Creating a computer-based interactive food web to illustrate food-web dynamics for children aged 8-12

by

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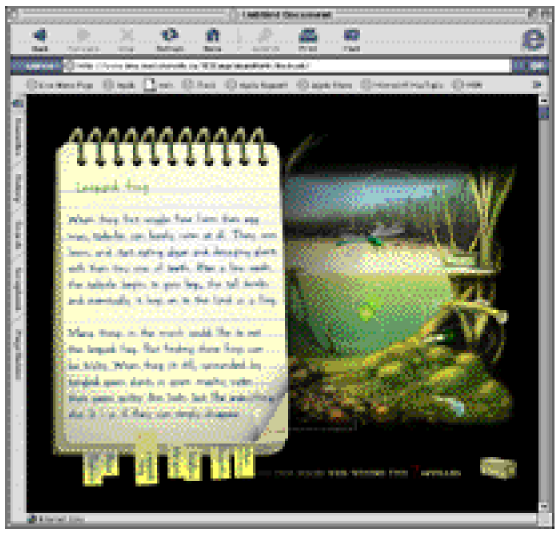

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Abstract

Studies have shown that many students have misconceptions about food webs and often understand them only in terms of food chains. A prototype interactive computer program was developed to help clarify some of these commonly held misconceptions, and to communicate how changes in the population level of one species can affect other species in the same system, even if they are not directly linked by a food chain. Three alternative visual approaches were explored in an effort to communicate how population changes in one organism impact on other species in the food web. Testing demonstrated that the program did have some educational and entertainment value to 8 - 12 year olds, although its ability to challenge misconceptions about food web dynamics was limited.

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Introduction

Ecological topics form a prominent aspect of most biological syllabuses today, with food chains and webs being central to the material being taught. Science teachers in the United States identified food chains and webs as important topics to learn, but also stated that they believed them to be relatively easy for most students to understand (Barman & Mayer 1994). While it may be true that food chains and webs are relatively simple concepts, studies suggest that certain misconceptions are common, particularly about food webs. S. Brumby (1982) found that the students he tested often appreciated food webs only in terms of food chains. Similarly, Griffiths and Grants (1985) found that many students believed that a change in the population of one species would affect another species' population only if the two were directly related as consumer and food item.

Schools in Ontario first introduce children to food chains in grade 4. In grade 7, children are learning about food webs, along with other ecological topics such as the roles of producers and consumers in a system (Ministry of Education 1998). The typical food web found in school textbooks illustrate a number of species that are typically found together in a particular habitat. Arrows are used to indicate the flow of energy from one species to another (Hall and Day 1997). Some webs make use of species' names, whereas others use images of the species. However, when Barmen and Mayer (1994) looked at 11 high school text book depictions of food webs, they found that little explanation was offered along with the food web about the interactions that occur within them.

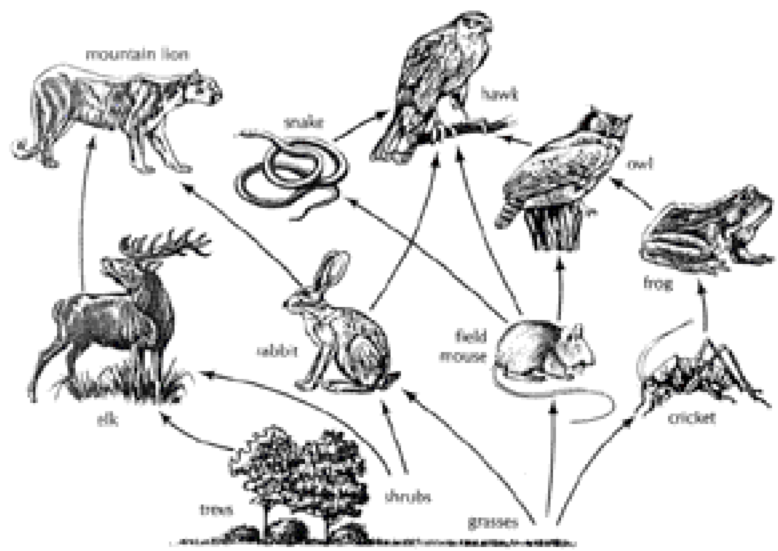

Figure 1. A simple food web, as shown in the school text book *Biology: The Study of Life* (Schraer and Stoltze 1990)

Various food web games also exist and can be played in the classroom environment. The children act out the roles of the species in the food web, with some being the predators and others being the prey (Pfaffinger 1999). How effective and widely used such games are is not known, but their focus on population change may help students appreciate how species in a food web can affect the populations of each other. It is evident, however, that such games can only be played when a willing teacher and several students are present.

Food webs can be complex, but they are not random (Pimm 1982). How populations in a community relate to and affect each other is, theoretically, predictable (Andrewartha and Birch 1984). The prey population is then likely to decrease. Food webs and chains are predator-prey models and rest on the assumption that the rate of increase in a population is entirely determined by the supply of food. This is not true in the real world; as Pimm (1982) points out, food webs must miss out much important biology. Nevertheless, the availability of food and the effects of predation on a species are often more important determinants of population size than factors such as intraspecies competition or changes in predation habits with prey availability (Calver and Porter 1986). So while their representation of nature is distorted, food webs retain enough truth to be valuable models.

The theoretical predictability of food web dynamics allows us to anticipate how all species in a system may be affected by a certain event. Computer simulations of natural systems can be developed and some interactivity with the computer based food web is then possible. Such models are used by ecologists to predict the behaviors of natural systems (Hall and Day 1997; Jorgensen 1986). Yet a computer based food web, which allows for some interactivity, could also to be an effective way to teach children about food web dynamics.

