them

Lightweight protective clothing, like a lycra "swim skin" or panty hose, or a layer of petroleum jelly spread on unprotected skin, will protect a swimmers against stings. If you are stung by a jellyfish, liberally sprinkling a meat tenderizer or baking soda (or vinegar for *Physalia*) on the sting may reduce the irritation. Severe allergic reactions (anaphylaxis) are uncommon to jellyfish in U.S. waters, but emergency treatment is essential in such cases.

Where do the sea nettles come from each year?

The swimming jellyfish are either male or female. They produce eggs or sperm, which are shed daily into the water during the summer. Fertilized eggs form larvae that attach to hard surfaces, like oyster shells, and grow into tiny polyps. The bottom-dwelling polyps live through the winter in a dormant state. During May through August, the polyps bud off tiny sea nettles about 1/25 of an inch in diameter, that grow rapidly into the visible jellyfish.

How do sea nettles feed and what do they eat?

Sea nettles capture prey that contact the tentacles trailing behind the swimming bell. These tentacles have millions of microscopic stinging cells that inject toxins to stun or kill tiny animals, and which are responsible for the stings swimmers feel. The prey are transported up the central tentacles to the heart-shaped gastric pouches in the swimming bell where digestion occurs. Jellyfish are prodigious predators because they swim and feed continuously. They do not have eyes, and so do not need light to feed. They feed without interruption because the many tentacles function independently of the others. The tentacles provide a very large surface area for prey capture. Sea nettles feed mostly on microscopic crustaceans called copepods that are very abundant in Bay waters. They also eat young minnows, bay anchovy eggs, worms, mosquito larvae, and comb jellies, so they would seldom be without something to eat.

Why are there so many sea nettles in Chesapeake Bay?

Sea nettles are made up mostly of water and salts, with organic materials totalling only about 0.2k of their entire live weight. For this reason, very little food can provide enough organic materials to result in a lot of growth. The jellyfish can get bigger very rapidly, and the amount of food they catch increases directly with their increasing size. Sea nettles are geared for high reproduction. They begin producing eggs when the swimming bell is only about 1 1/2 inches in diameter. The number of eggs increases tremendously as they grow, with a nettle about 4 inches in diameter shedding about 40,000 eggs into the water daily. The polyps can bud to produce more polyps. Each polyp produces up to 45 jellyfish each summer. The Sea Nettle is unusual in its ability to live in water of low salinity (salt content). Most jellyfish species live at ocean water salinity, about 35 ppt (35 parts salt to 965 parts water). The Sea Nettle prefers waters having as little as 12 ppt salinity, and may have estuaries like Chesapeake Bay, to itself without serious competition from most other jellyfish. In fact, sea nettles eat their most abundant competitors in the Bay, the comb jellies. Populations of plants and animals often are controlled by other organisms that feed on them. However, adult sea nettles may have few natural predators in the middle reaches of Chesapeake Bay. Sea turtles, which are known to eat Portuguese men-of-war and some other jellyfish, rarely come far into the Bay. And fish species (harvestfish, butterfish) observed feeding on sea nettles prefer waters of higher salinity.

Are there more sea nettles now than in earlier years?

It is possible that the changes in Chesapeake Bay caused by human activities have led to larger populations of the Sea Nettle in recent times. The waters of the Bay have been enriched with organic materials and nutrients from waste products and fertilizers due to heavy human settlement around the Bay. This kind of enrichment can change the species of microscopic plants suspended in the waters from large to small types. The small plants are more suitable as food for small grazers (copepods), which in turn are more suitable for predators like jellyfish, and less suitable for visual predators like fishes. Dr. Roger Newell proposed that removal of most of the oysters that were once so abundant in the Bay also may leave much uneaten plant material suspended in the water to be

consumed by copepods, which in turn could be used by jellyfish and increase their populations. Unfortunately, no early records document the abundance of the Sea Nettle before Man began to seriously change Chesapeake Bay, so there is little with which to compare the present abundance. Mr. David Cargo kept daily records of the numbers of sea nettles at the Chesapeake Biological Laboratory in Solomons, MD for nearly 30 years. He found great annual variation in jellyfish numbers: more occurred in dry years than in rainy years, but no overall increase in abundance was apparent. Such records would need to go back more than 100 years to reveal if human-caused changes in the Bay have affected the abundance of sea nettles.

Is it possible to reduce the numbers of jellyfish?
A lot of effort was spent on jellyfish control in the 1960s, but no method has been very successful. Nets and bubble screens were used to keep them away from swimming areas. The jellyfish tended to clog the nets and to break into pieces that continued to sting. The bottom-living polyp stage also was targeted. Chemicals that killed the polyps also killed many other organisms, and so were unsuitable. A small species of sea slug was found that ate the polyps, but culture methods to produce large numbers of the sea slugs were unsuccessful, and they did not live well at the low salinities favored by the polyps. So far, the greatest reduction of the jellyfish populations occurred after Hurricane Agnes in 1972, but this method of control cannot be recommended.

