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INTEGRATING THE EFFECTS OF DAMS ON RIVERS AS A MEANS OF TEACHING BASIC ECOLOGICAL CONCEPTS

By

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ABSTRACT

INTEGRATING THE EFFECTS OF DAMS ON RIVERS AS A MEANS OF TEACHING BASIC ECOLOGICAL CONCEPTS

By

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An experimental teaching unit concerning the biological effects of dams on rivers was designed to replace a previously taught unit on populations, communities and ecosystems. This unit was taught to two sophomore biology classes at Kewaskum High School in Kewaskum, Wisconsin. Two other classes were taught a traditional curriculum, and comparisons in learning were made between the two groups.

The experimental unit was designed to provide more laboratory instruction than the traditional approach, to provide a cohesive theme for the teaching of ecology, and to bring local relevancy to the student's education. Students taught the experimental unit learned more about the effects of dams on rivers than those taught in the traditional manner, as hypothesized. They also learned as much about populations, communities and ecosystems as those taught in the traditional manner.

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INTRODUCTION

Dams have long been a fixture in American life and are a commonly accepted part of many communities. In recent decades the effects of dams on aquatic ecosystems have become apparent. As physical obstructions, dams have been known for some time to interfere with migrations of anadromous fish on their upstream spawning runs (Trefethen 1972). Fish ladders installed at the dams are not utilized by some of the adult fish. Many pacific salmon populations have been threatened or eliminated because of dams. Recently, dams have been shown to be a peril to young salmon on their downstream migrations to the sea as well. Eley and Watkins (1991) estimate that up to 90% of smolts are lost to generating equipment or to other factors as they swim aimlessly in the pools behind the dams.

There are some fish species that benefit from the construction of dams, as lake-like conditions are produced. However, it is now known that many fish found in inland waters migrate extensively. Becker (1983) lists several native Wisconsin species which have declined due to dams blocking spawning migrations. Many fish are known to migrate to deep areas of rivers to overwinter (Tyus 1990). Smallmouth Bass, previously thought to migrate only very short distances, have been found to migrate 69 to 87 km in autumn to reach deep wintering areas (Langhurst and Schoenicke 1990). Channel Catfish are known to migrate from small waters downstream long distances to deep areas of the Mississippi River (Parduhn 1992). All of these species would be harmed if dams were constructed on rivers where the fish are now maintaining successful populations.

In addition to creating a physical barrier, dams change other aspects of the environment as well. Many aquatic food webs are significantly altered by the transformation of bottom composition in the reservoir. Often the existing gravel or clay bottom is covered with silt as water velocity decreases. Invertebrates which could hide, feed and grow on solid substrates are often unable to maintain populations on a bottom of silt. Different invertebrates often will replace the original community, but the new community is generally less productive, less diverse and less stable. Higher trophic levels are also affected by these changes. Many fish species are directly affected by changes in bottom structure due to their inability to spawn successfully on unstable bottoms like those found behind many dams (Becker 1983).

Temperature and dissolved oxygen levels often are different in areas behind dams than in free-flowing sections or rivers. As water slows and rapids disappear there is less exchange of oxygen between water and air. While phytoplankton blooms may at times create high oxygen levels, darkness or the decay of plants may cause quick decreases in oxygen, killing oxygen-sensitive protists and animals.

Summer temperatures in areas behind dams often rise several degrees above those in undammed sections of river. This occurs as water molecules are retained for long periods of time in the reservoir behind the dam, allowing heat energy to be absorbed (Keefer 1990). Some organisms may be killed directly as high temperatures denature vital proteins or suffer from the increased oxygen demand of their warmer tissues. Also, because the solubility of oxygen in water varies inversely with temperature, low dissolved oxygen levels may coincide with higher oxygen consumption during the summer. Thus, many species may be restricted from areas behind dams because of a lack of oxygen at some time during the year. While oxygen levels often improve as water flows over a dam, increased temperatures can affect rivers for long distances downstream.

Dams are abundant in eastern Wisconsin and throughout the upper midwest. Many of them are small, old and in need of removal or repair. Although individuals, corporations or governmental units may own the dams, states often license them and determine when they must be repaired in the interests of public safety. The discussions surrounding the future of such dams often are filled with controversy. Many dams are found in the area of Kewaskum, Wisconsin. In the past few years one small dam near the village of Kewaskum has been removed at a cost of $47,000 and another renovated at a cost of over

$500,000 (Anonymous 1992). A small dam still exists in the village of Kewaskum about 0.5 km below Kewaskum High School. Despite financial considerations against repair many local residents are in favor of renovation rather than removal of the dams. Often the dams are considered to be historic landmarks, and aesthetically pleasing parts of the community. At times ecological arguments both for and against dam removal are presented. Students should find a study of how these dams affect aquatic ecosystems to be relevant and interesting. While the dams are the focal point of this unit, students learn basic ecological concepts concerning populations, communities and ecosystems as they study dams and the effects they have on rivers.

The use of local issues in science education is currently being encouraged. Students can come to see science as a current, meaningful endeavor if applications of knowledge to real situations are attempted (Dowling 1986). This unit attempts to accomplish this by replacing traditional instruction concerning populations, communities and ecosystems. Previous instruction followed chapters two and three in Biological Science: An Ecological Approach (Biological Science Curriculum Study, 1987). This text uses a variety of examples, some aquatic and some terrestrial to teach about relationships between organisms and their environment. The "new" unit teaches the same concepts, but in a more organized approach which utilizes many laboratory experiences. This laboratory based unit should also promote higher level thinking skills as students develop hypotheses, collect and analyze data, and evaluate their hypotheses (Bloom 1965). Although the products of the Biological Science Curriculum Study are generally strong in this regard, the chapters concerning ecology do not challenge the students enough. In order to evaluate the effectiveness of the unit concerning the effects of dams on rivers, two sophomore biology classes at Kewaskum High School were taught in the traditional manner and serve as controls, while two others were taught using the new method. The basic objectives for both groups were the same, although the activities were different. It was thought that the experimental group would learn about the effects of dams on rivers, while also learning basic ecological concepts as well as the control group.

