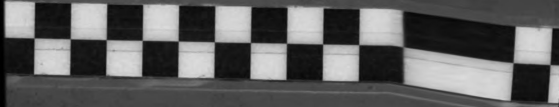


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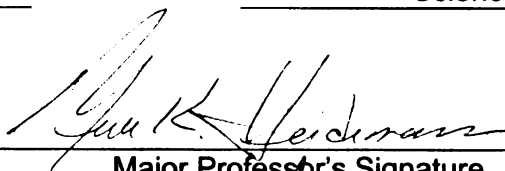
ECOLOGICAL INTERACTION OF ABIOTIC AND BIOTIC
FACTORS IN THE ENVIRONMENT THAT ELICITS
COMMUNITY CHANGE OVER TIME (EVIDENCED IN THE
PRIMARY SUCCESSION OF A SOUTHWESTERN
MICHIGAN SAND DUNE)

presented by

Mark William Woolcock

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ENVIRONMENT THAT ELICITS COMMUNITY CHANGE OVER TIME
(EVIDENCED IN THE PRIMARY SUCCESSION OF A SOUTHWESTERN
MICHIGAN SAND DUNE)**

By

Mark William Woolcock

A THESIS

**Submitted to
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ABSTRACT

ECOLOGICAL INTERACTION OF ABIOTIC AND BIOTIC FACTORS IN THE ENVIRONMENT THAT ELICITS COMMUNITY CHANGE OVER TIME (EVIDENCED IN THE PRIMARY SUCCESSION OF A SOUTHWESTERN MICHIGAN SAND DUNE)

By

Mark William Woolcock

Sophomore general biology students at South Haven High School were taught ecological concepts and their practical application to the Southwestern Michigan sand dunes. The dunes, in close proximity to the school, were intended to evoke an affective response from students while learning ecological concepts. Two classes, consisting of 19 and 18 students respectively, were taught basic ecological concepts, geology of the Great Lakes region, soil ecology, dune flora, abiotic/biotic factors, and primary succession for nine weeks. They were exposed to direct, inductive, and cooperative learning strategies and completed labs, homework assignments, quizzes, tests (pre-, post-), and a culminating activity -- a field trip to a Southwestern Michigan sand dune. Hypothetically, high school students will retain more knowledge during an ecology unit when exposed to "hands-on" labs and interactive learning. A pretest and two posttests containing ten overarching short answer essay questions measured the students' learning. A paired t-test of the students' test scores indicated a significant difference from pre- to posttest results. The goal of teaching the basic ecological concepts in relation to the sand dunes was apparently successful. Future revisions will be made to foster continued success.

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INTRODUCTION

Statement of Problem and Rationale for the Study

The primary goal of my unit was to improve the learning of ecology by focusing on the students' interests, life experiences, and prior knowledge. The unit was expected to affectively drive students by associating ecological concepts to a part of their community's natural heritage – the Lake Michigan sand dunes. Learning can be engaging and enjoyable for students when they utilize the “real world” application of concepts. This unit's design served to increase the use of “hands-on” activities while applying key ecological concepts to the dune's flora, coastline geological formations, and primary succession. My intention was to challenge students in my two core sophomore general biology classes with relevant, affectively driven lectures, assignments, weekly quizzes, and pre- and posttest questions.

I wanted to evoke ideas and knowledge that benefit our existence and interdependence within nature for future generations. The modified ecology unit attempted to engage the students' prior scientific knowledge while facilitating the “transfer” of new knowledge. Their affective response could serve to improve Earth's environmental future. This has allowed me to remain “generative” -- teaching and learning the subject matter I love, and attempting to enhance humanity through the practice of unconditional positive regard.

I believe as educators, “we teach who we are.” I have attempted this self-efficacy while planning, constructing, and implementing this ecology unit. Being raised on a small family farm in rural Ingham County, the youngest of four boys,

and the son of two educators, I was always interested in nature and education. As a child and young adult, my love of nature was fostered and modeled by caring for livestock, maintaining and harvesting crops, and perusing the “back 40” acres filled with intriguing flora and fauna. Throughout my career as a student in high school and college I’ve been fortunate to have outstanding, influential science instructors. Their demeanor, rapport with students, and enthusiasm about biology and wildlife continued to influence my already stimulated interest in nature. My career in education and past job experiences, within the Michigan Department of Natural Resources and National Park Service at Sleeping Bear Dunes National Lakeshore (Biological Technician), have provoked an interest in the pursuit of further scientific knowledge. My past experiences and current job opportunities have also created a link between nature - the dunes - and my teaching career. The basic tenet of my educational career remains true in the ecology unit I’ve developed: my ability to positively influence and affect the lives of students by sharing myself through the subject matter I’ve grown to love – biology and ultimately ecology of the dunes.

The pedagogical techniques employed in previous years during the ecology unit stymied reflective learning by the students. Lecture and direct learning strategies were implemented using the textbook only. Students used their short-term memories while applying the ecological concepts to assignments or assessments. Instead, students need to incorporate the ideas into the conceptual framework of their long-term memory using prior knowledge and meaningful relationships. Students need to “learn by doing” and from

experiences instead of by reading or hearing about certain scientific discoveries. The essence of science is developing knowledge based on empirical evidence provided through relentless research, testing, experimentation, and logical analysis (thinking). Developing a sense of the extraordinary complexity of past scientific endeavors was targeted during the unit revision. Students needed a realistic understanding of science, how it works – community of research sharing, and its relationship to their needs and life. Learning the scientific method and its implications on the pursuit of ecological knowledge for today and tomorrow is essential for students. Current knowledge regarding ecological research and methods will help convey the constructivist nature of science for the benefit of tomorrow's world.

During my previous four years of teaching general biology, the ecology unit was condensed into the last two to three weeks at the end of the year. Using the textbook, "Modern Biology" by Holt, Rinehart and Winston (Towle 358-413), I taught introductory ecological concepts and issues, the ecology of organisms, populations, and communities. Teaching often consisted of lectures, notes, and assignments to review the concepts. Very little time was spent on each topic and the culminating activity usually consisted of answering study guide or review questions related to the concepts. If time permitted, I was able to provide an overview of ecosystems, the biosphere, and environmental science, but these were generally omitted due to time constraints.

The two other biology teachers and I often incorporated a study of the major human organ systems into the end of the year, followed by the dissection

of a fetal pig or rat. This often caused the ecology unit to be expedited, and the focus resulted in, “a breadth of knowledge instead of a depth of knowledge” regarding ecology. Even though it engaged students, the concepts covered during the human biology unit were not a significant component of the Michigan Curriculum Framework of Science Benchmarks. This unit has since been removed from our curriculum and was not taught during the 2004-05 school year.

The revised ecology unit, implemented in the fall, was intended to increase both the teacher’s and students’ motivation for teaching and learning, respectively. Progressive, innovative teaching strategies were needed for this unit to encourage “in-depth” classroom learning. Lecture and the assignment of worksheets or book questions can become monotonous, and rote knowledge from this pedagogical practice becomes uninspiring. The development of more interactive laboratories and activities incorporating the unique “intelligences” of all students was necessary. Students of high to average to low motivation, and special education students, were considered and acknowledged while constructing the unit. The lab activities increased “hands-on” learning and forced cooperative learning situations amongst students of differing backgrounds and experiences. They needed to develop and use social skills while incorporating cognitive functions into the discovery of new knowledge. Films, PowerPoint/overhead lectures and the demonstration of labs were implemented to engage the visual learners. Numerous reading and writing opportunities and assignments were incorporated throughout the unit for the literal or compositional types of thinking and learning. Cooperative learners benefited from labs and

group activities (Gardner, 1983). The development and implementation of these strategies can foster renewed excitement for the teacher as well. Researching, developing, and utilizing progressive teaching methods in the classroom ignites an optimistic spirit within the teacher. This renewed spirit can be transferred to students and can facilitate learning.

Contemporary biological science research and discovery seems focused on the microscopic structures -- like cells, tissues and biochemical reactions -- and their functions within organisms (e.g. human genome project, proteomics, etc.). The analysis of such complex relationships warrants abstract thought and often broad scientific knowledge of chemical, physical, and biological concepts. Nature, on the other hand, ultimately conveyed as a display of relationships between organisms and their non-living environments, becomes evident to us during childhood. I believe this innate connection between humans and nature initially starts before birth and develops throughout life as we experience and relate to the environment around us. Students in my biology classroom come to class with this background knowledge. I believe younger students, such as my high school students, can become more interested in science if prior experiences and knowledge of nature is conveyed and taught before investigations of microscopic cells, organisms, and biochemical processes. The "big picture" investigation of nature and organisms will link the underlying, lifetime experiences of students to biology, and hopefully lure students into a further pursuit of knowledge regarding cells and microbiology. Students need to see a

connection of their life to the subject or will become uninterested and “turn-off” to learning.

The beginning of the unit was delayed by almost a month for two unforeseen circumstances. I was hired in the fall as the Junior Varsity Boys' Golf coach. This job required hours of commitment outside of the classroom, negating my ability to focus solely on the implementation of the unit. Students also needed a basic understanding of the scientific method and classification before studying dune plants and ecology. The scientific method was taught to explain the process scientists take to discover ideas/concepts in science. It provided a foundation for understanding the layout and design of labs/activities that were incorporated into the ecology unit and other units throughout the year. The study of classification delayed the onset of the unit while providing students with a glimpse of organisms' similarities and differences that lead to their categorization. The knowledge of scientific names and the evolution of organisms over time was crucial to the study of dune plants, and the ecological relationships of other organisms to their environment.