Can anything good be said about sea nettles?
Research in my laboratory has shown that sea nettles may help oysters. Oysters have a larval stage that spends about two weeks swimming in the Bay before they settle to grow into large oysters. During this swimming stage, they are vulnerable to predators such as sea nettles and comb jellies. Although sea nettles can catch the larval oysters, they spit them out undigested and unharmed. In contrast, comb jellies catch and digest the larvae readily. Comb jellies are a favorite food of sea nettles, and they reduce comb jelly populations to zero in the tributaries during the summer when oyster larvae are most abundant. Therefore, sea nettles appear to protect oyster larvae from a major predator.

What recent research is there on Sea Nettles?

In my laboratory, we have been working to determine the importance of sea nettles as predators of copepods. This is of interest because if sea nettles reduce copepod populations, then less food would be available for planktivorous fish, for example bay anchovy and menhaden, which then are food for piscivorous fish like striped bass and bluefish. We have found that sea nettles eat at most 5% of the copepods daily in mid Chesapeake Bay, which is small compared with the growth rate of the copepod population. In the tributaries, however, Sea Nettles can consume 50 - 90% of the copepods daily, and copepod abundances seem to decline over the summer, possibly due to this predation. Sea Nettles consume up to 50% daily of the bay anchovy eggs and larvae during the peak spawning in July. This research was in collaboration with Dr. Ed Houde of the Chesapeake Biological Laboratory. We also are studying which environmental factors have the greatest effects on the population size of sea nettles. We have done experiments to measure the numbers of sea nettles produced by polyps, and the survival and growth of the baby jellyfish at varlous comblnatlons of salinity, temperature, and food concentrations. Few sea nettles are produced at low salinities (< 7 ppt) or at high salinities (> 25 ppt). I am beginning a large-scale project to map the distributions of jellies throughout Chesapeake Bay in April, July, and October. In collaboration with several other scientists, I will examine environmental and biological (e.g. food) factors that may determine the distribution and abundance of jellies in the Bay.

ECOLOGICAL FORECASTING LESSON PLAN APPENDIX B

How to Calculate and Graph Average January-June River Discharge From Monthly Stream Flow Data Using Microsoft Excel®

1.

Open the downloaded data file in Microsoft Excel®:
Select "Open" from the "File" pulldown menu. Be sure that "All files" is selected in the "List files of type" window, then navigate to the file named "monthly" and click "Open." You will get the Text Import Wizard.

a. Select "Delimited," "Start Import at Row: 1," and the operating system you are using next to "File Origin." Click "Next."

b. Select "Delimiters: Tab" and "Text Qualifier: ". " Click "Next."

c. Click the "General" button under "Column Data Format." Click "Finish."

You now have a spreadsheet with all of the data for USGS site number 01578310, Susquehanna River at Conowingo, MD.

2.

Calculate the average monthly discharge from January through June for 1987:

For each of the sample years (1987–1990 and 1995–2000):

a. Scroll down the spreadsheet to locate the rows corresponding to "month_nu" 1 through 6 (column D) for "year_nu" 1987 (column C).

b. In column F for one of these rows, write the year number (1987). In column G of the same row, write a formula to calculate the average of the cells in col-

umn E (which are the monthly mean stream dis-
charge values) for these six rows. For example, if rows
257 through 262 contain the data for "month_nu" 1
through 6 for "year_nu" 1987, the formula should read:

=AVERAGE(E257:E262)

c. Repeat step b for "month_nu" 1 through 6 for "year_
nu" 1988, 1989, 1990, 1995, 1996, 1997, 1998, 1999,
and 2000.

3.
Plot data from Table 1:

a. Enter the data for abundance and temperature in col-
umns H and I in the same rows that contain the aver-
ages calculated in part 2.

b. Highlight columns F and G.

c. Click on the Chart Wizard icon. Select "XY (Scatter)"
under "Chart type" and the lower left icon under
"Chart sub-type." Click "Next."

d. Be sure the button next to "Columns" is selected
under "Series in." Click the "Series" tab. In the box
next to "Name" enter "Average Discharge." Click
"Next."

e. Click the "Titles" tab. Enter a title for your chart (such
as "Average Stream Discharge, 1987 - 2000"). Enter
"Year" in the "Category (X) axis:" box and "Average
Discharge" in the "Value (Y) axis:" box. Click "Next."

f. Click the button next to "As new sheet" and enter
the name that you want to appear on the tab for your
chart in the spreadsheet workspace. Click "Finish."
You now have a column chart that shows the average
discharge from January through June for each of the
sample years.

g. To plot *Chrysaora quinquecirrha* abundance data, repeat steps b. through f., highlighting columns F and H in step b. In step d., enter "Abundance" in the box next to "Name." In step e., change the Title and Value labels to something like "Abundance."

h. To plot temperature data, Repeat steps b. through f., highlighting columns F and I in step b. In step d., enter "Temperature" in the box next to "Name." In step e., change the Title and Value labels to something like " Temperature."