SimRiver

Environmental Modeling Software for the Science Classroom

by Jeannette Hoffer, Shigeki Mayama, Kristin Lingle, Kathryn Conroy, and Matthew Julius

While students may acknowledge the impact that land use and development have on our environment, they do not necessarily understand the relationship between human activities and ecosystem responses. The reasons for this are numerous, and include the length of time it takes an ecosystem to respond, cascading effects within the food web, the “downstream” impacts extending from the immediate disturbance area, the complexity involved in an environmental survey, and so on. The complexity of the relationships leaves the science teacher to most often present information in a purely narrative form without any hands-on or experimental experience. In this article, we introduce a free, simple, and realistic computer simulation program, SimRiver, which allows students to develop a river basin and identify the development implications on producers, specifically diatoms. This allows students to develop a skill set for understanding nonlinear problems where relationships are not simply cause and effect.

SimRiver was originally developed for use in Japanese middle and high school science classrooms (Mayama et al. 2008). Recently, the authors adapted the program for English-speaking students and are using it in middle school science classrooms in the United States. This English-translation effort is part of an ongoing international collaboration to develop water education resources for use by students globally (see *www.u-gakugei.ac.jp/~diatom/en*). This effort is called the DiatomProject, reflecting the microorganisms studied by the collaborators, which are often the inspiration for these educational products.

FIGURE 1 **Diatoms viewed under different microscopes and different conditions**

Row 1: Scanning electron microscope and light microscope views of a planktonic diatom, *Cyclotella meneghiniana*, without organic components, and light microscope view of living *Cyclotella*. Row 2: Scanning electron microscope and light microscope view of a bottom-dwelling diatom, *Gomphoneis eriensis*, without organic components, and light microscope view of living *Gomphoneis*.

Diatoms

Diatoms are single-celled photosynthetic organisms, most often characterized by their highly ornamented, and often beautiful, glass cell wall (Figure 1). They are amazingly abundant, with over 20,000 described species, and are found in virtually every freshwater and marine habitat. They potentially account for 40% of the world's primary production, generate much of the energy that drives aquatic food webs (Round, Crawford, and Mann 1990), are a highly prized food source for many organisms, and supply essential dietary components (Julius and Theriot 2010). Diatom species and their ecological diversity make them excellent indicators of current and past environments (Stoermer and Smol 1999); diatoms are a major indicator species used for monitoring U.S. watersheds (see *http://diatom.acnatsci.org/nawqa*). Julius and Theriot (2010) provide a summary of diatom science for nondiatomists.

SimRiver tutorial

In many classroom lessons dealing with environmental change and succession, the hardest task is getting students to understand a process of change that takes place over a long period of time. Many students have a basic understanding that water samples can be analyzed to detect the impacts or presence of pollution. However, students do not realize what is analyzed and how the presence of pollution has an impact on aquatic ecology. If students are able to observe how organisms in a river change in response to disturbances, the association between water samples and pollution impact becomes clearer. SimRiver allows students to create their own river environment, and vary the season, land use, and population. Students then assess the health of the river by analyzing the diatom communities generated by the program. Factors in this analysis include species richness and the ratio between species present and their pollution tolerance. Pollution tolerance is scored by a saprobic index, with diatom species being placed into one of three categories. The saprobic index system is used for many indicator species other than diatoms, and a system can be created for any group of organisms that varies species composition in response to pollution. The pollution categories and diatom populations produced by SimRiver are highly accurate and reflective of actual riverine systems. This is because simulations are modeled using historical collection information for evaluation of water quality by aquatic science professionals (Mayama 2006).

Step-by-step use of SimRiver

SimRiver is free and can be accessed at *http://web.stcloudstate.edu/phytolab/srhtml/diatom.htm*. If a stand-alone copy of the program is needed, it can be requested directly from the authors at *phytolab@stcloudstate.edu* or downloaded at *www.u-gakugei.ac.jp/~diatom/en*. The program will execute on a Mac or PC-based system using Internet Explorer or Safari. A step-by-step guide to the program follows.

FIGURE 2 Screenshot of SimRiver opening navigation screen

Users can select difficulty level and check toggles for auto saprobic index and slow internet connections.