School started on Tuesday, September 7th, 2004 and the unit began approximately four weeks later, on Thursday, September 30th, 2004. The unit lasted approximately three months or until Friday, December 17th, 2004, the last day of school before winter break. Several distractions delayed the unit's implementation over this time period, including a two-day orientation of our county's vocational technologies building and programs, homecoming week, assemblies, a professional development day, and several sick days due to a

personal illness. The nine-week unit forced time constraints on units for the remainder of the year, covering cells, heredity, the organization of living things, and evolution. Only one of the three planned culminating activities was implemented, but not until the beginning of June. The onset of winter and cold temperatures delayed this lab/activity, a dune visit, until Friday, June 3rd, 2005. Ecology unit Chapters 19-21 in the "Modern Biology" textbook by Holt, Rinehart, and Winston (Towle 358-413) were utilized throughout the unit as an introduction to the topics and as a resource pertaining to concepts of: ecology of organisms, populations, communities, and succession. The third section of Chapter 20 was omitted because a study of the human population was not a part of the Michigan Curriculum Framework of Science Benchmarks. Ecosystem and biosphere concepts were covered briefly after winter break in January, but were not a part of the unit.

Students applied the instruction of background knowledge regarding several ecological concepts while analyzing aspects of the sand dune community. These concepts included: the ecology of organisms (biotic/abiotic factors and niche concepts), geology of the Lake Michigan region, population ecology (properties, dynamics, growth, regulation), and community ecology (predation, parasitism, competition, mutualism, commensalism, species diversity and richness, succession). The main focus was to relate the relevant concepts to dune plant (biotic factor) and soil (abiotic factor) relationships in a sand dune ultimately eliciting primary succession. Four labs, designed to construct student understanding regarding this relationship, included the identification of soil

composition in differing habitats, the study of abiotic factors of soil, how these factors affect the growth of three different plant species, and identifying limiting nutrients of three different plant species. Twenty-four of the most common dune plants were taught while studying population concepts. One dune plant, Sea Rocket, was incorporated into two of the above labs. Population and community concepts background information was applied to the dunes while completing four other labs – intraspecific competition, interspecific competition, biotic/abiotic factors of an old field, and biotic/abiotic factors of a Lake Michigan sand dune. The last lab, on the dunes, was designed as a culminating activity for students to apply and review all unit concepts. Reading/writing assignments, films, notes, quizzes, and tests were used to reinforce and assess the cognitive concepts introduced by the book and applied within the modified labs.

Overall, students were expected to grasp the objectives and key concepts of the ecosystems benchmarks in the Michigan Curriculum Framework of Science Benchmarks (2000), listed in the implementation section of this paper. The unit was designed to introduce students to the field of ecology, and the classical experiments used in studying biotic/abiotic factors of a natural community – the sand dunes. I planned to improve students' motivation for learning by engaging their prior knowledge, and utilizing "hands-on," student-driven, cooperative, and analytical pedagogical teaching strategies.

Literature Review

“Concern for the environment predates any formal attempts to study natural relationships” (Vandervoort, 1999). This quote summarizes my motivation for teaching biology and for implementing an ecology unit aimed to summon an affective, emotional, and positive response to an adjacent natural community – the sand dunes. The sand dunes of Southwestern Michigan lie at the doorstep of many of my students’ homes. Ecological conceptual knowledge can be facilitated and fostered in my high school classroom using the meaningful, “real” examples of their natural occurrence in the immediate environment. Students’ interests, prior knowledge, and life experiences were a focal point upon developing, planning, and implementing the ecology unit. Prior years’ archaic pedagogical teaching strategies impeded critical analytical, applicatory thinking skills and promoted the rote memorization of knowledge. The key concentration of the unit’s modification was to increase “hands-on,” student-driven learning of ecological key concepts utilizing the sand dunes. The roots of ecology, a century old scientific discipline, lie in the analytical experimentation and research of the environment. “Ecology and its contemporary spin-offs, environmental awareness and action, pervade human thinking” (Vandervoort, 1999).

Henry Chandler Cowles (1869-1939), former botany professor at the University of Chicago, has sometimes been referred to as the “first professional ecologist” (Vandervoort, 1999). He was the first noted ecologist to study and research ecological succession in the Lake Michigan sand dunes east of Chicago. The dunes, formed after glaciers receded northward about 10,000

years ago, have developed over time from wind and wave action turning glacial till and bedrock into sand particles. These particles pile up on the lakeshore's southeastern and eastern coastlines (Vandervoort, 1999). The dunes migrate and pile up inland when longshore water currents, and prevailing southwest winds cause sand to move by "saltation." The dunes usually form on a "stage" or an area lacking glacial moraines adjacent to the lakeshore. Cowles is acknowledged for bringing "before the minds of ecologists the reality and universality of the concept of the process (of succession)" especially from his work on the dunes (Vandervoort, 1999). The "dunes, streams, ponds, marshes, and forests" around Lake Michigan gave him a chance to research succession. He was noted for researching the "responses of plant groups to local environmental factors." He also emphasized the processes involved in change over time (Vandervoort, 1999). These concepts of succession, change over time, and plant responses to their surrounding abiotic/biotic environmental factors were central scientific doctrines in my unit utilizing the dunes. The dune community provided a rare and unique glimpse into these natural processes of succession. Danish geographer Eugenius Warming explained, during his study of the biological and physical changes in the North Sea dunes, "virtually no species of plant or animal lives without the help of other species, and that reciprocal relationships often join unrelated species which occupy the same area" (Vandervoort, 1999). Ecological conceptual knowledge, like that explained in this quote are, "too often relegated to the back of the book." Students need to develop enthusiasm for ecology before studying cellular processes and

microbiology. James Watson, co-discoverer of the structure of DNA, explained the personal significance of dune ecology while studying as an undergraduate student at the University of Chicago. He wrote of his experience, "Ecology was the prime motivating force for my becoming a biologist" (Vandervoort, 1999).

Jerry Vaske, a professor in the Department of Natural Resource Recreation and Tourism at Colorado State University and Katherine Kobrin, a research assistant in the same department, have suggested through research that, "an attachment to a local resource can influence environmentally responsible behavior in an individuals life." They also found that, "environmental education programs in local settings may help individuals realize that their actions can make a positive difference in their own community." Attachment means that a person had an emotional or affective bond with a place in the environment (Vaske and Kobrin, 2001). The bond between my students and the sand dunes was hypothetically presumed to link their affective and cognitive realms of knowledge. This link could help to increase their learning of ecological key concepts, and develop them into environmentally responsible citizens and community members. As a high school biology teacher, my main responsibilities include teaching students the subject matter, and providing opportunities that positively influence their social development into contributing adults within society. This warrants a biology curriculum that is, "centered on human beings and the realities of life and living" (Hurd, 2001).

Typically, citizens have only had one biology class in their lives. They will not likely retain knowledge from the memorization and regurgitation of abstract

concepts such as - the Calvin cycle, how much ATP is produced in the electron transport chain, the Krebs cycle, or sodium-potassium pumps. The focus instead should be on a more practical approach to biology. This would mean “teaching the basic ecological foundations and critical thinking skills they will need to make ethical and sound decisions concerning the environment” in the future (Bishop, 2002). Teaching students to become environmentally conscious, responsible citizens using ecology can benefit their and future generations in society.

Students that study both the “concept and action perspectives of ecology” will no doubt contribute to tomorrow’s communities and society (McComas, 2003). While describing the rationale for ecology’s inclusion into future science curriculum, William McComas of the Rossier School of Education at the University of Southern California stated:

“This realm of study encompasses a variety of interesting laboratory techniques, encourages students to work both in the field and with living organisms in the laboratory, permits discussion of fascinating interspecies relationships and the exploration of energy flow in nature, and provides the practical and intellectual tools so that students might effectively gauge the impact of humans on the environment and suggest solutions to problems.Even the most basic study of ecology has the potential to affect students’ understanding of the interaction of science and society” (McComas, 2002).

Some educators have researched pedagogical strategies that effectively teach ecology in today’s classrooms. Thomas Lord, professor of biology at Indiana University of Pennsylvania, has discovered pedagogical techniques that produce a “sense of enlightenment...in a science course taken by students whose specialties lie outside the science disciplines” (Lord, 1999). He implemented teacher versus student-centered pedagogical paradigms within

several classrooms. Students in the teacher-centered classrooms were taught using lecture, rote memorization, and reiteration. They rarely answered test questions correct requiring the interpretation, analysis, or critical thinking of concepts. True understanding of the material was usually short-term in this traditional instructor-centered classroom. Cognitive psychologists have noted "lasting knowledge occurs when the learner attempts to make sense of the new information by applying it to his or her already perceived notions about the topic. Once the new information is properly assimilated in the learner's established knowledge, true understanding takes place" (Lord, 1999). The students within student-centered classrooms were taught using constructivist strategies and showed more knowledge retention and understanding. They developed deeper, lasting connections with the topics utilizing critical thinking activities and analyzing reflective learning scenarios in student-centered, cooperative groups. The teacher only gave enough short presentations of the information for students to complete the activities. Overall, the "constructivist group found the course more informative and enjoyable than students in the control group" (Lord, 1999). My intention in the ecology unit was to enlighten and engage students within a student-centered, cooperative learning setting using numerous labs/activities. Students were taught the basic ecological concepts, utilizing readings and short lectures, before completing analytical and applicatory lab activities in cooperative groups. These group settings can help me guide and facilitate the learning of ecological concepts at a deeper level (Pratt, 2003). Students' "already perceived notions" (Lord, 1999) of the sand dunes were also expected to facilitate the

attainment of new knowledge regarding ecology. Overall, these newly implemented pedagogical strategies were expected to increase the overall retention of lasting, meaningful knowledge.

Two other biological educators have researched pedagogical dichotomies to more fully understand effective strategies in teaching ecology. The first study focused on four dimensions believed to cause difficulties in learning ecology, including: the macro level, the micro level, space, and time. The four dimensions were analyzed as students studied food chains in ecosystems. Two of the ninth grade classrooms were in a traditional setting (control group), and the other two classes (experimental group) were exposed to, “a specifically designed learning context for ecology study” involving mainly the processes of active involvement and inquiry (Eilam, 2002). The control group was given three ecology and physics lessons per week, and completed teacher-designed labs that covered single topics with expected results. The experimental group attended only one ecology, and two physics lessons per week, but completed an experimental inquiry project to model ecosystem functioning. They also participated in constructivist discussions, with the teacher and fellow students, regarding the ecology issues spawned from their work. The final analysis of data suggested, “that the active physical and mental involvement of the experimental group’s students in the inquiry of their ecosystems brought about an improvement in their ability to understand the systems’ complex relations and processes, which exceeded their peers’ gains based solely on traditional learning” (Eilam, 2002).