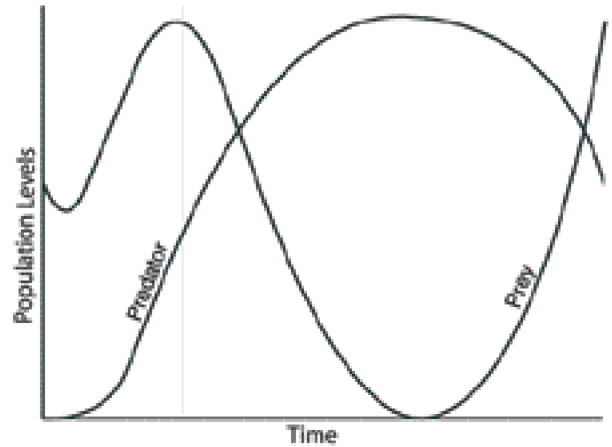

Figure 2. Graph, similar to those used by Rueter and Perrin (1999) showing changes that occur in predator / prey populations over time.

Interactivity in educational computer programs is potentially a powerful learning tool. Schank and Jona (1991) argue that its greater educational value comes from allowing students to learn from experience, rather than having them try to absorb information presented to them in a theoretical way. Computer programs may be used to illustrate concepts such as time and movement in ways that traditional media cannot (Panagiotakopoulos and Ioannidis 2000).

Some computer simulations of food webs have been developed for educational purposes. Rueter and Perrin (1999) created a program with a basic food web of seven species. They used a systems simulation model to generate data about how the population levels might change with a particular manipulation of one of the populations. They found that the program did help provide some students with a better understanding of food web and population dynamics. Programs like this, that can use the computer's unique capabilities, are welcome. However, Rueter and Perrins's program is designed for classroom use and does not attempt to entertain. It simulates nature with a static, traditional food web diagram and the fluctuations of species populations with graphs (figure 2). Its interactivity is limited to allowing the student to select which population to change and by how much.

When scientific accuracy is important, graphs are appropriate ways to display changes over time. However, many students find graphical data confusing and misinterpret it (Barker & Beare 1999). Children do not need the detailed information required by researchers who make use of such population graphs and for a target audience of 8-12 year olds a more appropriate goal is to convey fundamental food web concepts.

As the Rueter and Perrin program does not attempt to be particularly entertaining, children would probably not use it outside of the classroom. Research suggests that the way in which children experience and use the computer at home and at school is becoming more and more different. Mumtaz (2001) found that children use computers more at home than they do at school: playing games is the most popular computer activity when children are at home, whereas school computers are often used for word processing and other things the students consider boring. Mumtaz suggests that those who wish to educate children should learn from the activities children do on their home computers, and provide them with a more valuable computer learning experience.

The aim of this project was to create a program that could help students develop a better understanding of food web dynamics via the Internet. Because the program was intended for use at home it had to be entertaining as well as educational. Three different ways of representing population change over time were developed and each version was evaluated by the target audience for its educational value and engagability. One of the versions developed used graphs to show population change, and was the control from which to judge the effectiveness of the other two versions. The most effective version was then selected for use in the program.

PROJECT DESCRIPTION

CREATION OF THE FOOD WEB

Before the foodweb was created, the habitat on which it was to be based was selected. As the completed program would be used by both the Ontario Science Centre and Darlington Power Station, an Ontario marsh habitat was chosen since a marsh is present at both sites. After the identification of the habitat, the food web was constructed. It had to be:

- complex enough to illustrate the interactions that exist between species in the community, even if they were not directly linked by a food chain.
- simple enough to effectively show the flow of energy through a system.
- have a representative selection of species groups (e.g. plants, invertebrates, vertebrates) at 3 trophic levels (producers, herbivores, carnivores).
- represent both the juvenile and adult forms of species when these different life stages occupy different niches in the community.
- select species characteristic of a marsh habitat, and sup ply them with appropriate food sources from within the web itself.
- have species that are of interest to the target audience.

Encapsulating all of these features was challenging and several food webs were constructed (see appendix A). Finally a food web was created that best satisfied the above criteria (figure 3). The food web contained seven species, three of which had juvenile aquatic states very different from their adult forms. These therefore need to be represented separately, which brought the total number of life forms to 10.

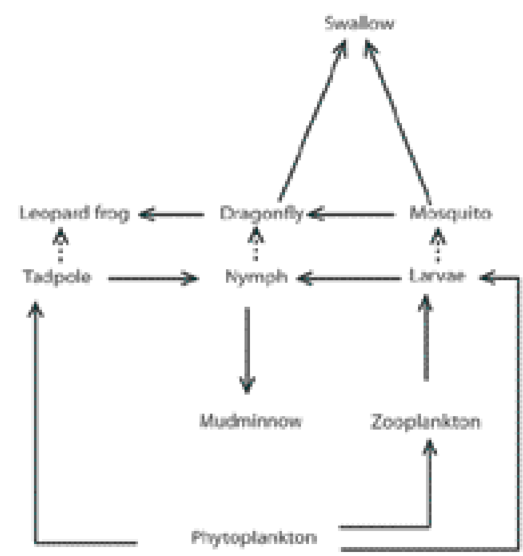

Figure 3. The food web on which the interactive system was based

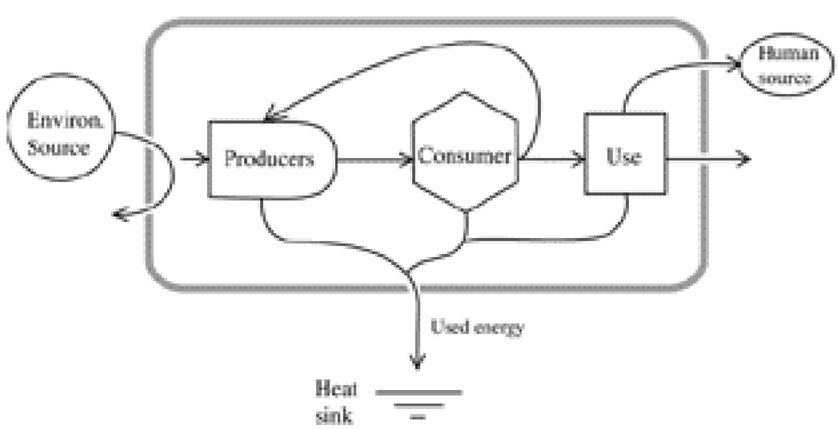

Figure 4. Odum and Odum's (2000) basic diagram of an ecosystem, with group symbols

VISUAL REPRESENTATIONS OF THE FOOD WEB

Models used by ecologists to predict changes in energy flow through a food web system often use simple shapes to represent the different trophic levels. They take on a grid-like, almost circuit board appearance (figure 4), the emphasis being on where the energy is being channeled. (Odum and Odum 2000).