IMPLEMENTATION

This teaching unit was designed to occupy the same time period as previous instruction concerning populations, communities and ecosystems. As time progressed it became necessary to make small modifications in each so that they would conclude at the same time. In most cases the basic objectives were the same for the experimental group and the control group. The experimental and control groups each consisted of two sophomore biology classes. Their makeup will be further described later. An outline of the activities for the experimental and control units is found in in appendix A, and a description of activities for the experimental unit is found below.

A role play concerning a hypothetical controversy over the repair or removal of a local dam was a new technique for our biology program. It involved students playing roles of individuals who would be interested in the fate of the Kewaskum Dam. This activity is designed to cause students to utilize their understanding of river ecology by synthesizing arguments for or against removal of the dam. Since this activity was completed near the end of the unit, students had a good base of knowledge to work with. Groups of three or four were formed, and randomly given a role (village board members, a sportfishing group, village property owners, residents living near the dam or residents of a downstream community). A more complete description is found in Appendix E. Students used the viewpoint of their group and the knowledge they had gained in the unit to construct position statements. These were presented at a mock village board meeting, with the group playing the role of the board deciding the fate of the dam. Reading and discussion of "Flowing Free" a Milwaukee Journal newspaper article (Keefer 1990) was used to summarize effects seen when small dams were removed in Wisconsin. Several examples were presented of local opposition to the removal of old dams, along with the generally positive effects on the aquatic ecosystems once the dams were actually removed.

"Where Have All the Salmon Gone?" is an exercise provided by Project WILD (Western Regional Environmental Education Council 1987). A modification of this exercise was used in an effort to help students identify factors which can alter population size. The exercise also is designed to promote critical thinking as they are required to make inferences about the causes of population changes. Students were provided with catch data for Chinook Salmon Oncorhynchus tshawytscha, Coho Salmon Onchorynchus kisutch, Chum Salmon Onchorynchus keta, Sockeye Salmon Onchorynchus nerka and Steelhead Onchorynchus mykiss. They then plotted trends in the catch of each species in the Columbia River since the late 1800s. Biological information concerning the life history of each species and historical data about changes in the Columbia River ecosystem were then provided to the students. Working in groups of two, the students wrote paragraphs describing possible reasons for changes in the catch data, and presumably the population size, of each species. For most of the species construction of dams was considered to be a major factor contributing to their decline. Although most of the dams were equipped with fish ladders they appeared to affect significantly the fish populations. Also, extreme fishing pressure at times was considered to be detrimental to the populations. Most students noted that while an increase in commercial fishing pressure would temporarily increase the catch, it could cause decreases over time.

Students shared their findings with the entire class. During this time, the question of whether catch data was a reliable predictor of population size was raised. This point led to a discussion of sampling methods as tools to estimate, rather than actually count populations. Some people had experience with introduced salmonid fish in the midwest, and gave examples of migratory native fish that could be affected by dams in this area.

"The Analysis of Organisms From Two Areas of the Milwaukee River" involved the collection of bottom-dwelling invertebrates and an attempt at their identification. The use of aquatic organisms as indicators of water quality is growing in popularity among governmental regulatory agencies (Kurtenbach, 1992). Since the organisms are present in the water at all times, they would detect and possibly indicate the presence of transient water quality problems that sporadic chemical and physical tests might miss. The presence of a variety of pollution intolerant species such as stonefly larvae, dobsonfly larvae and certain mayfly larvae would indicate that water quality was probably good throughout the year. A lack of these organisms would indicate past water quality problems even if current chemical tests indicated acceptable water quality.

Students collected bottom samples as a group from a millpond area in the village of Kewaskum about 0.5 km above a small dam. The bottom consisted of deep silty mud. Upon return to the laboratory, students looked for macroinvertebrates in the sediment. Most found no visible organisms in their sample. Two groups found one flatworm each. Although too few organisms were found to conduct a formal biological stream assessment, the lack of macroscopic organisms quickly led students to conclude that water quality was poor in this area. Most believed that oxygen levels could be low in this area, a feeling reinforced by the sulfide smell of the sediment they were working with. Students also suggested that the silt which had been deposited over the decades did not provide a suitable substrate for most bottom-dwelling organisms. In the discussions which followed, students reasoned that larger animals would not do well in this area, either, partly because of a lack of lower order consumers on which to feed.

The instructor collected bottom sediment about 2 km above the village site in an area of the Milwaukee River unaffected by dams. This area had a bottom composed of a mixture of sand and rock. In the laboratory each pair of students received a portion of this material and once again looked for organisms. Identification was accomplished using a Citizen Stream Monitoring Manual (Illinois Department of Energy and Natural Resources 1990). Many caddisfly Trichoptera sp. larvae were found, along with lesser numbers of water pennies Psephenidae sp. and mayfly larvae of several genera. Small numbers of mollusks and flatworms were also present. Using an assessment form present in the manual, each kind of organism found was placed in a group pertaining to its pollution tolerance. Group I organisms are highly intolerant of pollution, group II organisms moderately intolerant, group III organisms fairly tolerant and group IV organisms very tolerant. Students found that most of the organisms present fell into the group II category, with a mean group number of 2.3. This indicated that the water quality in this region of the river was good. In the reports generated by this investigation, students stated that the more diverse bottom makeup and the faster flowing current in this area provided better conditions for a variety of invertebrates than the site in the village millpond. Students indicated that the combination of the dam causing a reduction in velocity of the water and siltation from fields in the area contributed to the silty bottom of the village site.