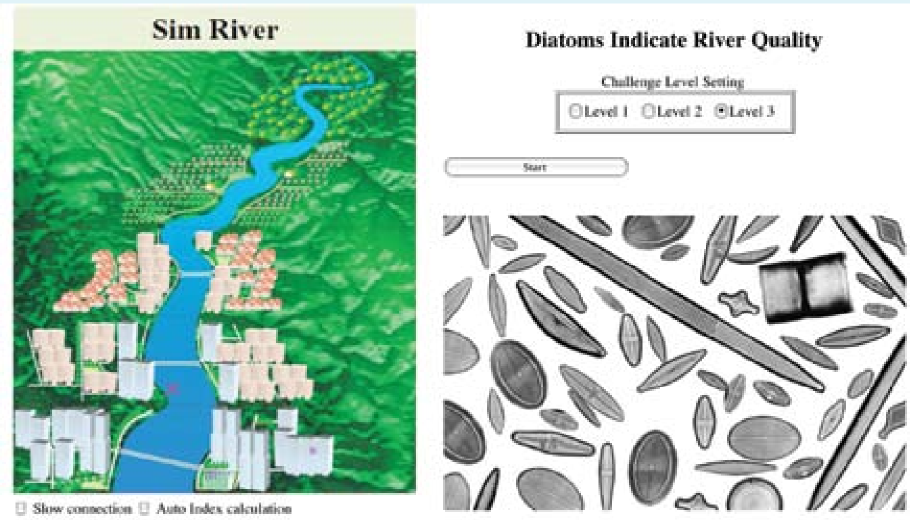
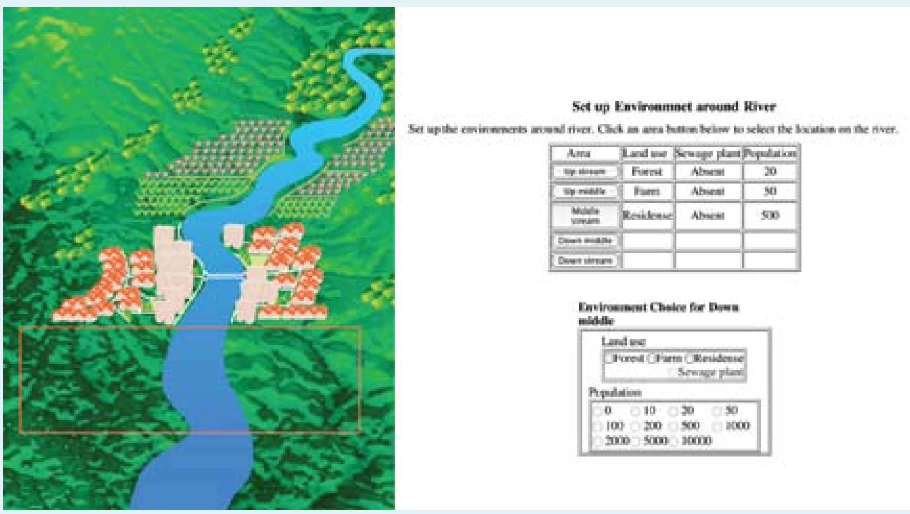


FIGURE 3 Screenshot of a user-developed river watershed

Upstream areas have had development parameters selected including a forest, farm, and city, respectively. Red box indicates area currently having development parameters selected, and most upstream settings remain unmodified by user.



I. SimRiver begins by asking students to select a language. Users select the language and press start to proceed. Teachers can mention that the program is used in many countries and that water-resource issues are a common problem throughout the world.

II. There are three level options that students can select (most classes go through all three levels, beginning with Level 1.). Additionally, toggles can be checked, adjusting the program for slow internet connections and auto saprobic index calculation (described in Step III) (see Figure 2). Once the level has been selected, a new web page depicting a river basin appears, where students can choose from various parameters depending on the level previously selected (see Figure 3). Variations in level are described below.

a. Level 1 includes a predeveloped river basin; however, students can choose between summer or winter for the season. The river basin consists of forest, agriculture, and urban areas. The population density in these areas increases, moving from upstream to downstream. Students can select one of three areas (upstream, midstream, and downstream) to simulate a diatom population for water-quality quantification. At this level, students can observe alterations in water quality with development in a linear fashion from upstream to downstream. They can also begin to understand the complexity of this cause/effect relationship by observing differences in the system caused by seasonality.

b. Level 2 allows students to further explore complex interactions within the same basin-development parameters as Level 1. This is done by letting students vary all four seasons and sample the river within each of the five land-use areas (the sections of the river basin that students have designated as either farm, forest, or city) for diatom community simulations. This allows students to identify subtle differences along the river-basin gradient, such as variations in community structure from a small town or large city.

c. In Level 3, students can vary all parameters, including land use and population size. This allows full exploration of multiple parameters and their impact on water quality.