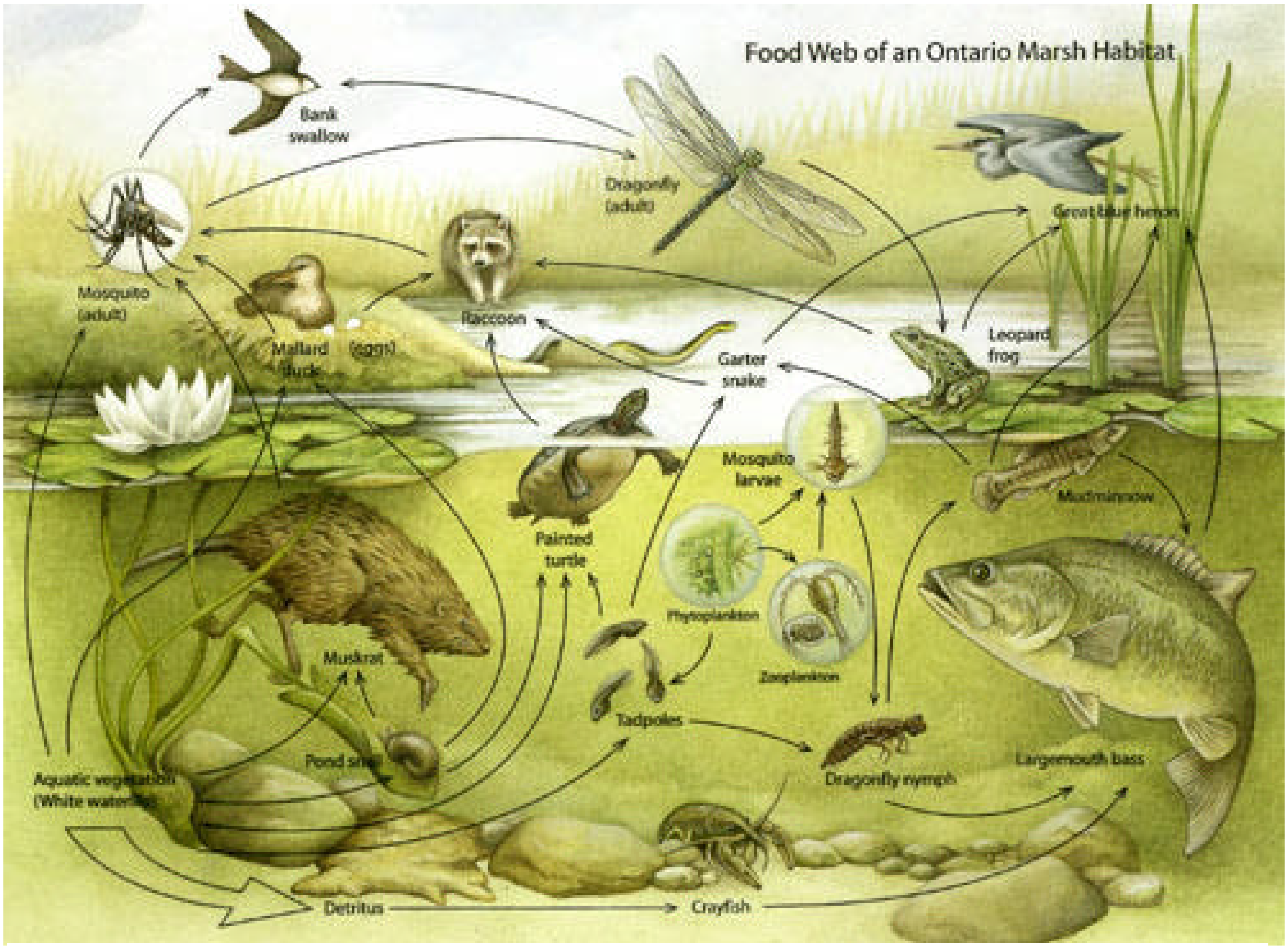

Figure 5. Food web of a marsh habitat, showing the species and habitat together

In contrast, food webs created for a lay audience and those seen in most student textbooks (see figure 1) make use of species names or images, or both (Hall & Day 1997; Savan 1991). A background depiction of the environment may also be included (figure 5), with food web species occupying a suitable place within it (Godkin 1999).
Something of both approaches would be used in creating the program's food web. The aim was to combine a grid-like food web structure with straight lines that would emphasize the flow of energy, with the visual richness of species depictions and an accompanying background environment. Images can help focus the attention of a young audience (Bogert 1988) and also help familiarize the user with the appearance of the various marsh dwellers.

Arrows

Food webs make use of arrows to indicate the direction in which energy is flowing; that is, from food species to consumer. Because this was not a static food web, this flow was shown with moving pulses of energy travelling between the species. The arrowheads could then be removed and this greatly reduced the visual noise and gave the web a grid like appearance (figure 6).

The sun was included to emphasize that it is the flow of energy that is being depicted in a food web. The sun was placed in the top left-hand corner of the screen, which is the normal place for the eye to begin viewing a visual (Goldsmith 1987).

Elipses indicated the various positions for the species in the food web. These were positioned with care so that when the background image was added the species would occupy a suitable habitat. It would not, for example, be appropriate for the fish to be sitting above the water or for the adult mosquitoes to be submerged. Species with both adult and juvenile states were shown partially joined together. This helped clarify that one species was being considered, while retaining the important information about its changing life patterns.