Several other laboratory investigations were also completed. The objectives of one, "The Effects of Varying Salt Concentrations on Scud and Brine Shrimp" were to evaluate how a chemical factor could influence population levels, and to compare the tolerance of two organisms to the same chemical factor. Students were expected to extrapolate their findings concerning sodium chloride and these organisms to other situations. Students worked in groups of two throughout the experiment. Each group wrote a hypothesis concerning the response of their organism to different salt concentrations. Students generally hypothesized that brine shrimp, given their name, would survive best at higher salt concentrations. They thought that scud, which they knew to be freshwater organisms, would survive best in a mixture of distilled water and 1% salt. Using a medicine dropper, they obtained about five scud or about ten brine shrimp, and recorded the exact number. These were placed in a beaker of either distilled water, 1% salt, 2% salt, 4% salt or 8% salt as designated by the instructor. Students observed the organisms, recorded and converted to a percentage the number living (moving) after 10 minutes, 20 minutes and 24 hours. Class data were compiled and group comparisons were made. In general the brine shrimp survived better than scud even at low salt concentrations. All of the scud, even those in low salt mixtures, were dead after 24 hours, leading students to state that factors other than salt concentration may have been involved in their death. Brine Shrimp survived best in 1%, 2% and 4% salt, with no significant differences between these levels.

Another investigation which utilized aquatic organisms was "Temperature and Operculum Rate in Goldfish." This relatively simple experiment measured how a population of organisms would respond to a change in an abiotic factor in their environment. Students mixed cold (about 10°C) water and hot (about 50°C) water to obtain their test temperature. Some groups used 100 ml of cold water and 300 ml of hot water, others 200 ml of cold water and 200 ml of hot water, and others 300 ml of cold water and 100 ml of hot water. Each group placed a single goldfish Carassius auratus in a 500 ml beaker containing the test water. Following a five minute interval to allow the goldfish to reach the water temperature, students measured and recorded the water temperature. Opercular movements of the fish were counted for 60 seconds. The counts were repeated for two more 60 second intervals, with temperatures taken at the start of each interval. The operculum rates were then averaged. Class data were compiled and discussed. Each group then compared mean temperature and mean operculum rates by constructing a line graph, with roughly linear results. In general, students found that operculum rates increased with increased temperature. However, extreme temperatures of about 40°C used by a few groups resulted in an operculum rate of 0 per minute within a very short time! During class discussion and in their laboratory report conclusions, students attributed the general increase in operculum rate to a lack of oxygen in the warm water, and made little note of an increase in oxygen use by the fish as temperatures increased. The temperatures which caused death to the goldfish provoked much discussion, and it was noted that extreme temperatures can cause death to organisms in their natural environments also.

The purpose of the measurement of chemical and physical factors in two areas of the Milwaukee River was to compare two ecosystems. Also, students were to measure abiotic factors and evaluate how they would impact the biotic component of the ecosystem. Organisms were collected at these locations also, as described below. A large survey of many chemical factors was not attempted, since most would not likely vary between the two sites. Temperature, ph, dissolved oxygen and biochemical oxygen demand were the factors measured. Students collected water samples during class on October 13, 1992 from the Kewaskum millpond site, about 0.5 km upstream from the dam. Temperatures of 10°C to 11°C were found, along with dissolved oxygen concentrations of 6 ppm to 7 ppm, as measured by a YSI model 51B temperature and oxygen meter. These measurements were taken on the morning of October 13, 1992. Ph readings averaged 7.8. Bottles of water for the biochemical oxygen demand tests were collected and stored for five days in the dark. When final oxygen readings were to be made, the oxygen meter was found to be malfunctioning, prematurely concluding the experiment. Water was collected on October 15, 1992 by the instructor at the upriver site, about 2 km above the Kewaskum dam, in an area of swiftly flowing water relatively unaffected by dams. The water temperature at the site was 10°C. Dissolved oxygen readings taken soon after returning to the laboratory varied between 8.0 ppm and 8.5 ppm. pH readings averaged 7.7. Biochemical oxygen demand readings were not completed at this site, either. Students discussed and summarized their findings about the two sites. Although large differences were not noted, many felt that the dam in Kewaskum caused temperatures to increase and oxygen levels to decrease as the water slowed.

"The Effects of Acid on Brine Shrimp" was a simple lab designed to cause students to describe the effects of an abiotic factor on a member of an ecosystem. Students were supplied with either tap water, which had a pH of 7.8, or solutions of pH 2.0, 4.0, or 6.0. They then obtained about 10 brine shrimp and recorded the exact number. These were placed in a 400 ml beaker of their test solution and observed. The number of living (moving) brine shrimp was recorded 1 minute, 5 minutes, 10 minutes and 20 minutes after the brine shrimp were placed in the test solutions. Students pooled data as a class, and described the overall effects of varying acidity on the brine shrimp. The shrimp died very quickly at pH 2.0, and most died within 20 minutes at pH 4.0. Very few of the brine shrimp placed in pH 6.0 water or tap water died during the duration of the experiment.

EVALUATION

The classes which took part in the testing of this unit were all sophomore biology classes at Kewaskum High School in Kewaskum, Wisconsin. These students are primarily from middle-class families. Some of their parents are employed in farming, but most commute to manufacturing, service or professional jobs. The classes involved are fairly heterogeneous in ability, except that the 15% of the students who have had the most difficulty in science classes in the past are excluded. These individuals were selected by guidance counselors prior to the school year to be part of two smaller classes.

Two of the classes were chosen by the instructor to be the experimental group. Morning classes were chosen for this role so that their laboratory experiments could be prepared prior to the start of the school day and finished before other classes needed to use the lab. Seventeen students participated in one experimental class, while 24 students were in the other experimental class for most of the unit. Some students moved into and out of both classes. The control group, which was taught in the traditional manner, had average enrollments of 25 and 27, although students again moved into and out of the classes.

None of the four classes involved was scheduled as a "high" or "low" section. There was no significant difference between the combined experimental classes and the combined control classes on the pretests concerning ecological concepts and the effects of dams on rivers (t=.043, see Appendix B) (Lind, 1983).

Differences between pretest and posttest scores were evaluated for all students who completed both tests. Some students moved into and out of classes which resulted in a lower number of score changes than the average class sizes. Scores were evaluated for tests on the effects of dams on rivers and on basic ecological concepts. The Differences in scores for each student are presented in Appendices C and D. The test on the effects of dams on rivers was a short answer test. Appendix E contains the complete tests. Students were asked a variety of questions concerning their knowledge of river ecology and how dams would affect it. The test on populations, communities and ecosystems was a multiple choice test similar to those given in past years on these subjects. The same tests were used for pretests and posttests, although the section of the posttest on populations was given during the middle of the unit, and the rest at the end. The prestest was presented as one test and was given immediately prior to the beginning of the unit.