III. Once a location for diatom community simulation is chosen, a web page with images of diatoms reflecting species richness and diversity appears (see Figure 4). Students can select any diatom image for identification. Once a diatom image is selected, an identification guide will appear on the right-hand side of the screen (see Figure 5). Students can then select a diatom from the identification guide that they think corresponds to the image selected for identification. A box will appear, indicating if the diatom from the identification guide is the correct choice. At the top of the web page are buttons providing navigation options:

a. "Back" allows students to return to the river-basin web page where environmental parameters and sampling locations were originally selected.

b. "Full Picture" removes the identification guide, allowing all diatoms in the simulated population to be observed.

c. "Species Table" will navigate to a species table, giving the name of each diatom found in the simulated sample, the abundance of each diatom species in the simulated sample, and the diatom's saprobic value based on a 1 to 4 rating where 1 is the least polluted environment and 4 is the most polluted. Students can use this table to calculate the saprobic index for the simulated community. If auto saprobic calculation was toggled in Step II, this calculation will appear completed.

d. "Graph" produces a bar graph, placing diatom species into three categories (most tolerant, moderately tolerant, and sensitive) (see Figure 6). The categories reflect three pollution-tolerance levels, and category size reflects percentage abundance in the simulated community.

FIGURE 4 Screenshot of diatom community generated by SimRiver

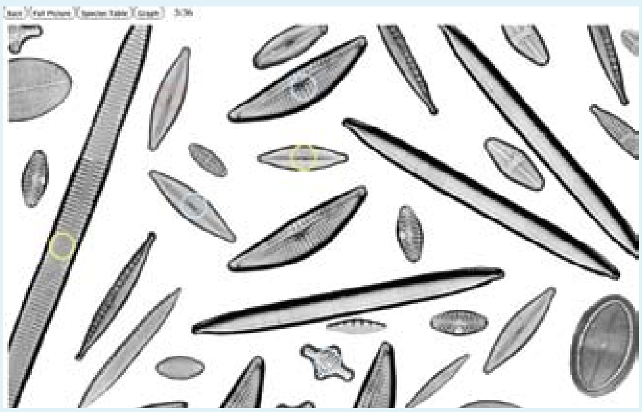


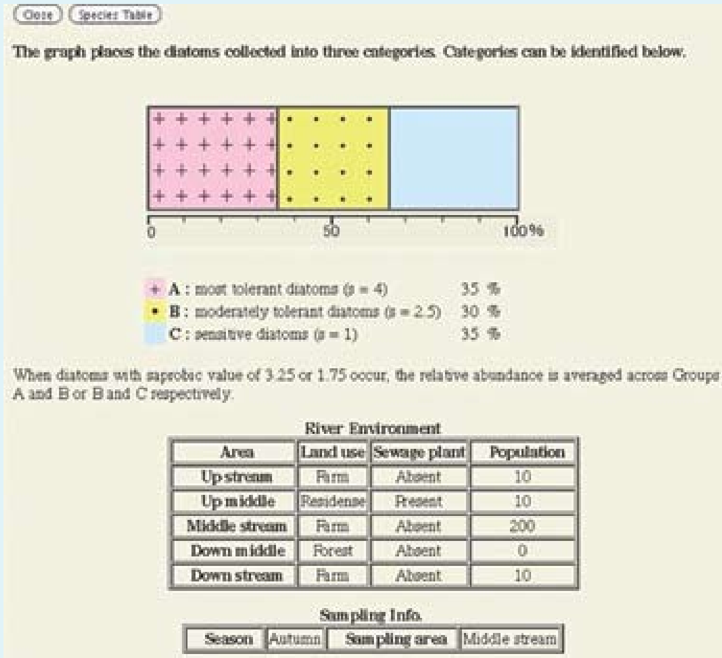
FIGURE 5 Screenshot of simulated diatom community with individuals selected for identification; colored circles represent identified diatoms and pollution-tolerance levels

Class activities with SimRiver

Often, the entire class will be introduced to the simulation via a projector screen and the class will use the program together; from there, students may move to a computer laboratory where they can use the program individually or in small groups. Previous assignments with SimRiver have included requiring students to populate a river basin with specific land-use and population parameters in a manner that minimizes impact on the environment. Other assignments have had students construct a river basin similar to that in their community using existing maps or Google Earth to evaluate the likely local water quality. This exercise can be supplemented by taking water samples from the local river and observing diatoms in class for comparison with simulated diatom communities. These past uses of the program represent only suggestions and users should feel free to develop their own exercises.

FIGURE 6 **Screenshot of graph showing percentage of community for three diatom pollution-indication levels**

In this graph, 35% of the population represent pollution-tolerant diatoms, 30% are moderately pollution-tolerant taxa, and 35% are pollution-intolerant taxa.



Effectiveness of SimRiver

SimRiver has been used in U.S. classrooms for two years, and data are still being collected. Readers who decide to use SimRiver are welcome to share experiences with the authors at *phytolab@stcloudstate.edu*. In Japan, SimRiver has been used for over a decade with an abundance of data collected. These data have been used to modify the program in the context of learning outcomes and to ease student use with the software (Mayama et al. 2008). ■

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