The second study tested 37 ninth graders that had developed misconceptions about the ecological role (niche) of an organism in everyday life. The experimental design aimed to discover whether two texts could “induce accommodation” in students. Accommodation is a change that occurs when “the student’s current concepts are inadequate to allow him to grasp new phenomenon successfully. Then the student must replace or reorganize his central concepts” (Palmer, 2002). One text “refuted the misconception” and the other “consisted of a didactic explanation of ecological role.” It was shown through post assessments that both texts induced accommodation in students. This prompted researcher David Palmer to assume, “...in a balanced combination with other teaching strategies, textual material still has a role to play in the learning of science” (Palmer, 2002). My students were expected to read portions of the textbook throughout the unit’s implementation. The PQ3R reading strategy was used for previewing, questioning, reading, reciting, and reviewing each section of the text.

Many active science teachers have implemented other unique “hands-on”, cooperative learning, student-centered teaching strategies. All were designed to deepen the understanding of ecological knowledge. These strategies “have been shown to enhance academic achievement, higher order thinking skills, positive attitudes toward the subject matter, and student retention” (Mulnix and Penhale, 1997). Amy Mulnix and Sara Penhale, of Earlham College in Richmond, Indiana implemented a collaborative research project designed to use primary research literature and peer communication. This activity was intended

to teach the activities of research scientists by emulating a team design approach often used in the contemporary research setting. The students “used the most recent literature to investigate the cellular/molecular aspects of a disease.” They then summarized their findings on a poster to be presented during a “scientific mini-symposium” in class (Mulnix and Penhale, 1997). This type of culminating activity was planned for my dune ecology unit. It would require literature research and the presentation of ecological data regarding a previously learned dune plant.

Jack Tessier, of Central Connecticut State University, has applied an ecological problem-based learning activity into his classroom. In the assignment, student groups acted as an environmental consulting firm to assess ecological field research in a local natural setting. The teams were given a fictitious scenario that, “the town wanted to sell a portion of a nearby, forested park for development” (Tessier, 2004). Teams had to assess the consequences that urban sprawl and ecosystem fragmentation would place on the land. They planned and designed a problem-based strategy involving ecological principles and field research techniques to provide suggestions for land development. They needed to discover which portion could be sold with minimal negative ecological repercussions. Data, results, and conclusions of their findings were produced in a written report and presented at a fictitious “town meeting” (Tessier, 2004). Similar problem-based ecological scenarios could be given to my students regarding development in the sand dunes.

Students applied problem-based learning in James Singletary's Bunnell High School Science classroom in Stratford, Connecticut. His tenth grade biology class studied the coastal ecology of Long Island Sound. Students were assigned to groups in which they worked on solving the following hypothetical problem:

"Stratford's town government has information on local tourist spots, but no current information on Stratford's coastal biology. The town government is trying to attract marine researchers to study the coast and compile information on it, and they would like to advertise the information in local publications. The town would also like to display an aquarium representative of Stratford's marine ecosystem for newcomers to enjoy" (Singletary, 2000).

The students were expected to pinpoint the problem, brainstorm solutions, and develop a plan for gathering research information to complete the task. Some teacher direction was necessary for certain "how to" student inquiries like using dichotomous keys or doing library research. Generally, though, the students completed the task within their groups. Students collected organisms and measured biotic/abiotic factors along the coastline to develop fish tanks symbolizing the aquarium. They were evaluated on weekly quizzes, the unit test, and by answering 3 questions in a daily logbook. They were also expected to develop a group report whereby each student was held responsible for their work (Singletary, 2000). This problem-based learning activity is a good pedagogical strategy for my dune ecology unit. Similar scenarios regarding fictitious town government issues could be used, and students could apply their knowledge of the dune and abiotic/biotic factors toward solving the problem. Materials could possibly be supplied to produce dune models or even aquariums.

Georgia Lind and colleagues at Kingsborough Community College in New York City use a “hands-on” activity called “TRASH Ecology” to teach ecological concepts. It was designed for the enrichment or possibly reteaching of scientific knowledge for mostly African American, Hispanic, or underprivileged students in the summer. The activity involves measuring density, frequency, and biomass of trash items by using transects and quadrats. It occurs in a local vacant lot, park, or beach where an abundance and diversity of trash items are found. Students use, “a random sampling technique for estimating species numbers using transects and quadrats” (Lind, 2004). Instead of estimating species they estimate numbers of different and similar trash particles. Objects like pop cans, bottles, candy wrappers, and cigarette butts each symbolize a species. After gathering the data, students can determine the density, frequency, and biomass of each trash item (species) (Lind, 2004). This activity not only teaches ecological concepts, but also inspires and enriches students' lives through community service. It may also help develop environmentally conscious citizenry. This activity could precede the *“Biotic/Abiotic Factors of a Lake Michigan Sand Dune”* (Appendix C8) lab in my unit. Students can learn about transects, sampling techniques, and other field research methods before applying them in the dune lab. A local field, community park, local school property (e.g. sports fields/bleachers), or the beach could be a target for its implementation in my class.

High school students experience another local good deed when they develop science learning activities to teach elementary students. Anna Gahl

Cole, a life science teacher at Jemez Valley High School in Jemez Pueblo, New Mexico achieved this with her high school environmental science students. Her students researched and developed inquiry-based outdoor ecology activities from their classroom content and objectives to teach younger elementary students. The concepts were taught using a game or activities incorporated within a nearby field, stream, pond, or woods. The high school students prepared and distributed vocabulary lists and personalized notebooks for the elementary students prior to the activity. This was a very successful, positive experience for both groups of students. They were both filled with enthusiasm and cooperative spirit (Gahl Cole, 2004). Ecology unit revisions could be made for this activity to become a reality for my future classes.

Ecology vocabulary can be complex and intimidating for the average biology student. Some students will not learn words by simply writing the definitions and using the words in assignments and labs. Therefore, teachers like Thomas Lauer (2003), an associate professor of biology at Ball State University, have developed, "games and simulations to help students learn terms." This method of vocabulary transfer can replace or coincide the monotonous, traditional methods for learning vocabulary. During these games, Lauer teaches concepts like "physiological ecology, population ecology, and ecosystem ecology." The games often involve small group involvement, and occur in "three-phase learning cycles." The "Explorative Phase" involves an activity in which students explore the concept, usually by following instructions on an index card. The instructions tell students of the tasks they are to complete.

For example, two students are instructed to go outside in the winter. One student is instructed to keep their coat on, but the other is told to remove their coat. The student without a coat records the temperature with a thermometer for 5 minutes, while the other student makes observations. The "Term Introduction Phase" requires the organization and analysis of data leading to the vocabulary terms introduction. Proceeding with the aforementioned example, the students come inside after 5 minutes and the outside temperature is recorded. The student with a coat explains the physiological reactions of the student without a coat. The teacher then explains the adaptations that have helped the student stay warm – "shivering, jumping around, and wrapping arms around the body." The final phase called the "Concept Application Phase" has students describe or write "about other animal adaptations to temperature extremes."

The above educational research and pedagogical methods should enhance the teaching and learning of any ecology unit. Research and development of progressive teaching methods is critical to thoughtful educators. It helps to improve student interest and involvement, while renewing a teacher's determination, commitment, and spirit. This document describes a unit that focuses on many of the above strategies – student-centered activities, cooperative learning, developing affective/emotional attachments to a local natural resource, and teaching ecology. Students become more highly motivated learners and retain more knowledge when these techniques are implemented in the classroom.

Demographics of the School/Classroom

South Haven is a rural community, in Van Buren County along the shore of Lake Michigan, about 40 miles northwest of Kalamazoo. The population of between 19,000 and 20,000 people is uniquely diverse compared to other towns of equal or lesser size. Diversity has always been celebrated as an integral part of South Haven, both economically and racially. The community's ethnic population includes approximately 75% Caucasian, 16% African American, 2% Native American, 1% Asian, and 8% of Hispanic origin. Almost one-third of the adult population has not graduated from high school, whereas slightly more than one-third have attained this achievement. Roughly 30% of the population has attended college to earn some sort of degree. The majority of permanent household owners earn between 10,000 and 50,000 dollars a year.

South Haven has become a popular summer vacation spot for Midwesterners and other Americans, and also has become one of the most popular towns in the nation for building or buying second homes. Many homes and businesses on the north side of town remain vacant during the winter months, and then become flooded with seasonal tourists and homeowners during the summer. Unfortunately, the summer residents' tax contributions go unnoticed as far as school funding is concerned. South Haven Public Schools have faced financial setbacks and funding issues since I started teaching here in 2000. There is no industrial tax base to provide for significant revenue.

South Haven High School, also called L.C. Mohr High School, enrolled 799 students during the 2004-05 school year. The high school population mirrors

that of the community, and consists of a significant number of minority students. Approximately 17% of the students are African American, 2-5% are of Hispanic origin, and there is a small percentage (less than 1%) of Native American and Asian students. All students come from varying levels of socio-economic status. Almost 50% of South Haven Public School students qualify for free or reduced hot lunches. Diversity provides for a unique and challenging educational setting, as teachers are required to help all segments of society to learn and obtain a high level of academic achievement.

The ecology unit was implemented in two sophomore general biology classes. This core class is a required science credit for graduation. Concepts and objectives covered during this class, including the ecology unit, are assessed on the Michigan Educational Assessment Program (MEAP) test. If students pass the MEAP, they receive an endorsement on their graduation diploma. Future students in Michigan and South Haven will have to pass a similar exam developed by ACT, Inc. Students within the 10th grade are split up amongst three biology teachers, including myself.