Finally, the grid was converted from a solid to a dotted line. A broken line can help to create distance between it and other elements that sit over it (Wilson-Pauwels 1997). Here the grid is in the forefront but the broken line helps create a distance between it and the other visual elements. It also helped to lighten the visual impact of the grid.

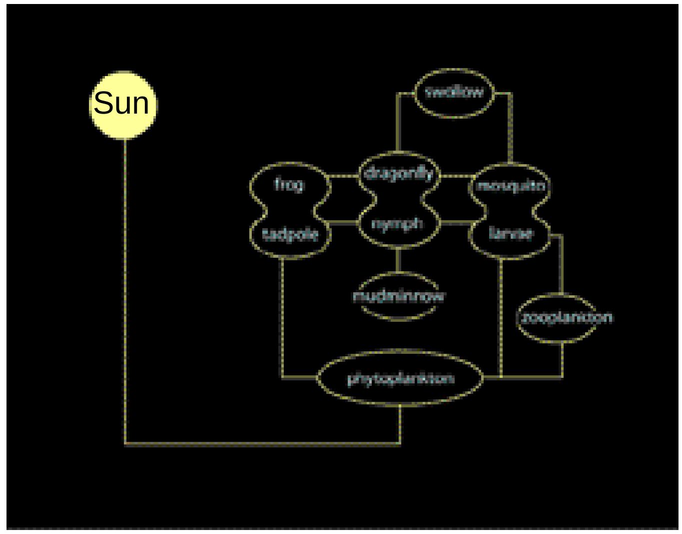

Figure 6. Layout of the interactive food web

Background Image

As John Lasseter, director of *A Bugs Life*, noted "People have a real love of looking at small worlds" (Kurtti 1998). To evoke some of this wonder for the miniature, a close, intimate view of the marsh habitat was chosen. The image was hand draw in pencil to give it a natural, soft feel and to help it sit comfortably in the background without competing with the vector based elements that would be placed on top of it. Reeds, half submerged in the marsh water and half towering into the sky, part to reveal the marsh. Pebbles on the marsh floor lead the eye into the composition, while the stems and leaves of the reeds frame the scene and create a transition from the marsh to the plain black of the remaining screen (figure 7). Black is used here for its dramatic effect and for its capacity to make colours placed above it appear rich and luminous (Feisner 2000).

Figure 7. Background image of the interactive food web

Often background images are created with a lower level of contrast and saturation to give the impression of distance (Feisner 2000) and so they do not compete with the foreground (Tufte 1990). Using a pale, muted background here, however, would not have been successful. Since dark borders tend to lighten the objects they surround (Feisner 2000) a pale background image would have been overpowered by the black. The habitat was therefore coloured in Photoshop 6.0, with saturated colours of similar value. The palette was restricted to cooler shades of green, with some blue and brown. In some areas the image was blurred, with those parts of the image supposedly at a greater distance from the viewer blurred the most, to create a sense of depth.

Colour was used to draw the viewers attention to important elements in the food web. In compositions that have a very dark or black background, the most prominent objects are those lightest in colour (Feisner 2000). Once placed over the habitat image, the pale yellow grid and the sun become the objects that first demand the viewer's attention. Since the instructional text at the bottom of the screen was the same colour, it also attracts the viewer's attention. The notepad, added to provide the user with helpful information about the species, is also light in colour, but this was more out of necessity than because of design. Its impact on the composition was reduced somewhat by shading the paper with a gray tint.

Red as a complement to the green was used in small amounts, to signify active spots and buttons. Warm colours advance and red, as the warmest colour, will attract the users attention (Wilson-Pauwels 1997). The various species were coloured in hues similar to those found in the background image. This is realistic, since the species often make use of natural colours for camouflage. The species were animated, and it is their movement around the screen, rather than their position in it or their colour that helps the user notice them when requested to find them.

The many elements that go to create the opening food web scene create a complex and detailed image designed to convey some of the complexity of the marsh habitat. To minimize visual overload, this detail was balanced by the generous area of black that surrounds the marsh depiction, which separates it from the strong visual elements of the sun and notepad. Great attention was given to the creation of the visuals for this program (figure 8).

Figure 8. The interactive food web, complete with background image, species, grid and notepad

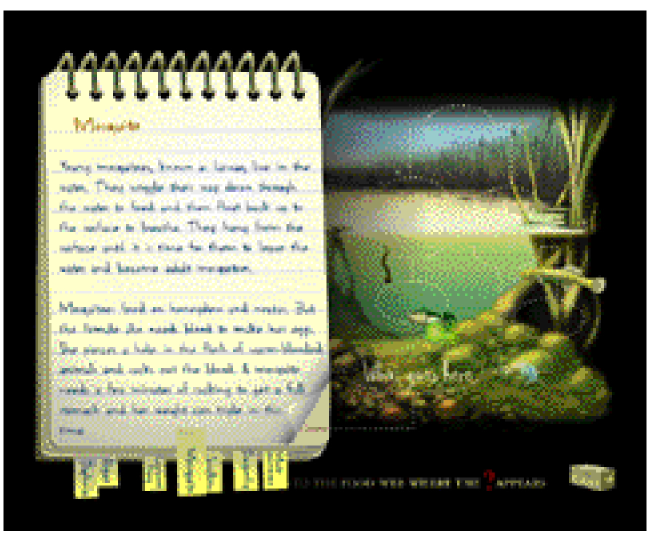

Figure 9. Enlarged notepad, giving extra information on the marsh species

Creation of the program

A flow chart showing the navigation through the site was created (see appendix B). Three levels were envisaged, with a page of instructional information loading first and being accessible to the user while the rest of the program loads.