Students in the experimental group increased their scores on the part of the test concerning the effects of dams on rivers by 24% while the control group increased by only 0.5%. The difference in the two means was significant at the .05

level (t=9.77; see Appendix D). It was expected that the experimental group would fare better on this part of the posttest, since they were taught most of the specifics found on it, while the control group was taught very few of these details.

Increases in learning as measured by differences between pretest and posttest scores on the basic ecology part of the test concerning populations, communities and ecosystems were similar for experimental and control groups. The experimental group increased by a mean of 13.4 (19%), while the control group increased by a mean of 14.2 (20%); these were found to be not significantly different (t=0.58; see Appendix C). The experimental group therefore learned as much about basic ecological concepts as the control group did, with the added benefit of learning more about the effects of dams on rivers.

Student exit interviews were conducted approximately two months after the unit was completed. The main purpose of the interviews was to assess how student's attitudes about dams on rivers had been affected by the unit. Thirteen students from the experimental group were asked to tell whether they believed prior to the unit and after the unit if dams were in general beneficial, neutral or harmful to rivers. Each was given an opportunity to explain his or her answers. 46% of the students changed to a more negative view of dams as a result of the unit; 8% changed from an original positive feeling to a neutral one, 23% changed from a neutral feeling to a negative feeling about dams, and 15% changed from a positive feeling about dams to a negative one. 54% of the students reported no change in their feelings about dams as a result of the unit. No students changed to a more positive view of dams on rivers. Students who changed to a more negative view often gave the physical barrier provided by the dam as their main reason for the change. Some also mentioned the slowing of the water as a negative consequence of dams. The students did not become overwhelmingly anti-dam, but rather seemed to acquire a feeling for the negative effects of dams, while maintaining their knowledge of some positive aspects.

DISCUSSION AND CONCLUSIONS

Several aspects of the unit proved to be quite effective, and each of the laboratory experiences was of some value. The comparison of organisms from dammed and undammed sections of the Milwaukee River impressed students; especially the lack of organisms in the dammed section. They theorized that the low oxygen content and heavy siltation limited the diversity of organisms. This led them to conclude that the dam was negatively impacting the river ecosystem.

The analysis of chemical and physical factors was not as effective as hoped because of the previously mentioned problems, but it did impress upon the students the fact that chemical and physical factors were quite variable from place to place in the same river, limiting particular organisms in some areas.

"Where have All the Salmon Gone?" proved especially valuable in allowing students to form hypotheses and interpret data. Students were at first reluctant to make predictions based on the limited information provided in the lab but gradually became more confident and more accurate in their thinking. This activity could also be useful as a beginning of the year activity to acquaint students with the processes of scientific inquiry. Students correctly identified that dams provided a physical barrier to migrating salmon, even when fish ladders were present.

"Temperature and Operculum Rate in Goldfish" was a highly successful experience. Students correctly deduced that high temperatures would be harmful to the fish. Most said that "hot water holds less oxygen" than cool water, and realized that the goldfish needed oxygen. They also predicted the higher operculum rates at higher temperatures. However only a few made a direct association between temperature and metabolic rate in the fish. Students were extremely enthusiastic about working with the living organisms in the lab.

"The Effects of Varying Salt Concentrations on Scud and Brine Shrimp" was exciting for students as they were again using living organisms. Their confidence grew as most correctly hypothesized that the brine shrimp would withstand high salt concentrations better than the freshwater scuds. This lab, as well as the "Goldfish" lab was a valuable exercise in the cooperative pooling of scientific data. Each group of students was collecting data on only one organism at one salt concentration. They needed to obtain data from the rest of the class to see if their hypotheses were correct. Although salt concentration is not something that is affected by dams on rivers, students did observe how a change in a chemical factor can quickly kill small aquatic organisms.

"The Effects of Acid on Brine Shrimp" proved valuable as well. Students could quickly see that an abiotic factor that human activity can influence may kill small organisms. Most were impressed by their ability to correctly predict that low pH water would be detrimental to the brine shrimp. Another particularly effective activity was the role play concerning the hypothetical controversy over the fate of the Kewaskum Dam. Students captured the essence of the energy, controversy and noise that often accompanies real debates over dam removal or repair. Especially realistic was the fact that very few students changed their minds once the debate was underway, even though extensive arguments were presented during the mock town board meeting.

Several areas of this unit need to be improved before they are used again. Each of the laboratory activities needs refinements. The analysis of organisms could be improved by allowing more time for the actual identification of organisms and especially by the construction of food webs for areas of the river where a large variety of species were present. This year's organism analysis was disrupted more than expected by a school-wide sit in of students who believed a rumor that their homecoming activities were going to be cancelled. Many of my students missed part of a lab due to participation in the sit-in.

"Temperature and Operculum Rate in Goldfish" will be refined by incorporating a longer time period and by acclimating the organisms to temperatures similar to those found in a river environment before proceeding with the lab. A major extension of the lab would be to use different acclimation temperatures over a period of several days. Also, it would be advantageous to use fish species found in a normal aquatic ecosystem in the Midwest. Perhaps Creek Chubs Semotilus atromaculatus would be a more realistic test organism.

"The Effects of Varying Salt Concentrations on Scud and Brine Shrimp" will be refined by incorporating a longer observation period. Very few organisms died during the class period in which the lab was set up, but most were dead when they were checked again the next day. Periodic observations over a twenty four hour period will be needed to provide for the most meaningful data.

The chemical tests which were conducted were not as effective as hoped. Since these tests were done during October, there was little difference in temperature and dissolved oxygen levels at the two sites. Certainly summer readings would have been more informative. Perhaps data collected during the summer could be provided to the students, who could compare it to that collected in the fall.

Another area which needs major improvement is the correlation of the lab investigations to the posttest. The students did increase their knowledge of river ecology and the effects of dams on rivers, but the posttest did not show all of these increases. The posttest will be revised to tie in more directly with the labs. Students need to be directed to the connection between each lab and the effects of dams. Also, the length of the unit itself may have lowered the test scores, since the posttests concerning dams did not occur until six weeks after the unit started. Some information was probably forgotten during this time. In the future, the posttest concerning dams may be done in two parts, with one occurring approximately in the middle of the unit.