My fourth hour class consisted of 23 students that signed the *"Parent/Student Consent Form"* (Appendix A) allowing their data to be collected and analyzed during the unit. Of the twenty-three, four students' pre- and posttest scores were eliminated from the study because they joined or left the class and didn't complete one or both instruments. The consenting individuals consisted of 9 girls and 10 boys. There were 12 Caucasian, 4 African American, and 3 Hispanic consenting students. They ranged from below average to above

average in academic ability and achievement as measured by previous assessments.

My fifth hour class consisted of 21 students that signed the *"Parent/Student Consent Form"* (Appendix A). The pre- and posttest assessment data for 3 of the 21 students was eliminated from the study. They joined or left the class and didn't complete one or both of the assessments. The consenting individuals consisted of 7 girls and 11 boys. There were 14 Caucasian, 2 African American, 1 Hispanic, and 1 Native American that consented for the study. Students ranged from below average to above average in academic ability and achievement as measured by previous assessments. This class contained seven "inclusion" or "special needs" students that had mild to moderate learning difficulties. A teacher in our special education department assisted me in providing these students adaptations for assignments and assessments. Generally, this consisted of reading assignments, quizzes, or tests "out loud" or assisting with the reading and writing of class work. Two of the seven "special needs" students did not complete the posttest, so their data was not used in the study.

IMPLEMENTATION

Research and the unit design were completed during June and July of 2004 under the direction and guidance of Dr. Chuck Elzinga, at the Michigan State University (MSU) Kellogg Biological Station (KBS) near Augusta (Battle Creek), Michigan, and on the campus of MSU under the direction and guidance of Drs. Merle Heidemann and Ken Nadler. An outline of the unit activities and key concepts was one goal of the first week of research, and was followed by a beginning development of notes using PowerPoint software. I next obtained resources from my school and the library to find activities/labs that would reinforce the concepts. These resources were adapted to aid the transfer and retention of key concepts during the unit. I adapted labs from three "Prentice Hall Biology Laboratory Manuals" (73-78)(1003-1004b)(Hampton/Hampton, 271-280), my "Holt BioSources Laboratory Techniques and Experimental Design" book by Holt, Rinehart, Winston (115-126), a "Glencoe Science: Biology: The Dynamics of Life Laboratory Manual" (9-10) and a book I found titled, "A guide to the Study of Terrestrial Ecology" by William A. Andrews (Andrews, 106-239) that became an invaluable resource. The discovery of this book "got the ball rolling," in terms of the inception of teaching the ecological concepts using cooperative, "hands-on" activities. A majority of the remaining time at KBS and on campus focused on adapting and testing the labs/activities, and constructing assessments, such as quizzes and the pre- and posttests.

The ecology unit began on Thursday, September 30th, 2004 in my fourth and fifth hour sophomore general biology classes. The unit was implemented

during approximately 55-minute class periods over 45 days, or until December 17th, 2004, the day before winter break. The culminating activity – dune field trip and final lab – was completed on June 3rd, 2005 due to limited time and weather conditions. These general biology core classes were required for graduation and covered the benchmarks, objectives, and key concepts in the following areas: “Constructing New Scientific Knowledge,” “Reflecting on Scientific Knowledge,” “Using Life Science Knowledge” – “Cells, Organization of Living Things, Heredity, Evolution, and Ecosystems.”

The unit was specifically developed to enhance the teaching of ecosystems benchmarks within the Michigan Curriculum Framework of Science Benchmarks (2000). These benchmarks included:

- (LEC) III.5.1: Describe common ecological relationships between and among species and their environments.
- (LEC) III.5.3: Describe general factors regulating population size in ecosystems.
- (LEC) III.5.4: Describe responses of an ecosystem to events that cause it to change.
- (LEC) III.5.5: Describe how carbon and soil nutrients cycle through selected ecosystems.

Students were also expected to learn these objectives developed by me:

- Explain how organisms/ecosystems change over time.
- Analyze plant physiological adaptations to their environment.
- Identify numerous plants found in the sand dunes.

I developed lectures, labs/activities, homework assignments, quizzes, and a pre- and posttest to teach “key concepts” and “real-world contexts” within these benchmarks. An emphasis was placed on dune flora, coastline geological formations, and the overall ecological relationships between dune plants and their environment.

One unit goal was to facilitate learning of ecological concepts by using a local resource, the sand dunes, and by increasing “hands on”, cooperative learning activities. Hypothetically, students would become more motivated to learn ecological concepts if they were related to their “real world” by engaging their prior knowledge and life experiences.

Guiding principles were developed to facilitate and provide a focus for the construction of relevant teaching strategies. These principles were not assessed as were the aforementioned objectives, but rather provided a foundation upon which new pedagogical techniques were developed within the unit. The objective and subjective assessments incorporated within the unit could provide insight into their successful impact. The principles were:

- ✓ Increase student involvement in learning ecological concepts.
- ✓ Introduce and teach students about a natural community unique to their area (i.e. sand dunes).
- ✓ Utilize an abundance of diverse learning activities to increase student achievement in learning ecology.
- ✓ Develop students' appreciation for the delicate nature of sand dune communities and for nature itself.
- ✓ Increase student comprehension of “key concepts” and “real world contexts” within the ecosystems category of the Michigan Curriculum Framework of Science Benchmarks (2000).

The unit built upon pedagogical techniques used in previous years, generally requiring students to read the book, take notes, and answer questions from the book or worksheets. The revised unit used the book as a resource for learning key ecological concepts and background knowledge. This information was then reinforced using relevant, ready designed labs, activities and assessments linking the concepts to the sand dunes of Southwestern Michigan. The book used was "Modern Biology," by Holt, Rinehart, and Winston (Towle 358-413). I also utilized a book titled, "The Geology of Michigan" by John A. Dorr (Dorr 198-227) during the part of the unit emphasizing coastline geological formations (dunes). A portion of the quiz and test questions were obtained from a test bank provided with the "Modern Biology" textbook, by Holt, Rinehart, and Winston.

The unit was originally scheduled for 6 to 8 weeks of instruction, but actually required 9 weeks. The following unit outline (Figure 1) shows the topics, labs/activities, and assessments that were implemented during this 9-week period. The first day was a Thursday denoted by "Day 0" on the outline. Days were listed instead of weeks due to unforeseen distractions delaying the onset and continuation of the unit. A few days were missed or skipped from week to week. These distractions included a two-day orientation of our counties vocational technologies building and programs, homecoming week, assemblies, a professional development day, and several sick days due to a personal illness. Unfortunately, the successful implementation of some lab activities was partially hindered by time constraints, material shortfalls (i.e. light banks, pots, soil, etc.),

and inadequate facilities. These labs were either demonstrated, or completed by recording data and making observations of a previously set-up lab procedure. Students were able to complete some lab activities, not requiring as many supplies and space, in cooperative learning groups.

Figure 1. Dune Ecology Unit Outline

**Labs/activities adapted for the unit are denoted by italics.*

Day 0	• Ecology Unit Pretest • Introduction to Unit: discuss New York Times article "A Far-Reaching Fire Makes a Point About Pollution" (effect of non-living component of the environment on the living) • PQ3R: Section 19-1: Introduction to Ecology (review questions as a class - end of section)
Day 1	• Define Chp. 19 vocabulary in notes composition book • Film and questions: Unitedstreaming: Biology: The Science of Life: Ecology: Organisms in their Environment • Notes: PowerPoint (Sec. 19-1: Intro. to Ecology) • Homework: Sec. 19-1 review questions
Day 2	• Finish notes: PowerPoint (Sec. 19-1: Intro. to Ecology) • Finish homework in class
Day 3	• Correct homework • PQ3R: Sec. 19-2: Ecology of Organisms (read half as a class/half individually) • Homework: Sec. 19-2 review questions
Day 4	• Notes: PowerPoint (Sec. 19-2: Ecology of Organisms) • Finish homework in class
Day 5	• Quiz: Intro to Ecology • Correct homework • Notes due • Ecology Unit Survey
Day 6	• Introduction to Geology of Michigan • Define Geology of Michigan vocabulary in notes composition book • Vocabulary: Geology of Michigan (look up vocabulary in handout)

Day 7	• Notes: PowerPoint (Geology/Glaciation of Lake Michigan Region) • Read: "Wind" pgs. 198-205 (handout)
Day 8	• Notes: PowerPoint (Sand Dunes of Southwestern Michigan: dune formation)
Day 9	• Read: "Shoreline Processes in General" "Waves and Shore Currents" pgs. 205-213 (handout) • Finish notes: PowerPoint (Sand Dunes of Southwestern Michigan: parts of dune/properties)
Day 10	• Quiz: Geology/Glaciation of the Great Lakes Region • Ecology Unit Survey • Film and questions: Unitedstreaming: Biology: The Science of Life: Ecosystems: The Role of Abiotic Factors
Day 11	• Lab Safety handout • Lab Safety video and questions (materials, precautions, etc.)
Day 12	• Lab: write-up "<i>Physical Factors of Soil</i>" in lab composition book • Begin lab: explain procedure
Day 13	• Lab: "<i>Physical Factors of Soil</i>" (Hypothesis, Procedure, Data as a class; answer Analysis questions, write a Conclusion individually)
Day 14	• Lab: write-up "<i>Abiotic Factors of Soil</i>" in lab composition book
Day 15	• Lab: begin write-ups for "<i>How do Abiotic Factors Affect Different Plant Species?</i>" and "<i>Identifying Limiting Nutrients of Fast Plants®, Garlic Mustard, and Sea Rocket</i>" (to be completed during 2nd half of unit, complete as homework or during class time)
Day 16	• Lab: "<i>Abiotic Factors of Soil</i>" – begin Part A • Lab: continue write-ups
Day 17	• Lab: finish Part A (Procedure, Data, Analysis questions) • Lab: continue write-ups