The first level was designed to familiarize the user with the community, before they have the opportunity to manipulate one of the species populations. The user has to build the food web by clicking on and dragging the species into the grid. Starting with the producer species, and ending with the top carnivore species, the user is guided through the food webs construction by a red question mark, and a "What goes here?" statement that appears in that part of the grid for which the species has to be found. If the wrong species is selected for a position, the notepad informs the user to try again. When the correct species has been found, the user will see the energy spread to the next level in the food web. At the first level, a larger notepad that contains more information about the marsh species was provided. Yellow tabs help users navigate through the various pages of the notepad (figure 9).

Following the theme of a field trip to a marsh, users may choose to access a pair of binoculars. Selecting the binoculars allows them to view a larger food web that contains the seven species included in the interactive food web along with eleven additional species. Users view the larger food web through two circles, as if they were looking through a real pair of binoculars (figure 10). As they roll over the various species, the name and the arrows to and from that species appear. The larger food web was included to illustrate that the interactive system, with only seven species, is greatly simplified and many more species may be found in a marsh that could be included in the food web.

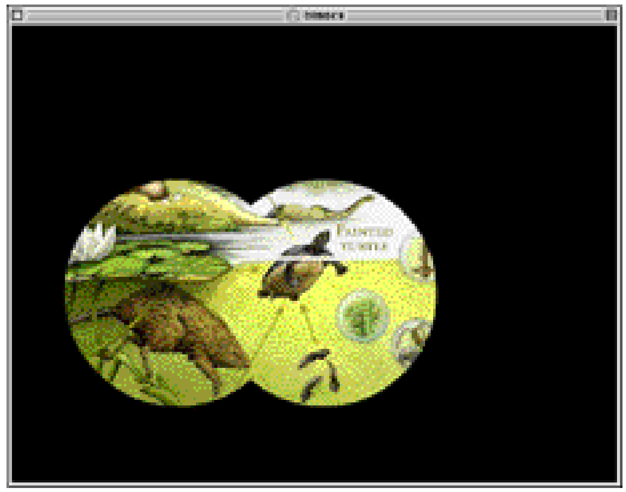

Figure 10. The view through the binoculars, showing a portion of the larger food web with 21 species

Once users have completed level 1 by building the food web they automatically enter level 2. This is a narrative section that introduces terms such as *producer, consumer, carnivore* and *herbivore*. The notepad and background image are removed to leave only the grid and the species of the constructed web. Boxes section off parts of the food web and are accompanied by text (figure 11). Short simple animations are used to illustrate the actions of herbivores and carnivores. With the aid of a "next" and "back" button, users control their progress through this section.

Figure 11. Level 2. Here a short animation shows the behaviour of the carnivores in the system

Once they have passed through all sections in level 2, users progress on to level 3. It is here that they have the opportunity to alter the population level of the mudminnow fish species and observe the effect that this has on the other species in the marsh. In order to anticipate the consequences of user manipulations, the changes which could be made to the mudminnow population was limited to increasing, doubling, reducing or completely removing the fish from the system. This allowed the consequences of a manipulation to be known and so depicted beforehand. Professor Peter Abrams, an expert in food webs and aquatic zoology at the University of Toronto, was consulted on the effects such changes to the mudminnow population might have on the other marsh populations.

In an attempt to evaluate the best method of conveying population changes over time, the results of manipulating the mudminnow population were presented in three distinctly different visual ways.

Figure 12. The first version of level 3. A reduction in the number of mudminnow fish in the marsh has just taken place

The first version attempted to show changes in population size within the food web grid itself. Rather than the various species in the food web being represented by only one image of the individual, repeated images were used. Fluctuations in population size were shown by increasing or decreasing the number of individuals within the circles of the grid as well as changes in the size of the circles themselves (figure 12).

The second version made use of a type of bar chart, with individuals of a species lined up in rows to form the bars. To show populations increasing and decreasing individuals were added to or removed from the bar chart. The food web was reduced in size and placed in the top right of the screen, for reference (figure 13).

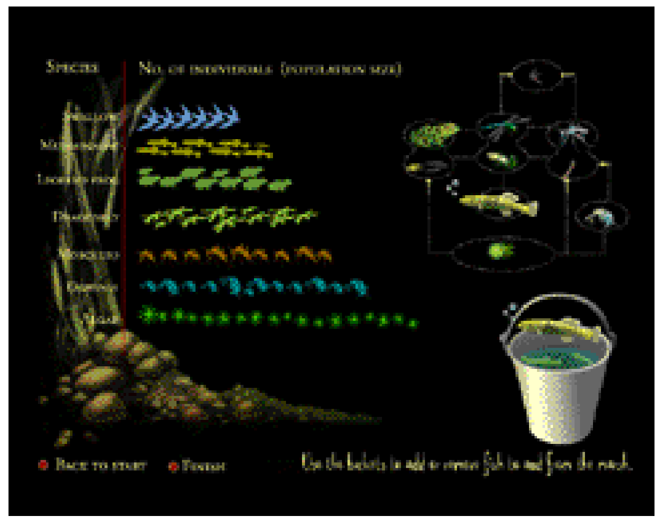

Figure 13. The second version of level 3, showing the bar chart

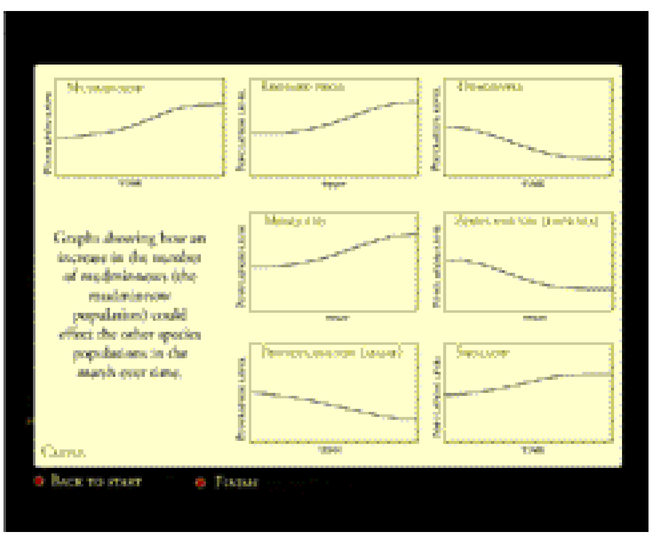

Figure 14. The third version of level 3, showing the graphs used to display information about population fluctuations

The third version used graphs similar to those used in Rueter and Perrin’s program, and was the control by which the effectiveness of the other two versions were judged. Users, after changing the muminnow population, can see how the other populations are affected by referring to graphs that plot population numbers against time for each of the species (figure 14).