In general, this unit was a success. While many parts need to be refined, the majority of the activities are worth doing again. The general attitude of the students during the unit was encouraging. They especially liked the laboratory exercises which involved using organisms. It seems that often biological instruction today uses simulations or only chemicals important to organisms. Students need to see intact living organisms responding to their environment. As the unit progressed, students in the control group began to ask "why they did not get to do the neat stuff" that the experimental classes were doing. This indicates that good reports about the unit were circulating through the student body. Students both learned more and enjoyed biology more with the experimental unit. The refinements which will be introduced will make the unit a viable long-term part of a high school curriculum.

APPENDICES

Appendix A Outline of Activities and Objectives

DAY	EXPERIMENTAL GROUP ACTIVITES	CONTROL GROUP ACTIVITIES	OBJECTIVES
1	Pre-tests	Pre-tests	Evaluate original knowledge
2	Fish population discussion	Deer population discussion	Define population parameters
3	Lab: Salmon populations	Reindeer lab	Graph and describe population changes
4	Lab: Salmon populations	Reindeer lab	Graph and describe population changes
5	Discuss changes in the size of fish populations	Discuss changes in the size of deer populations	Describe factors influencing population size
6	Discuss relationships among factors which change population size	Graphing of human world population	Interpret data on populations
7	Lab: Temperature and operculum rate in goldfish	Interpret human population graphs	Interpret factors influencing the size of populations
8	Discuss temperature and operculum rate in goldfish	Discuss factors affecting age structure in populations	Describe factors influencing the size of populations
9	Lab: The effect of varying salt concentrations on scud and brine shrimp	Student practice: factors that influence human population size	Describe factors influencing population size
10	Discuss the effect of varying salt concentrations on scud and brine shrimp	Review of populations	Describe factors influencing population size

Appendix A (cont'd)

DAY	EXPERIMENTAL ACTIVITIES	CONTROL ACTIVITIES	OBJECTIVES
11	Population post-test	Population post-test	Evaluate knowledge
12	Gather data for reports on aquatic biology	Gather data for reports on ecology	Search for biological information
14	Discuss and demonstrate pH measurement	Lab: Temperature in micro-environments	Describe abiotic factors in ecosystems
15	Present oral reports	Present oral reports	Share biological information
16	Present oral reports	Present oral reports	Share biological information
17	Lab: The effects of acid on brine shrimp	Lab: The effects of acid on beans	Describe the effects of pH changes on organisms
18	Discuss the effects on acid on brine shrimp	Discuss human influences on ecosystems	Exp.- evaluate an abiotic factor's role in an ecosystem Cont.- describe human influences on ecosystems
19	Discuss community interactions in rivers	Discuss community interactions in forests	Describe interactions among organisms
20	Video: Acid rain	Video: Forest ecosystem	List ecosystem interactions
21	Field trip to test pH, oxygen, temperature and B.O.D. in river in village	Finish lab: the effects of acid on beans	Assess how abiotic factors influence ecosystems
22	Discuss results of field trip	Discuss abiotic factors in ecosystems	Assess how abiotic factors influence ecosystems

Appendix A (cont'd)

DAY	EXPERIMENTAL GROUP ACTIVITIES	CONTROL GROUP ACTIVITIES	OBJECTIVES
23	Testing of pH, oxygen, B.O.D. and temperature in an area of river far above dam	Discuss biocides in ecosystems	Assess how abiotic factors influence ecosystems
24	Collect and evaluate invertebrates from river in millpond	Identify trees on a forest map	Identify organisms in a community
25	Collect and evaluate invertebrates from an area of river far upstream from dam	Identify trees on a forest map	Identify organisms in a community
26	Compare organisms from two areas of river	Calculate successional stage of forest	Describe reasons for community structure
27	Gather data for role play on dam removal or repair	Discuss reasons for successional changes	Exp.- Formulate positions on dams Cont.- Describe natural changes in communities
28	Role play: Dam removal or repair	Slides: Lake Succession	Exp.- Present positions on dams Cont.- Describe natural changes in communities
29	Reading and discussion of "Flowing Free"	Review of communities and ecosystems	Review ecosystem interactions
30	Posttest on communities, ecosystems and dams	Posttest on communites, ecosystems and dams	Evaluate knowledge

Appendix B Comparison of Pretest Scores

	EXPERIMENTAL TOTAL PRETEST SCORES	CONTROL TOTAL PRETEST SCORES
	41	50
	47	32
	62	41
	43	48
	44	32
	47	43
	33	41
	37	26
	45	23
	45	31
	39	38
	34	45
	55	36
	42	41
	55	49
	42	51
	37	42
	39	48
	46	46
	38	55
	52	37
	43	20
	48	47
	51	37
	35	47
	42	64
	62	31
	48	49
	65	55
	21	45
	38	40
	46	42
	47	52
	45	36
	40	52
	49	58
	43	62
	40	45
	35	62
	59	58
		38
mean	44.0	43.8

Appendix B (cont'd)

	EXPERIMENTAL GROUP	CONTROL GROUP
mean	44.0	43.8
n	40	41
standard error	1.63	1.63

COMPARISON OF MEANS

Null Hypothesis: There is no significant difference between the means of the experimental and control groups.

standard deviation of the means	2.31
degrees of freedom	79
t; .05, 79	1.67
t observed	0.43

The null hypothesis is not rejected at the 0.05 level of significance.