Day 18	• Lab: <i>"Abiotic Factors of Soil"</i> – begin Parts B, C, D, and E
Day 19	• Lab: finish Parts B, C, D, and E (Procedure, Data, Analysis, Conclusion)
Day 20	• Practice Test: Intro. to Ecology/Geology of the Great Lakes Region • Lab composition books due
Day 21	• Test: Intro. to Ecology/Geology of the Great Lakes Region • Ecology Unit Survey (combination of two weeks)
Day 22	• Review test • PQ3R: Sec. 20-1: Understanding Populations and Sec. 20-2: Measuring Populations
Day 23	• Define Chp. 20 vocabulary in notes composition book • Notes: Populations (overhead) • Homework: Sec. 20-1, 20-2 review questions
Day 24	• Correct homework • PowerPoint slideshow: Plants of the Southwestern Michigan Sand Dunes (handout and explain)
Day 25	• Populations activity (worksheet) • Lab: begin <i>"How do Abiotic Factors Affect Different Plant Species?"</i> and <i>"Identifying Limiting Nutrients...."</i> (explain Procedure/Data collection –wait for plants to germinate)
Day 26	• Quiz: Populations • Ecology Unit Survey • Lab: begin collecting data daily over the next couple of weeks- above labs
Day 27	• Film and questions: Unitedstreaming: Biologix: Interactions and Relationships Among Organisms • Define Chp. 21 vocabulary in notes composition book • PQ3R: Sec. 21-1: Species Interactions
Day 28	• PowerPoint slideshow: review Plants of the Southwestern Michigan Sand Dunes • Notes: Sec. 21-1 • Homework: Sec. 21-1 review questions

Day 29	• Correct homework • Lab: begin write-ups for <i>"Intraspecific Competition in Plants"</i> and <i>"Interspecific Competition in Plants"</i>
Day 30	• Lab: begin above (explain Procedure/Data collection –wait for plants to germinate) • PowerPoint slideshow: review Plants of the Southwestern Michigan Sand Dunes (without names) • PQ3R: Sec. 21-2: Properties of Communities
Day 31	• Quiz: Populations/Dune Plant Identification (first 12: common names) • Ecology Unit Survey • Notes: Sec. 21-2: Properties of Communities • Homework: Sec. 21-2 review questions
Day 32	• Correct homework • PQ3R: Sec. 21-3: Succession • Film and notes: Unitedstreaming: Biologix: Succession and Climax Communities
Day 33	• PowerPoint slideshow: review Plants of the Southwestern Michigan Sand Dunes (last 12) • Notes: Outline Sec. 21-3 individually • Homework: Sec. 21-3 review questions
Day 34	• Correct homework • Lab: write-up <i>"Biotic/Abiotic Factors of an Old Field"</i>
Day 35	• PowerPoint slideshow: review Plants of the Southwestern Michigan Sand Dunes (without names-last 12) • Lab: continue write-up, explain Procedure/Data collection for <i>"Biotic/Abiotic Factors of an Old Field"</i>
Day 36	• Quiz: Properties of Communities/Succession (Dune Plant Identification - last 12: common names) • Ecology Unit Survey • Lab: collect data, finish any write-ups
Day 37	• Concept Web: vocabulary from Chps. 20 and 21 (central concept: Ecology)
Day 38	• Lab: <i>"Biotic/Abiotic Factors of an Old Field"</i> (gather Data; begin Analysis, Conclusion)

Day 39	• Lab: finish <i>"Biotic/Abiotic Factors of an Old Field"</i> (Analysis, Conclusion)
Day 40	• Practice Test: Populations/Communities • Lab composition books due
Day 41	• Test: Populations/Communities • Ecology Unit Survey
Day 42	• Review Test • Lab: finish <i>"How do Abiotic Factors Affect Different Plant Species?"</i> and <i>"Identifying Limiting Nutrients of Fast Plants®, Garlic Mustard, and Sea Rocket"</i> (Data, Analysis, Conclusion)
Day 43	• Lab: finish above labs • Lab: finish <i>"Intraspecific....."</i> and <i>"Interspecific....."</i> (Data, Analysis, Conclusion)
Day 44	• Lab: finish above labs • Lab composition books due
Day 45	• Culminating Activity: Dune Visit (Saugatuck) • Subjective Survey of Dune Visit (What did you think of it?) • Lab: <i>"Biotic/Abiotic Factors of a Lake Michigan Sand Dune"</i> (students with top ten grades on Intro. to Ecology/Geology of the Great Lakes Region Test)

Day 0

Students were given the *"Ecology Unit Pretest"* (Appendix B1) without any prior discussion about its contents. They were told to answer the questions to the best of their abilities, using prior knowledge. The pretest consisted of ten short answer essay questions pertaining to the key concepts and benchmarks of the unit. Many students completed the test, some left questions blank, and others simply wrote "I don't know" in the blank. A few students tried to ask for

help, but I explained the significance of the pretest as a “measuring stick” for their development of knowledge during the unit. Initially, they were given credit for attempting the pretest, but were not penalized for writing incorrect answers. Assessment of the content for each question was analyzed once both the pre- and posttests were finished. The rubric, *“Ecology Unit Pretest/Posttest Rubric”* (Appendix B3) was used to assess the short answer essay questions on both assessment instruments.

While completing my research for the unit during the summer of 2004, I stumbled across an article titled, “A Far-Reaching Fire Makes a Point About Pollution” by Andrew C. Revkin. It was published in the Tuesday, July 27th, 2004 Science Times section of the New York Times. The article was used to introduce the concepts of biotic and abiotic factors to be studied and learned. Revkin explained the effect that pollutants, including smoke and other by-products released by forest fires in Alaska, had on the immediate and global environments. After reading the article to students, I explained the impact that the abiotic factors - combustion products - had on the biotic factors - populations of organisms in its path. We also discussed other examples of non-living components of the environment affecting the living components. Students were told that ecology is a branch of biology dealing with these types of relationships in nature, and that we would specifically apply ecological concepts to the relationships between the living plants and non-living components of the sand dunes.

An introduction to the relevant portions of the “Modern Biology” textbook (Towle 358-367) was then completed. Students were provided an overview of the objectives and vocabulary for this section. The pedagogical technique of previewing, questioning, reading, reciting and reviewing (PQ3R) of the section, which was new to me, was implemented. I continued its use when beginning new sections of the textbook throughout the unit. I thought reading the book to cover the background information should be a prerequisite to completing the labs and other activities. The first couple of weeks included readings, notes, and assignments over the concepts in the first part of the unit.

Days 1-10: Background Information - Building Unit Framework

Day 1

All students were notified of the requirement to buy two, 200 page composition books on the first day of school. One of the books was used for notes and the other for labs. We started to define the vocabulary for Chp. 19 in the notes composition book for 15-20 minutes. Students were then told to finish any remaining words as homework.

A short 15-20 minute film was downloaded and shown using the website *unitedstreaming.com*. Our school subscribes to this website, which contains thousands of educational films over all topics aligned with their corresponding Michigan Curriculum Framework benchmark. The film was titled, “Biology: The Science of Life: Ecology: Organisms in their Environment.” It served as a platform to studying and learning ecology by discussing the main concepts of the field.

I developed PowerPoint notes by reading and writing down the main related text ideas for the section, "Ecology" (Towle 359-365). These notes were displayed and explained to the students, as they wrote the notes in their composition books. The first half of the notes were taken, and then students were assigned review questions for homework.

Day 2

The PowerPoint notes were completed for this section, and students were given time to finish answering the homework review questions over the section in class. I wanted students to work on the questions during class, so I could provide help and support.

Day 3

Homework review questions were corrected in class. Students exchanged papers and I gave them red pens to correct all of the homework assignments in class. I read the questions and provided explanations regarding the answers, while students revised their classmates' answers, if necessary. The homework assignments were worth 10% of their grade, and were not assessed particularly for correct content but rather if the students answered the questions. I reinforced the correct answers while orally explaining them.

We then began the PQ3R activity for the next section, "Ecology of Organisms" (Towle 368-372). This section covered the central concepts of the unit including biotic and abiotic factors, tolerance curves, acclimation, adaptation, physiological and physical regulatory factors, and niches.

PowerPoint notes were begun covering the main ideas of the section, and students started homework review questions.

Day 4

The PowerPoint notes were finished, and students were given time to finish answering the homework review questions over the section in class.

Day 5

Students were given weekly quizzes to assess their learning from the past five days. This first week's quiz was titled, "*Introduction to Ecology*" (Appendix C9a) and was designed to assess the reading and notes. Students were given 15 to 20 minutes to take the quiz. They were also asked to complete an "*Ecology Unit Survey*" (Appendix B4) at the end of each week to subjectively analyze the lessons and activities. Responses to these survey questions are included in the results/evaluation section of this paper. Homework review questions were corrected after the quiz.

Because I collected notes at the middle and end of each marking period, students turned in their composition books for assessment. Students were given a grade based on the expected culmination of notes throughout the elapsed time period.

Day 6

The second week began with an introduction to "The Geology of Michigan" based on Dorr's book (198-277), supplemental materials and notes developed through the use of pamphlets acquired at Warren Dunes State Park, notes taken during a fall ecology class at the Sarett Nature Center in Benton Harbor,

Michigan, and notes acquired in the summer ecology course for teachers at Kellogg Biological Station (KBS).

Students defined the relevant vocabulary in “The Geology of Michigan” handout (Dorr 198-227). The readings covered mainly abiotic factors such as wind, waves and shore currents, and descriptions on the development of shore features (i.e. dunes).

Day 7

Notes were developed on the geology/glaciation of the Lake Michigan region. Students were given notes about the glacial history of the region and the resulting geological formations. Glaciation concepts including the zone of ablation, the zone of accumulation, till, moraines, and isostatic rebound were discussed.

We then read the section titled “Wind” in “The Geology of Michigan” handout as a class. The section explains the effects of wind on the development of differing dune formations.