All other aspects of the three versions remained constant.

Testing the program

Ethics Board approval from the University of Toronto was granted to test the program on children attending the University of Toronto Summer Camp. Informed consent was obtained from the participant's parent or guardian, and assent from the participant (see appendix C). Testing took place in the computer lab, on the first floor of the Athletics Centre. Nine children between 8 and 12 years old took part in the evaluation and tested the program for usability and its capacity to enhance their ecological understanding. Other than the child's willingness to take part and their age, no other selection criteria were employed. Three children were assigned to test each of the three different versions of level 3. The child's availability to test the program on a particular day was the only determining factor as to which version they tested.

Alreck and Settle (1995) state that a small sample size is justified when the study obtains large amounts of qualitative data from each individual respondent. The one-on-one sessions lasted on average 30 minutes and yielded much qualitative information about the program. Before using the program, each child was asked to fill out a short questionnaire designed to assess their understanding of food web dynamics (see appendix C). The questionnaire was a combination of multiple choice and short answer questions. They were then asked to explore the program. They were encouraged to ask for assistance if they needed it or to ask questions about the food web. Their approach to the program was observed and notes were taken. After completing all levels of the program, the participants were asked to fill out a second questionnaire, that was similar to the first (see appendix C) to assess whether using the program had changed or improved their understanding of web dynamics.

The children were then encouraged to say what they liked and disliked about the program, along with any suggestions they had for changes. This was done as an informal one-on-one interview and, again, notes were taken on the comments made.

Results

Of the 9 participants that agreed to take part in this study, 8 were female, and one was male.

Introduction Page

The children tended to ignore large amounts of text when it appeared as part of the instructions at the start of the program. All of the children explored some of the information offered on this page, but only one of the participants read all the information in this section.

Level 1

The children were able to grasp the concept of building the food web quickly. Construction of the food web often retained the children's attention even if they found it difficult to identify the correct species for a spot in the food web. Only one participant asked for assistance when she could not identify the correct species for a place in the food web. All the species were easily identified as dragable objects by the participants, except for the fish which sometimes proved difficult to find. Only 2 of the 9 students opened up the larger notepad and only one used the binoculars. Those participants that did explore the notepad and binoculars had no difficulty using them, and returning to the main game once they had finished.

Level 2

The narrative text that appeared in level 2 was carefully read by all of the children. They were all capable of navigating their way through the various sections on *energy flow, carnivores*, *herbivore, producers* and c*onsumers*. Question 1 in questionnaire 1 demonstrates that children normally understand the arrows in a food chain and web to represent what certain species eat. After using the program 8 of the 9 participants still believed the arrows in a food web to represent the eating habits of the species they lead to or came from. One participant changed her response from "what is eaten by what" in the first questionnaire to "flow of energy" in the second (see appendix D, page 29). The program, and in particular level 2, did therefore have some success in portraying this concept.

Level 3

All the children understood that in level 3 they needed to add and remove fish to and from the food web. They also understood that they were to do this by dragging the fish out off, or into the system. Why they were doing this, however, was not always initially apparent to them. One participant expressed that she initially believed the goal of version two, (which makes use of the bar chart), was to try and make all the bars equal in length. One participant expressed regret at not being able to manipulate other species populations. Several children attempted to click on and drag species other than the mudminnow out of the food web, after they had altered the fish population two or three times.

Comparison of the pre and post-test questionnaires suggested that none of the three versions of level 3 were capable of improving the children's understanding of food web dynamics (see appendix D, page 32). For the most part the questionnaires revealed that either the children had a good understanding of food web dynamics before they used the program or that they persisted in the view that a change to one species would affect another only if they were directly connected as predator and prey. However, one child, that exhibited only moderate understanding in the post-test questionnaire, did verbally express a greater understanding for the dynamics of the food web in the program.

There were some differences in the way the three versions were used by the children. Those children that stayed in level 3 the longest were those that used the second version, with the bar chart, while the least time was spent by those using the third version, with the graphs.

Discussion

Introduction Page

It was very apparent from the opening page that the children did not like to have to read a lot of text before they started the program. Since this part of the program is meant to be accessed only as the user is waiting for the program to load, and since almost all the children easily grasped what they were required to do once the program had started, this was not considered to be a problem.

Level 1

The use of motion in level 1 was effective at guiding the participant's attention to a particular part of the food web, and in helping them to identify the various species to be placed into the grid. How important a cue motion was to the children was evident when some had difficulty finding the fish species. The fish does not travel around the screen as the other species do, but stays in one place, moving only its tail and blowing bubbles. As a lack of motion is characteristic of the mudminnow, and as seeing creatures in the wild often requires careful observation, the challenge involved in finding the fish was considered a desirable thing to maintain. Those children that did have difficulty finding the mudminnow were focused enough on the task to persist until it was discovered.

Focusing on the task, however, did mean that few children were prepared to fully explore the tools also available in level 1. While Schank and Jona (1999) state that a computer program that allows the user to explore can be both highly rewarding and educationally effective, they also note that there is always the possibility that the user would not actually take the initiative to do so. It does seem that in this case the children attempted to complete the task first and failed to explore other areas. Possibly they were so engrossed in the task at hand that they failed to notice the tool box. Having a larger tool box might correct this problem by making it more conspicuous. Similarly, with the notepad, attention could be drawn to it by having words flash at appropriate moments. Yet it could also be that under the conditions of evaluation the children did not feel entirely free to explore, conscious perhaps that their performance was being monitored.