Appendix C Increase in Scores on Basic Ecological Concepts Test

	EXPERIMENTAL DIFFERENCE BETWEEN PRETEST AND POSTTEST SCORES	CONTROL DIFFERERENCE BETWEEN PRETEST AND POSTTEST SCORES
	3	14
	11	17
	5	17
	9	21
	13	15
	20	17
	18	0
	14	13
	13	28
	11	17
	13	4
	8	7
	16	24
	6	23
	4	22
	14	19
	28	4
	16	10
	15	19
	15	21
	18	6
	10	6
	24	16
	22	11
	9	14
	13	13
	24	15
	3	20
	23	14
	20	14
	20	16
	5	12
	18	18
	12	18
	18	12
	9	12
	14	6
	13	15
	1	19
		13
mean	13.4	14.2

Appendix C (cont'd)

	EXPERIMENTAL GROUP	CONTROL GROUP
mean	13.4	14.2
n	39	40
standard error	1.04	0.90

COMPARISON OF MEANS

Null Hypothesis: There is no significant difference between the means of the experimental and control groups.

standard deviation of the means	1.38
degrees of freedom	77
t: .05, 77	1.66
t observed	0.43

The null hypothesis is not rejected at the 0.05 level of significance.

Appendix D Increase in Learning on Test on the Effects of Dams on Rivers

	EXPERIMENTAL DIFFERENCE BETWEEN PRETEST AND POSTTEST SCORES	CONTROL DIFFERENCE BETWEEN PRETEST AND POSTTEST SCORES
	10	1
	9	0
	1	0
	6	-3
	5	0
	5	0
	5	1
	7	-1
	2	0
	7	2
	7	1
	7	1
	2	1
	4	3
	4	-1
	6	-2
	2	0
	0	-1
	3	0
	3	2
	5	0
	5	3
	3	-2
	5	1
	4	-1
	2	0
	8	0
	9	0
	3	-1
	5	1
	2	1
	5	0
	6	0
	6	-2
	5	2
	1	0
	3	2
	3	3
	3	-3
	3	-2
		0
mean	4.8	0.5

Appendix D (cont'd)

	EXPERIMENTAL GROUP	CONTROL GROUP
mean	4.8	0.5
n	40	41
standard error	0.37	0.23

COMPARISON OF MEANS

Null Hypothesis: There is no significant difference between the means of the experimental and control groups.

standard deviation of the means	0.44
degrees of freedom	79
t; .05, 79	1.67
t observed	9.77

The null hypothesis is rejected at the 0.05 level of significance, and the means are considered to be different.

APPENDIX E LABORATORY AND TEST MATERIALS

NAME____

Temperature and Operculum Rate in Goldfish

In this investigation you will be comparing the operculum rate of goldfish to their temperature. The operculum is sometimes called the gill cover and is moved back and forth by fish in order to move water past the gills. Each group will be using a different temperature and seeing how many times per minute their goldfish move their opercula. **Write a hypothesis concerning temperature and operculum rates in goldfish.**_____________________________________

____

____

Mix hot and cold water together in your beaker as directed by your instructor. Then obtain one goldfish from your instructor and place it in the beaker. Check the time and wait five minutes. **Check and record the temperature of your water.**__________ Immediately after this count and record the operculum rates of your fish for 60 seconds and record. Make two more 60 second counts and record them also.
Operculum counts per minute: ____________, ______________,
______________ Average the three counts. _____________

Record your data on the board and make a copy of the class data on the class data sheet.

Class Data Sheet

Temperature	Average Operculum Rate

Construct a graph comparing temperature to average operculum rate and write a paragraph describing the conclusions you can derive from this lab.

NAME________________________________

The Effects of Varying Salt Concentrations on Scud and Brine Shrimp

In this investigation you will be comparing two organism's response to a variety of salt concentrations. Scud and brine shrimp will be exposed to either distilled water, a 1% salt solution, a 2% salt solution, a 4% salt solution or an 8% salt solution. Write a hypothesis concerning how well you think each organism will respond to the different salt levels.

____

____

____

____

Obtain about 300 ml of the solution assigned by your instructor. Get about 10 brine shrimp or about 5 scud as assigned by your instructor and record the exact number. Note the time and wait 10 minutes. Record the number of living organisms. Repeat this procedure after a total of 20 minutes have elapsed and again tomorrow after 24 hours have elapsed.

Name of organism ________________

Original number of organisms____

Number alive after: 10 min____ 20 min____ 24 hours ____

Convert the number of living organisms at each count to a percentage of the original number and share this information with the class. Construct a data chart for the class data and record all data. Write a conclusion describing the relationship between the organisms tested and salt concentration.

NAME____

The Effects of Acid on Brine Shrimp

In this investigation you and your classmates will determine how brine shrimp respond to various pH levels. You will determine how long brine shrimp live at a particular pH, and compare that to other pH values tested by your classmates. Some groups will use pH 2.0 water, some pH 4.0 water, some pH 6.0 water and some tap water.

Write a hypothesis concerning the response of brine shrimp to different pH levels.____________________________________

____

____

Pour about 300 ml of the solution designated by your instructor into a 500 ml beaker. Obtain about 10 brine shrimp from your instructor and record the exact number.

Note the exact time and place the brine shrimp in your beaker.

After one minute record the number of brine shrimp still living (moving). Record the number living after 5 minutes, 10 minutes and 20 minutes of time have elapsed.

Your pH level _______

Number surviving after: 1 min_____ 5 min_____ 10 min_____

20 min_____

Record your data on the board and copy the class data on a data chart of your own design. Write a conclusion concerning brine shrimp and pH levels.

Role Play -Dam Removal

Groups for Role Play:

1. Local Citizens living near park.
2. Fishermen
3. West Bend Citizens
4. Taxpayers from the village.
5. Village Board

Scenario:

You have just been informed that the Kewaskum Dam is unsafe. In the next two years it will need to be either removed or fixed. After consulting with engineering firms, it has been determined that it will cost about $125,000 to remove the dam and $210,000 to fix it. If the dam is fixed, it would need to be repaired again in about 60 years. The Village Board has asked for input from several sources to help them decide how to proceed in this matter.

Your Job (Groups 1-4)

1. Meet with your group. Use your knowledge of this issue <u>and</u> the particular viewpoint of your group to develop a list of reasons for removing the dam and for fixing the dam. Develop a one paragraph statement to be read at the next Village Board meeting.

The statement should say whether you think the dam should be removed or replaced, and provide a brief summary of the reasons for your recommendation.

2. At the appropriate time, select a person to read your

statement to the village board. Each member of the group should be prepared to answer questions from the village board.