Day 8

Notes regarding the formation of sand dunes along the Southwestern Michigan coastline were continued. Students were expected to draw diagrams from the board, and were given notes pertaining to the sand dunes. Dune formation concepts including wave and shore currents, prevailing winds, moraines, and “saltation” were discussed.

We then began to read the three sections, “Shoreline Processes in General,” “Waves and Shore Currents,” and “Shore Features” from the handout.

Day 9

We finished reading the above sections as a class.

Notes over the sand dunes of Southwestern Michigan were finished. The final concepts taught and discussed included the different parts of the dunes and their properties. Concepts included foredune, interdune, backdune, blowouts, and the beach.

Day 10

Students were given the quiz, *"Geology/Glaciation of the Great Lakes Region"* (Appendix C9b), which assessed the readings and notes from the past week. Students also completed another *"Ecology Unit Survey."*

Students watched another *unitedstreaming.com* film titled, "Biology: The Science of Life: Ecosystems: The Role of Abiotic Factors." It reviewed the many types of abiotic factors affecting organisms within the environment. They answered questions pertaining to the film's content while watching it.

Days 11-45: General Information – Unit Labs/Activities, Unit Framework

Day 11

This week began the lab/activity segment of the first half of the unit. Students were given a "Lab Safety Handout" and shown a 30-minute lab safety video. The video reviewed safety procedures/precautions and common materials used in a laboratory. Questions regarding the film's content were discussed and analyzed. Students were told to have the "Lab Safety Handout" signed by their parents and brought back to me prior to starting any labs.

My classroom is not a typical science classroom; in fact, it used to be a home economics room. Mobile lab tables, 2 sinks, safety supplies and other materials have been incorporated within the classroom over the past few years. Correct laboratory techniques, procedures, and precautions were explained, and students were notified of the location and use of safety equipment found throughout the room.

Day 12

Students used their lab composition books to write-up the first lab activity that they would complete: *"Physical Factors of Soil"* (Appendix C1). The labs were written out the day before they were completed for students to preview the procedure. When writing out laboratories students included the lab title and the date at the top of the first blank page. All labs included these sections that were learned and reinforced while studying the scientific method: Problem or Question, Purpose, Hypothesis, Materials, Procedure, Data and Observations, Analysis, and Conclusions. Students were required to write each section in their composition books. All sections were given to them except the hypothesis, two analysis questions, and the conclusions. In some labs, the procedure notified students, for example, to "See Figure 1" but no figure was shown. I drew these figures on the board for students to copy during the lab write-up. Students were given an example hypothesis on the first couple of labs, and then they developed their own for later labs using the question/purpose. The two added analysis questions for every lab were: Identify and explain any experimental error that could have occurred during the lab; Rewrite your hypothesis and explain whether

your data allows you to support or reject it. The conclusions consisted of three paragraphs each with a specific topic: paragraph 1- Describe what you did in the lab (write a summary); paragraph 2- Explain what you could change or keep the same for further experimentation; paragraph 3- What did you learn? The labs were usually due the day after their completion unless students were informed otherwise. This allowed them to answer the analysis questions and write the conclusions section.

The procedure and pre-lab preparations for the *"Physical Factors of Soil"* demonstration lab were briefly explained before the end of the hour.

Day 13

The *"Physical Factors of Soil"* lab procedure was explained and demonstrated in front of the class while students recorded the data/observations. The purpose of the experiment was to compare the various particle types found in three different soil samples (forest, dune, and field). The three soil samples were collected prior to the lab in three separate "Ball Mason" jars. The samples were mixed with water and shaken to disperse the particles. Students could then observe the most dense/massive particles that settle to the bottom, and the least dense/massive particles that settled on top (see Figure 2). The soil types were compared and contrasted, and observations were made regarding their similarities and differences. My goal was for students to see the differences in soil particle abundance, richness, and diversity in the field and forest samples, as opposed to, the sand dune. Students completed the analysis and conclusions sections on their own after recording the data and making observations.

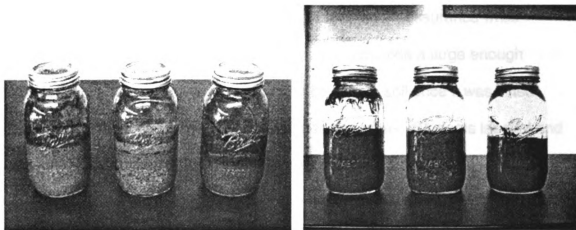


Figure 2. “Physical Factors of Soil” demonstration lab soil samples (forest, dune, field)

Day 14

Students wrote up the “Abiotic Factors of Soil” (Appendix C2) lab in their lab composition books.

Day 15

Students began lab write-ups for “How do Abiotic Factors Affect Different Plant Species (Fast Plants®-*Brassica rapa*, Garlic Mustard-*Alliaria petiolata*, and Sea Rocket- *Cakile edentula*)?” (Appendix C3), and “Identifying Limiting Nutrients of Fast Plants® (*Brassica rapa*), Garlic Mustard (*Alliaria petiolata*), and Sea Rocket (*Cakile edentula*)” (Appendix C4).

Day 16

The procedure for Part A of the “Abiotic Factors of Soil” lab began. Lab groups were assigned and consisted of 3-4 students. Each group was responsible for filling three 250-mL beakers with three soil samples from the foredune, interdune, and backdune. The samples were previously collected by me, and placed in labeled 1000-mL beakers. Students used wire screens to sift out sticks, stones, leaves, and other objects from mostly the interdune and

backdune samples. They needed some guidance and reassurance while completing this task. The 1000-mL beakers didn't provide a large enough sample, as we ran out of the interdune and backdune soil once it was sifted. Some groups only obtained 60-80 cm³ of these samples. Students labeled and placed their three 250-mL beakers in a tray. I took the trays home over the weekend, and baked the beakers in the oven at 210 degrees Fahrenheit for almost 24 hours.

Day 17

Students finished Part A of the lab by calculating the moisture in each sample. They used formulas given to them in the procedure, and recorded their results in Table 1 of the data and observations section. This part of the lab was messy; sand and soil accumulated on the tabletops and floor. Students cleaned up the individual lab tables and returned materials to a centralized table after each lab.

After finishing the Part A procedure and calculations, students continued to write-up the two labs for the second part of the unit.

Day 18

Students completed Parts B, C, D, and E of the *"Abiotic Factors of Soil"* lab. In Part B, students measured the water-holding capacity of the three soil samples. In Part C, students then put a small amount of each soil sample in a separate beaker, and added enough distilled water to "wet" the sample. They used pHHydriion paper to measure and record the pH of each sample. Part D required students to measure the organic content of the soil using hydrogen

peroxide. Part E required students to use NPK soil test kits to measure the nitrogen, phosphorus, and potassium levels in each sample. The results of this test were relatively inconclusive, but some students obtained data.

Day 19

Students finished Parts B, C, D, and E data/observations, analysis, and conclusions sections of the *"Abiotic Factors of Soil"* lab.

Day 20

The "Introduction to Ecology/Geology of the Great Lakes Region" Practice Test was given. The answers were then reviewed, and questions or concerns were addressed regarding the first part of the unit.

Students turned in their lab composition books for assessment, and the labs from the first part of the unit were assessed. I scanned through each student's lab and assigned them a check-plus (100%), check (80%), or check-minus (60%) based on its content, completeness, and neatness. Comments were written in certain sections to provide feedback for the guidance of student learning.

Day 21

Students took the test titled, *"Introduction to Ecology/Geology of the Great Lakes Region"* (Appendix B2a). The test had questions 1, 4, and 9 from the pretest, and several other questions about the concepts learned over the weeks. It was a relatively long test as some students required extra time to finish. An *"Ecology Unit Survey"* was also given so students could subjectively assess the past few weeks.

Day 22

The test answers were reviewed in class, and then another PQ3R activity of the next two sections, "Understanding Populations" and "Measuring Populations," occurred (Towle 379-387). Both of these sections were relatively small, so they were covered together.

Day 23

Students defined the vocabulary for these sections (see Day 22) in their notes composition books. Then notes were taken from the overhead on the key concepts from each section. These concepts included: population properties and dynamics, population growth – both exponential and logistic, population fluctuations or cycles, population regulation, density-dependent factors, and density-independent factors. These notes were used during previous years, and did not necessarily relate the concepts to examples in the dunes. Students would apply the concepts to certain populations of plants on the dunes, and by completing labs that utilize and showcase their practical occurrence in these species.

After the notes, students were assigned homework review questions.

Day 24

These review questions were corrected in class. Students were then given a PowerPoint slide handout of 24 common "Plants of the Southwestern Michigan Sand Dunes." Two plant picture slides were displayed on each page along with their common and scientific names. I identified and explained the common characteristics of each plant as we perused through the slides.

Students were told to write down the key characteristics (e.g. color, number of petals, shape, other common names, etc.) next to each slide. Students were assessed on the identification of these plants on a couple of quizzes and the last test. They were expected to know these plants for the dune visit, and to complete further unit labs.

Day 25

Students completed a populations worksheet activity used to calculate population sizes, extrapolate data from past population fluctuations, and predict future trends from observed data. This worksheet was used in past years during this class.

The labs titled, *"How do Abiotic Factors Affect Different Plant Species? (Fast Plants®-Brassica rapa, Garlic Mustard-Alliaria petiolata, and Sea Rocket-Cakile edentula", and "Identifying Limiting Nutrients of Fast Plants® (Brassica rapa), Garlic Mustard (Alliaria petiolata), and Sea Rocket (Cakile edentula)"* were started. I set up these two labs procedures ahead of time, and students were to observe and collect data. This was done due to a lack of equipment (i.e. light banks, pots, seeds, etc.), and to save time. These "hands-on" learning experiences may have been less influential and effective due to this modification, but students were still able to observe, record, and analyze the results.