Level 2

Unlike the information offered at the start of the program, the text in level 2 was carefully read by all of the participants. The illustrations and animations that accompanied this text may have helped to retain the children's attention (Bogert 1988) or, having already performed one task, the children may now have been more engaged in the program and so have been more willing to read.

The "sponge technique" of teaching, that requires children to read or listen, and then simply absorb the information given to them, can be one of the least stimulating ways to learn (Schank and Jona 1991). Yet it is still a highly effective teaching method and in this section information is given as text that would be difficult to convey in other ways. The one participant that demonstrated an appreciation for arrows representing energy flow in the post-test questionnaire could have acquired this knowledge from reading the text in level 2. Or she may have acquired that understanding from the representation of energy flowing from the sun, to and through the food web grid. Alternatively, it could have been a combination of both the visual and the written information provided.

Level 3

The purpose of level 3 was to allow the user to freely explore the consequences of their manipulations on the mudminnow population in the same way that Rueter and Perrin had allowed in their program (1999). Unlike Rueter and Perrin's program, however, it is not possible from this evaluation to say whether any of the versions developed helped the participants in their understanding of food web dynamics.

Nine children, with three testing each of the versions in level 3, was too small a sample size to test the educational value of this level. The sample size was effectively made even smaller for this part of the evaluation as four of the participants showed a high level of understanding before they used the program. No increase in understanding could therefore be monitored in these participants. For the other 5 children, the questionnaires suggested that their appreciation for food web dynamics was not greatly enhanced after using level 3.

Though the number of subjects testing this program was small, we still might have expected to see some evidence that level 3 did improve understanding of food web dynamics. It could be that all versions developed were inadequate at showing population change to the target audience. Alternatively it could be that correcting misconceptions in a game-like format such as this is difficult to do. Educational games may not be taken as seriously by children as that which they learn in the classroom environment. Thus it would be difficult to replace classroom-learned ideas with new ones such as those being portrayed in level 3. Self discovery as a learning mode is not always encouraged by the educational system, despite the fact that evidence suggests that learning from experience is an excellent teaching method (Schank and Jona 1991).

As with the belief that arrows in food chains and webs indicate species feeding habits, viewing food webs only in simple food chain terms is not so much incorrect as incomplete. While the program attempts to provide a more complete picture of food web dynamics to the user, when it came to answering formal questionnaires, it was too easy for the children to revert to what they already felt confident in knowing. The questionnaire was also perhaps too far removed from the program to be the best test of its value. Traditional, static food webs were used in the questionnaires to see if the knowledge gained from the program was transferable to models that the children were more likely to be exposed to. However, this approach meant that even if the dynamics of the interactive model were understood, this would not be detected if the participant failed to translate this knowledge to the food webs in the questionnaire. This was the case with at least one participant, who could verbally express an appreciation for many species in the interactive food web being effected when she changed the fish population and yet did not appreciate this scenario as a possibility for the food webs shown in the post-test questionnaire. Question 1 in the questionnaires could also have been confusing to the children. While the arrows in a food web do represent energy flow, in the food chain and webs shown in the questionnaires, it would also be correct to say that they represented what is eating what. Therefore, the option the check more that one box should have been made clear to the participants.

The answers given in the questionnaires could not be used to identify which of the three versions was the most effective at communicating population changes to the children. However, observations made as the children used level 3 did highlight certain positive and negative features about each version. The second version, with the bar chart, had the advantage of illustrating the "pyramid of numbers", with the producers having the largest population and occupying the bottom of the pyramid, and the top carnivores at the peak with the smallest number. This version seemed to retain the children's attention the longest. One participants, however, did find the bar chart to be initially confusing, although its purpose did became clear as she continued to play with it. Those children that used version 3 spent the least time in this level. While none of the participants that used version 3 stated that they did not like the graphs, or that they found them boring, the short time spent examining them suggested that they were not highly engaging to the children.

Version 2 of level 3 was selected for use in the program. As level 3 requires that the user takes the initiative to explore for themselves, having something that will entice them to do so is very important here. Version 2 makes use of new graphics and motion that seemed able to engage them more than version 1 (where visuals already very familiar to the user were used) and 3 (where graphs were used),

CONCLUSION

The study suggests that children are capable of both engaging with and learning from interactive, educational games. In the program developed, a variety of ways were used to educate and entertain the user. Some approaches where more successful than other.

When building the food web in level 1, the program was successful in engaging the user in this task. However, it was possibly less successful in educating the children, as they tended to put off reading or exploring information available to them while the task was being completed. Much of the factual information in the program was presented to the user as text. The program successfully demonstrated that children are prepared to read and absorb information when it is presented to them as an integral part of an engaging and interactive program.

The results of this study agree with those of other studies that suggest that misconceptions about food webs are relatively common amongst children. The results also suggest that such misconceptions can be difficult to correct in a computer, game-like format. The approach taken in level 3, where misconceptions about the complexity of food web dynamics were addressed, allowed the child to explore the consequences of their actions on the food web. The study suggests, however, that misconceptions need to be addressed in a more direct manner. Some of the children that tested this program were able to maintain their misconceptions and seemingly ignore the information that had been presented to them when later questioned about food web dynamics.

Directly challenging misconceptions about food web dynamics in the program could be done in a number of ways. One effective method would be to ask the user questions and then provide appropriate feedback. If this approach were to be coupled to a task the user had to perform, the desire to achieve the correct feedback would probably be enhanced and keep the child motivated. Only when the user demonstrated that they had discarded their misconception and adopted the correct response would the desired outcome be achieved.

A voice over, which accompanied and explained the animations as they illustrated the changes that occur to the various populations in the food web, could also be highly effective. Sound can greatly influence the interpretation of visual stimuli and spoken statements can be used to guide without distracting from a visual (Chion 1994). However, to add a voice over to the program would greatly increase its size and therefore the time it would take to download, which would reduce its accessibility.