Village Board Job.

1. Each member will develop a list of reasons for removing the dam and for fixing the dam. You may discuss these with other board members, but you do not have to reach a consensus.

2. At the village board meeting, listen carefully to the presentations of the other groups. Remember that many of these people will be voting in the next election. Ask a few questions if there are parts of the presentations that you do not understand. After the presentations, vote for removing the dam or repairing it.

Teacher Notes: **Follow up with "Flowing Free". Also, discuss how participants felt about the process of decision-making.**

POPULATIONS AND ECOSYSTEMS TEST

1. Individuals are difficult to distinguish in a population of A. grass B. people C. sheep D: bacteria

2. Which best defines a population? The number of: A. biology students in high school B. organisms in a defined area C. types of organisms in a defined area D. zebras in East Africa in 1982

3. The number of individuals of one kind that live in the same area at the same time is defined as a: A. community B. sample C. rate of increase D. population

4. Which of the following groups of organisms could make up a population? A. birds B. dogs C. mammals D. reptiles

5. Populations are made up of: A. communities B. ecosystems C. individuals D. biomes

6. The rate at which reproduction increases a population's size is called: A. density B. mortality C. motility D. natality

7. You would expect to find that emigration and immigration rates are zero for a population of: A. aphids on plants B. birds in a forest C. fish in a pond D. mice in a field

8. The population changes that tend to decrease a population's size are: A. emigration and mortality B. emigration and natality C. immigration and mortality D. immigration and natality

9. The rate of increase in the size of the world's human population can be calculated from the difference in A. emigration over natality B. immigration over mortality C. natality over immigration D.natality over mortality

10. The population changes that tend to increase a population's size are: A. emigration and mortality B. emigration and natality C. immigration and mortality D. immigration and natality

11. A population tends to increase in numbers as a result of: A. increasing food supply B. decreasing habitat C. increasing competition D. increasing predation

For questions 12 through 15 use the following terms as responses. Any term may be used more than once or not all.

KEY A. emigration
B. immigration
C. mortality
D. natality

12.____The number of organisms dying in a population within a given time is called:

13.____The number of organisms moving out of an area where that population lives is called:

14.____Fifteen fawns are born in a deer population in Florida. This is an example of:

15.____The rate of reproduction in a population is:

16. Doors that swing outward but not inward enabled mice to leave a population but not to enter it. An increase in population numbers followed as the result of an increased: A. emigration B. immigration C. mortality D. natality

17. The rate of change in a population's size is expressed in terms of: A. density of population and space occupied B. numbers of individuals and space occupied C. numbers of individuals and time D. space occupied and time

18. Why does the human population have such a large impact on the earth's plants and animals? A. all of the following B. Our poplation is large and increasing C. We use high amounts of resources D. We return resources as unusable waste

19. Why is the human population on earth increasing? A. Human mortality exceeds natality B. Human natality exceeds mortality C. The earth's resources are increasing D. It is not increasing

20. Today humans trade food for space. More land is taken out of agriculture and given to new streets, shopping centers, homes and industries. This leaves less agricultural land to feed increasing numbers of people. Assuming that this cannot go on indefinitely, the world's greatest problem is becoming: A. depletion of energy resources B. overpopulation C. pollution D. safe waste disposal

21. Which of the following factors is not a contributor to changes in the world human population? A. emigration B. natality C. competition D. mortality

22. Which domestic use of water is largest? A. bathing or showering B. brushing your teeth C. cooking a meal D. flushing the toilet

23. How can you reduce your direct use of water? A. all of the following B. take shorter showers C. wash clothes only when you have a full load D. do not let the water run when brushing your teeth

24. The production of which food item requires the greatest amount of water? A. one egg B. one kg of beef C. one kg of sugar D. one orange

25. Which of the following is part of the biotic environment? A. air B. sunlight C. vegetation D. weather

26. How does weather affect plants and animals? It: A. affects only special organisms B. often is a limiting factor C. seldom is a limiting factor D. does not affect them

27. Which affects the space an organism needs? A. all of the following B. availability of nutrients C. population density D. size of the organism

28. "Eleven grasshoppers per square meter in Douglas County, Nebraska, this year" is an expression of: A. density B. natality C. population explosion D. rate of increase

29. In the equation D=N/S, which expresses population density, the N stands for A. natality B. number of individuals C. rate of change D. time

30. Students captured nine, four and seven beetles of the same kind in three different 1 square meter plots of forest floor. Their calculation of the population of these beetles will be based on: A. carrying capacity B. homeostasis C. relative density D. sampling

31. A community is defined for a given place and time as a set of interacting: A. consumers B. ecosystems C. populations D. producers

32. The biotic component of an ecosystem is: A. climate B. a community C. temperature D. water

33. Which of the following pairs is an ecosystem? A. a biotic environment and a community B. a community and its abiotic environment C. a niche and a community D. a population and a community

34. An abiotic environment and all the kinds of organisms that live in it make up that area's: A. biome B. community C. ecosystem D. population

35. The difference between an ecosystem and its community of organisms is the: A. decomposers of the ecosystem B. food web of the ecosystem C. physical environment of the ecosystem D. producers of the ecosystem

36. In biological terms a human community could more accurately be described by the term: A. ecosystem B. habitat C. niche D. population

37. All the organisms living in and on a decaying log can best be described as a: A. community B. habitat C. niche D. population

38. Which of these is a community relationship? A. River turtles and snails eat tape grass. B. Snails are concealed among rocks in a river. C. Tape grass clogs the water current in a river. D. Turtle eggs are buried on the river bank.

39. What is the relationship between ecosystems? A. Their abiotic factors are distinct, but their biotic factors are interconnected. B. Their biotic factors are distinct but their abiotic factors are interconnected. C. Their boundaries are distinct. D. They are interconnected to form the biosphere.

The next seven items are based on the following feeding relationships in an ecosystem. Insects eat grasses and clover. Mice eat grass seeds and certain insects. Snakes eat insects, mice and rabbits. Rabbits eat grasses and clover. Hawks eat snakes, rabbits and mice. Wastes from mice, rabbits, insects and smakes are used by bacteria and fungi.