The procedure for the first lab, *"How do Abiotic Factors....?"* was explained and demonstrated. Students were able to observe the technique used to plant the seeds in the pots (see Figure 3). Small pots were used instead of the Styrofoam cups, as explained in the lab procedure.



Figure 3. “How do Abiotic Factors Affect Different Plant Species? (Fast Plants®-*Brassica rapa*, Garlic Mustard-*Alliaria petiolata*, and Sea Rocket-*Cakile edentula*)” demonstration lab seed planting pots.

The pots were placed under a light bank constructed by me prior to the lab (see Figure 4). Unfortunately, the Fast Plants® in the potting soil were the only seeds to germinate, while the Garlic Mustard and Sea Rocket remained dormant. Freezing the seeds for a period of time may have prompted better germination results. The students still collected data for the lab over the next couple of weeks. The lab results were analyzed and discussed.

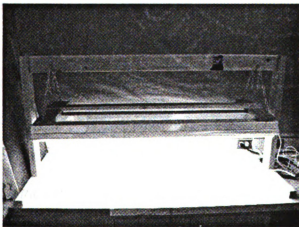


Figure 4. Light bank used for growing plants.

The procedure for the second lab, “Identifying Limiting Nutrients....” was explained and demonstrated. Students observed the techniques used to

assemble the growing apparatuses (see Figure 5). Plants in the pots from the previous lab replaced unsuccessful germinators. These finished apparatuses were placed under the light bank. Again, the Fast Plants® were the only successful germinators possibly due to inadequate pre-planting procedures. The students were able to measure and record the plants' growth progress over a two-week period. The lab results were again analyzed and discussed.



Figure 5. “Identifying Limiting Nutrients of Fast Plants® (*Brassica rapa*), Garlic Mustard (*Alliaria petiolata*), and Sea Rocket (*Cakile edentula*)” demonstration lab plant seed growing apparatuses.

Day 26

Students were given the “Populations Quiz” (Appendix C9c). This quiz assessed the reading, notes, and assignments from the past week. They also completed another “Ecology Unit Survey.” The remainder of the time was spent collecting data from the, “How do Abiotic Factors....?” and “Identifying Limiting Nutrients....” labs, which was continued each day for the next couple of weeks. Students made growth observations by measuring the height and width of the plants daily, and then measured their biomass differences after two weeks.

I provided the potted plant seeds, from the *"How do Abiotic Factors....?"* lab, with a controlled amount of water every day after school. This consisted of approximately 20 squirts of water from a spray bottle, or an adequate amount needed to wet the soil.

Day 27

The *unitedstreaming.com* film, "Biologix: Interactions and Relationships Among Organisms," was shown to introduce the dynamics of communities. Students again answered questions regarding the film's content, and we discussed the topics afterward. The section "Species Interactions" (Towle 397-402) was introduced, and students were told to define the vocabulary in their notes. We again completed a PQ3R activity of the section until the end of the hour. The section covered: predation, parasitism, competition, mutualism, and commensalism. Students were informed that competition between the common plant species of the dunes was a driving force for survival, adaptation, succession and ultimately evolution. The concept of competition would overshadow the other types of species interactions as we proceeded through the rest of the unit.

Day 28

The first 12 plants in the handout, "Plants of the Southwestern Michigan Sand Dunes" were reviewed with their names visible. Students were informed that they would need to identify these on the weekly quiz, and they would be shown each slide for approximately 30 seconds.

Notes were provided and explained for the “Species Interactions” section, and students were assigned and worked on homework review questions.

Day 29

The homework questions were corrected and reviewed in class.

Students wrote up the “*Intraspecific Competition in Plants*,” (Appendix C5) and the “*Interspecific Competition in Plants*” (Appendix C6) labs. Again, I provided any figures that were missing in the lab on the board. Students copied these figures into their lab composition books.

Day 30

The procedure and data collection methods for the above labs were explained. The students were required to assess and observe the effects on growth competition between plants of the same sunflower species, and the plants from two different species – sunflower and radish. The overall aspects of competition would become transferred or translated to the similar occurrences between dune plants. Students were informed that sunflower and radish seeds were used in the lab due to their easy accessibility, and in order to prevent dune plant disruption.

I constructed the eight planting trays prior to the lab. The lack of light banks and growing materials required this modification. The “*Intraspecific Competition....*” lab required four planting trays (see Figure 6), each with potting soil at least 5 cm deep. Using a ruler and pen, grid lines were assembled on each tray separated by distances of 10 cm, 5 cm, 3 cm, and 1 cm. At the conclusion of the growing period, students were required to calculate the

percentage of plants surviving, and to measure the average height, width, length of roots, and total/average weight of the plant tissue. Students found that the seeds separated by 3 cm resulted in the best germination results, followed by trays 2 (5 cm), 4 (1 cm), and 1 (10 cm).

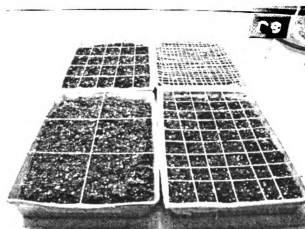


Figure 6. “Intraspecific Competition in Plants” demonstration lab seed (sunflower) planting trays.

The “Interspecific Competition....” lab also required four planting trays (see Figure 7), each with potting soil at least 5 cm deep. Using a ruler and pen, grid lines were assembled on each tray separated by distances of 2 cm. Tray 1 consisted of all radish seeds; Trays 2 and 3 consisted of alternating radish and sunflower seeds, while Tray 4 consisted of all sunflower seeds. The plants were allowed to grow until the results of competition were obvious or for about two weeks. Students calculated the percent of plants surviving, and measured the average height, width, length of roots, and total/average weight of the plant tissue at the end of the growing period. Students observed the most growth in Trays 2, 3, and 4 with the most growth occurring in Tray 3 where an alternating assemblage of radish and sunflower seeds were grown.



Figure 7. “Interspecific Competition in Plants” demonstration lab seed (sunflower, radish) planting trays.

Another slideshow reviewing the first 12 dune plants was completed without the plants’ names.

Finally, a PQ3R activity was completed for “Properties of Communities” (Towle 403-405) and students were expected to define the vocabulary for this section as homework. The main ideas included species diversity and richness.

Day 31

Students took the quiz titled, “Community-Interactions” (Appendix C9d) that also had a plant identification portion. Students were shown the slides of the first 12 dune plants, and wrote their common names on the quiz.

Another “Ecology Unit Survey” was completed, notes were started for the “Properties of Communities” section, and students were assigned the homework review questions.

Day 32

“Properties of Communities” review questions were corrected and explained in class. The last PQ3R activity was completed for “Succession” (Towle 406-408). The overarching concepts that would tie together the previous

topics/concepts from the unit included: successional changes in communities – primary and secondary succession, and the complexities of succession. The final assignments, assessments, and activities were developed and designed to bring together all aspects of the ecology unit. The students' progression of knowledge regarding primary succession of the dunes was facilitated through the study of dune plant species, their population characteristics, and their abiotic and biotic interactions within the community.

Students were then shown a brief *unitedstreaming.com* film titled, "Biologix: Succession and Climax Communities" to provide an overview of the process of succession in differing communities. They answered questions while watching the film.

"Succession" vocabulary definitions were assigned for homework.

Day 33

The last 12 plants of the "Plants of the Southwestern Michigan Sand Dunes" slideshow were reviewed with their names shown.

Students then read and outlined the notes individually from the "Succession" section. Homework questions were assigned to assess the reading and comprehension of the section's concepts.

Day 34

The homework for "Succession" was corrected and reviewed. Students then began to write up the "*Biotic/Abiotic Factors of an Old Field*" (Appendix C7) lab. This lab taught students how to systematically sample biotic factors and calculate quantitative data regarding different plant types in a field. It also served

to introduce techniques and calculations students would encounter in the final lab at the dunes.

Day 35

A final review of the last 12 dune plants, lacking common names, was completed using PowerPoint. The students then continued to write up the *"Biotic/Abiotic Factors of an Old Field"* lab.

In this lab, students were expected to record the number of grasses, forbs, vines, shrubs, and trees in each 1 m intercept interval. They were then expected to total up the number of plants for each type, measure the height of four to five plants of each type, and calculate their average heights. Every group was to share their data with the class to provide more conclusive and accurate results. The students were finally expected to make observations about the most numerous plant type, the tallest plants, the percent of ground shaded by vegetation, the percent not shaded by vegetation, and the distribution of plants. Unfortunately, modifications were developed whereby students collected the data from a pre-designed hypothetical belt transect map of a typical old field in Michigan. This again was enacted due to time constraints, and a lack of sufficient property, materials, and space to complete the lab. Students did not share data because each data sheet contained the same information. The data sheet students used is attached to the lab in the appendix. Separate letters on the data sheet denoted common old field plant types that were listed on the board. One data sheet was given to each lab group. Students found grasses, forbs, and shrubs to be the most numerous plant types.

Day 36

The *"Properties of Communities/Succession Quiz"* (Appendix C9e) was given. Students were assessed on the concepts from "Properties of Communities" and "Succession" sections, and also on the common name identification of the last 12 dune plants.

Another *"Ecology Unit Survey"* was given after the quiz, and students then collected data and finished any lab write-ups.

Day 37

A concept web of the populations and communities vocabulary was completed. The central concept was ecology. Students attached the words together with lines, and wrote phrases on the lines based on the words conceptual relationships. This activity served as a review for the upcoming test over populations, communities, and succession.

Day 38

Students collected the data for the *"Biotic/Abiotic Factors of an Old Field"* lab, and started the analysis and conclusions sections. Most students didn't finish the data collection before the end of the hour.

Day 39

Students finished the analysis and conclusions section for the above lab.

Day 40

A practice test was administered over the concepts of populations and communities. Students were given time to complete the test, and then the answers were given and explained.