As the children were more motivated to explore when new visuals were involved, developing some new and dramatic graphics to represent increase and decrease in species numbers could encourage them to keep experimenting with manipulations, and watching for changes to occur in certain populations. However, for this section to truly allow exploration, the user must feel able to pursue many different possibilities. Similar manipulations on the other species in the community should be made possible to help the child to fully appreciate the dynamics of the marsh food web.

The interactive marsh food web does have some shortcomings, but it also does many things very well. The lessons learnt in this study would be helpful in developing this program further, or as considerations for anyone who seeks to create a program that is both educational and fun for children to use.

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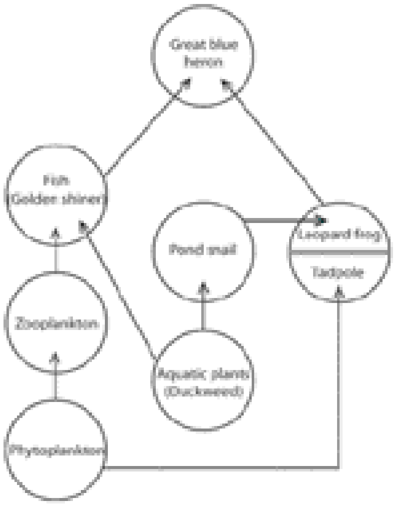
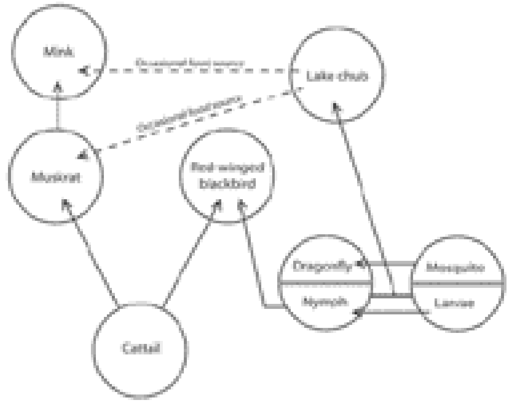
APPENDICES

APPENDIX A

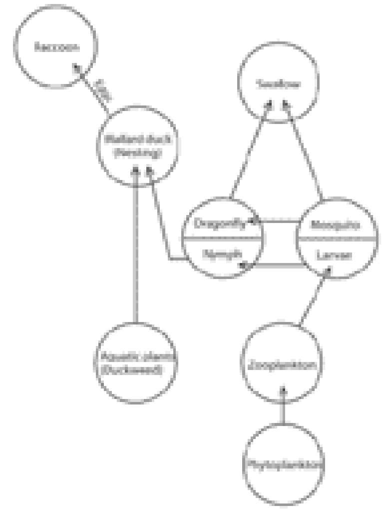
Development of food web model



Food web 1. This food web was rejected because it contained no insects.

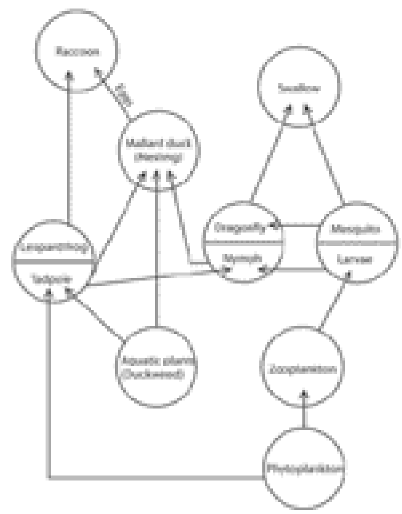


Food web 2 was rejected as the red-winged blackbirds did not have an adequate food source.

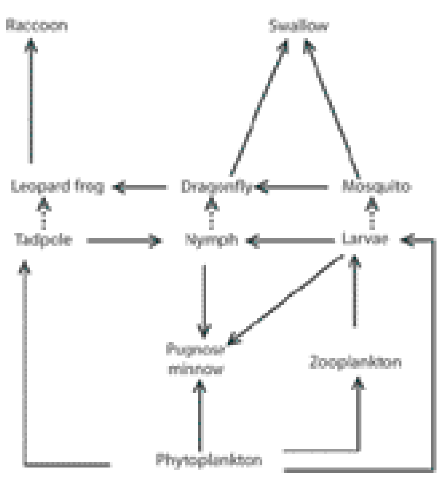


Food web 3. Rejected in favour of food web 4, which had the advantage of showing an amphibious species.

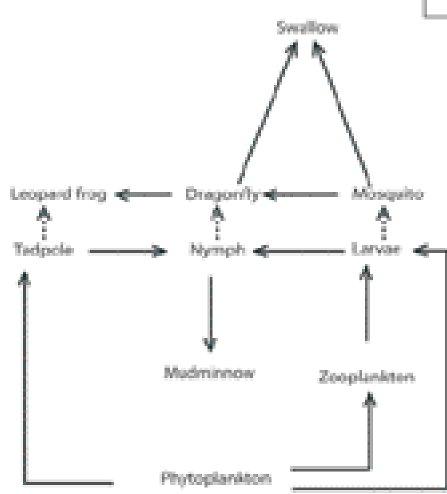
Food web 4, accepted in preferance to food web 3 as it contained leaopard frogs.



Food webs 1 to 4 were presented to the committee for selection. Food web 4 was choosen but underwent two further revisions before food web 6 was obtained.



Food web 5. Food web 4 lacked a fish species, and so a Pugnose minnow was added to the system.



Food web 6. A mudminnow replaced the Pugnose minnow which was felt to have too many connections to other species in the food web, making the system too complex for the user to easily follow the energy flow. The number of species was also too great in food web 5, and so the raccoon, being the most peripheral species, was removed.

Appendix B

Flowchart

Flowchart for Interactive Foodweb