40. Which organisms are producers? A. all of the following B. bacteria and mushrooms C. grasses D. mice, rabbits and deer

41. What does this paragraph best represent? A. a food chain B. a food web C. a pyramid of numbers D. a pyramid of mass

42. Which organisms can be considered consumers? A. all of the following B. bacteria and fungi C. grasses and clover D. insects, mice and rabbits

43. Which organisms are decomposers? A. all of the following B. bacteria and mushrooms C. grasses D. mice, rabbits and deer

44. Which organisms convert light energy to chemical energy via photosynthesis? A. all of the following B. bacteria and fungi C. grasses and clover D. insects, mice and rabbits

45. Which organisms get energy by breaking down the bodies of dead organisms? A. all of the following B. bacteria and fungi C. grasses and clover D. insects, mice and rabbits

46. Which organisms lose heat energy in respiration? A. all of the following B. bacteria and fungi C. grasses and clover D. insects, mice and rabbits

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47. Inorganic compounds are converted to organic compounds by: A. carnivores B. herbivores C. omnivores D. producers

48. Which of the following organisms is a carnivore? A. cat B. cow C. sheep D. rabbit

49. A herbivor eats: A. carnivores B. decomposers C. omnivores D. producers

50. A herbivore is also called a: A. decomposer B. first order consumer C. green plant D. second order consumer

Use the follwing interactions between organisms as responses for the next four items. Match the interactions with the terms.

Response	Organism I	Organism II
A	harmed	helped
B	helped	helped
C	helped	unaffected
D	harmed	unaffected

51. Predation

52. Parasitism

53. Commensalism

54. Mutualism

For the next five items, match a letter from the key to each term.

KEY: A. commensalism
B. mutualism
C. parasitism
D. predation

55. a cow and the cellulose-digesting microorganisms in its stomach

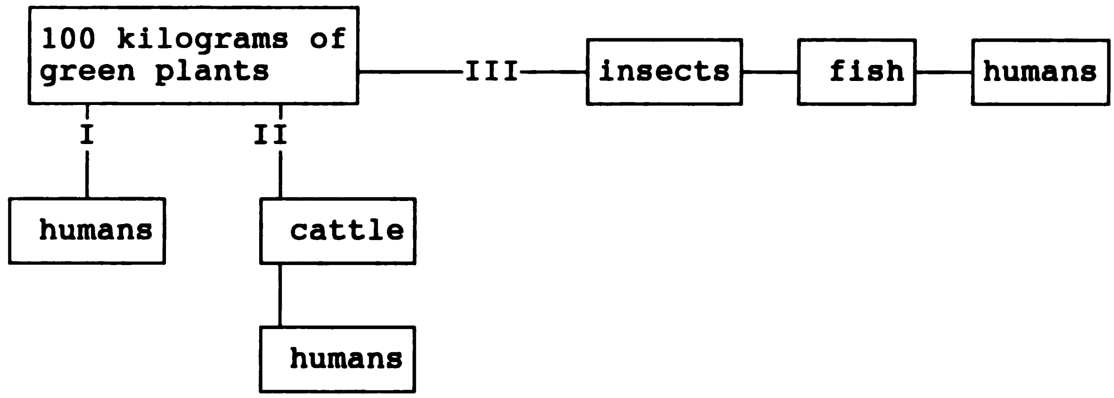
56. an owl and a mouse

57. a bluebird nesting in an abandoned woodpecker hole

58. fleas on a dog

59. fungus on a plant

The next four items refer to the following diagram. The lines indicate three possible pathways the energy produced by the green plants could take.



60. Through which pathway would the most energy be available to humans? A. I B. II C. II or III D. III

61. Through which pathway would the least energy be available to humans? A. I B I or II C. II D. III

62. In which pathway does the most energy escape as heat? A. I B. I or II C. II D. III

63. Which pathway will be favored more if the world human population doubles in size? A. I B. II C. II or III D. III

---

64. The stability of a community generally increases with A. greater diversity of organisms and more links in the food web B. greater number of organisms and fewer links in the food web C. lower diversity of organisms and fewer links in the food web D. smaller number of organisms and more links in the food web

65. Which best describes the relationship between the number of different kinds of organisms in an ecosystem and the ecosystem's stability? A. There is no relationship. B. The larger the number the greater the stability. C. The smaller the number the greater the stablility. D. Too small or toolarge a numbers lowers the stability.

66. How has our use of the insecticide DDT affected ecosystems? DDT has: A. accumulated in predators, killing them and resulting in ecosystem instability B. accumulated in predators, killing them and resulting in ecosystem stability C. Killed insects, resulting in a more complex and stable ecosystem D. Killed insects, resulting in a simpler and more stable ecosystem

67. Which is a biocide? A. all of the following B. fungicides C. herbicides D. insecticides

68. Which is not involved in the concentration of DDT in a food chain? A. DDT is not easily broken down by consumers. B. DDT is not stored in consumers C. Producer bodies are broken down and used by consumers D. A consumer eats many producers

69. As the human population has grown, the effect of changes made by people in the ecosystems surrounding them has been to: A. add to the number of species B. improve the climate C. leave the maximum number of ecosystems undisturbed D. simplify the ecosystems

70. Which explains how human activity can create biocide-resistant organisms? A. all of the following B. Biocide resistance is inherited from generation to generation. C. Most of the pests are killed by the pesticide. D. Surviving pests produce large numbers of offspring.

71. Human intervention in ecosystems usually has the result of: A. decreasing the number of species B. increasing the productivity for most consumers C. increasing the stability of the ecosystem D. modifying the ecological niches for decomposers

72. Two kinds of predators that compete for food and habitats in their ecosystem are probably in the same: A. ecological niche B. food chain C. population D. species

TEST: RIVER ECOLOGY **NAME**_______________________________

1. What do fish eat in the Milwaukee River?

2. Explain why oxygen is important to animals living in a river.

3. How does silt get into a river, and what problems does it cause?

4. Why is the temperature of a river important?

5. What changes do you think would occur in the Milwaukee River if the Kewaskum dam was removed?

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