Day 41

Students were given the *"Populations/Communities Test"* (Appendix B2b). The test had questions 2-3, 5-8, and 10 from the pretest, and several other questions about the concepts of populations and communities. The dune plant identification section was completed by showing all 24 plants in a slideshow using 30-second intervals. Repeats were accounted for at the end of the slideshow. It was a relatively long test as some students required extra time to finish. An *"Ecology Unit Survey"* was also given so students could subjectively assess the entire unit.

Day 42

The *"Populations/Communities Test"* answers were reviewed in class. Students collected the final data from the *"How do Abiotic Factors...."* and *"Identifying Limiting Nutrients...."* labs. The analysis and conclusions sections of these labs were assigned and completed as homework, if necessary.

Day 43

The above labs were finished, and the *"Intraspecific...."* and *"Interspecific...."* labs data was collected and finalized. The analysis and conclusions sections of these labs were assigned and completed as homework, if necessary.

Day 44

Labs were finished and the lab composition notebooks were collected and assessed. Assessment of the lab composition books occurred as explained previously.

Day 45

The final day of the unit occurred on Friday, June 3rd, 2005 with a visit to Oval Beach and the sand dunes in Saugatuck, Michigan. A lapse of time occurred between the final unit activity on December 17th and the dune visit, due to weather conditions and a need to proceed into new material. Students were prepared for the day by attending a couple of after school meetings, and reading through the lab titled, *"Biotic/Abiotic Factors of a Lake Michigan Sand Dune"* (Appendix C8). The students with the top ten grades on the *"Intro. to Ecology/Geology of the Great Lakes Region Test"* were rewarded with the opportunity to attend the field trip. Both classes were informed of this modification at the onset of the unit. Only ten students were taken to more easily facilitate transportation and chaperone requirements, protect the fragile dune environment's flora and fauna, and efficiently and effectively complete the lab without student behavioral distractions. A substitute teacher assigned a review activity of the current material to my other students staying behind in the classroom. Ideally, I intended to have the dune visitors provide data and give a lab presentation to their classmates upon returning. Unfortunately, this plan was excluded due to exams and the end of the year.

Upon arrival at the dunes, I proceeded to review the geological formations and history of the dunes, followed by a recap of the dune plants. The necessary equipment and materials were carried along in boxes, and students had copies of their lab and dune plant identification pictures on a clipboard. The procedure required students to collect data regarding plant types in each section of the

dunes: foredune, interdune, and backdune. The steps of the first part of the procedure resembled the *"Biotic/Abiotic Factors of an Old Field"* lab. The transects were set up parallel to the coastline in the appropriate areas. I demonstrated the correct technique in the foredune area, and the students carried out the data collection in the other areas. Students collected data regarding the plant species they could identify in their transects (see Figure 8). Students recorded the number of each species in each 1 m intercept interval. They were expected to total up the number of plants in each species, measure the height of four to five plants of each species, and calculate their average heights. They also were required to find the total number of the most numerous plant types, the total number of plants, and finally the percentage of the most numerous plant types. They made observations about the most numerous plant type, the tallest plants, the percent of ground shaded by vegetation, the percent not shaded by vegetation, and the distribution of plants. Students also recorded the abiotic factors of: light intensity, soil temperature, wind velocity and air temperature. Every group shared data from their transect with the other groups, so only one group was responsible for one dune area.

The data were discussed over lunch, and students turned in the labs without completing the analysis and conclusions sections. Students were amazed at the abundance of marram grass in the foredune and interdune. They also found it to be the most numerous plant type. They noticed a difference in the type, amount, and characteristics of species from the foredune to backdune. They also found a decrease in the four measured abiotic factors from foredune to

backdune. The lab wasn't completed for several reasons: the trip served as a reward for these high achieving students, they needed time to study for second semester exams, and sharing of the lab's data with other students in the class was not possible before summer break. Another lab titled, *"Observing Succession in Aged Tap Water,"* (Appendix D1) was also omitted from the unit due to limited time. The students provided a subjective assessment of the day, in writing, on the back of the lab. A few wrote that, "the day was very fun or awesome" or "It was good to see all the plants for real." One student wrote that this was, "The part of Biology I like the best, getting outside and getting hands-on experience!"



Figure 8. *"Biotic/Abiotic Factors of a Lake Michigan Sand Dune"* lab data collection transects in the interdune and backdune.

RESULTS/EVALUATION

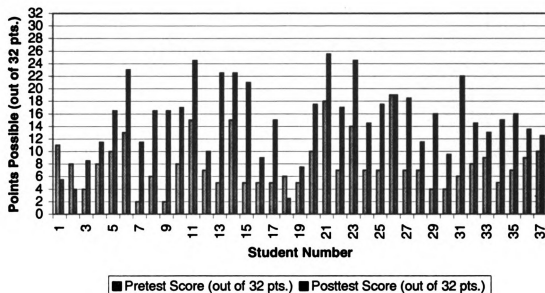
Student gains on this unit were assessed using a pretest and two posttests (Appendices B1 and B2) each containing 10 short answer essay questions, both objective and subjective in nature. Thirty-seven students in my 4th and 5th hour general biology classes gave me consent to use their data. The pretest consisted of only these 10 questions, while 2 posttests were given: the first consisting of questions 1, 4, and 9; the second consisting of questions 2-3, 5-8, and 10. The questions were developed using the key principles and concepts covered in the unit including: plant species, pioneer species, populations, communities, biotic and abiotic factors, soil content, geological features, change over time, and succession.

Pretest/Posttest Overall Comparison

Average overall scores were calculated for both the pretest and posttest questions (see Figure 1). Thirty-seven students averaged 8.05 points out of 32 possible points (25.2 % correct) for the 10 objective/subjective pretest questions. The same students averaged 15.2 out of 32 possible points (47.5%) for the same posttest questions. The low scores on the posttest questions were most likely attributable to their design - open-ended, subjective, application of concepts. Students may have had trouble understanding the questions or statements, or the high standards I imposed during their assessment could have affected the gains. The rubric used was *"Ecology Unit Pretest/Posttest Rubric"* (Appendix B3).

The pretest and posttest results for each student were calculated and graphed (see Figure 1).

Figure 1. Dune Ecology Unit Pretest and Posttest Student Scores for 10 Questions



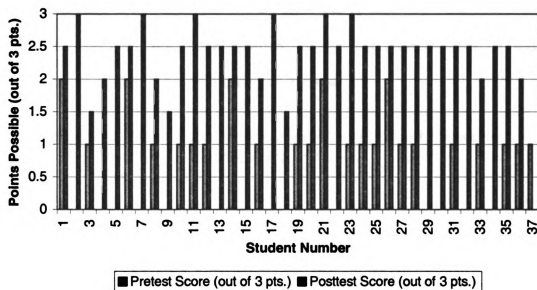
A statistical analysis of the 10 pretest and posttest questions was also completed using a paired t-test. Thirty-seven data points, each representing a students pretest and posttest total scores out of 32 points, were entered into the t-test. The mean difference between the two tests was calculated as 7.15 with a 95% confidence interval. The t-value was 8.20 with 36 degrees of freedom and a probability (p-value) of 0.0001. The t-test results provided data suggesting an improvement from pretest to posttest scores. Each pretest and posttest assessment question was statistically analyzed to expose the unit's strengths and weaknesses for future revisions.

Pretest/Posttest Item Analysis

Each test question was analyzed using a paired t-test with thirty-seven data points ($n = 37$) and a 95% confidence interval (cutoff p value of 0.05).

1) Question number one asked students to, "Define Ecology." A majority of students showed a statistically significant improvement, as indicated by a paired t-test, resulting in a t-value of 11.2 and a p-value of 0.0001. One student neglected to write an answer for the pretest, but wrote, "Ecology is the study of interactions between organisms and the living and non-living components of their environment," on the posttest. This posttest response shows a significant increase in conceptual knowledge from the pretest. The pre- and posttest question 1 results are shown in Figure 2.

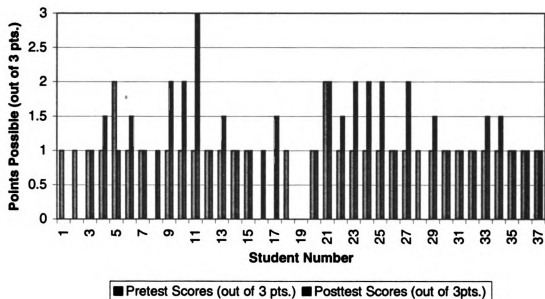
Figure 2. Dune Ecology Unit Pretest and Posttest Student Scores for Question 1



2) Question number two stated, "People, communities, and cities change in function and appearance over time. How can you tell if something in the environment changes over time?" Students struggled to identify three examples of change such as: physical appearance, social interactions, chemical

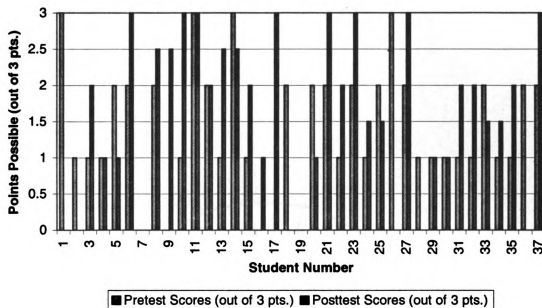
analysis, number of species, or the presence and absence of biotic/abiotic factors. This may have caused many students to obtain 1 point out of 3 points on both the pretest and posttest. Also, some students did not complete one or both of the assessments. Some students provided one vague example on the pretest, but managed to develop a more sophisticated answer on the posttest. The scientific conceptual knowledge needed to answer this question was improved slightly after instruction. Students showed a statistically significant improvement, as indicated by a paired t-test, resulting in a t-value of 2.31 and a p-value of 0.027. A dramatic change was observed in one student's two test responses. On the pretest, he/she answered, "You can observe changes in an environment." On the posttest, the same person wrote, "By keeping track of population, succession, species richness and diversity, also birth and death rates." The pre- and posttest question 2 results are shown in Figure 3.

Figure 3. Dune Ecology Unit Pretest and Posttest Student Scores for Question 2



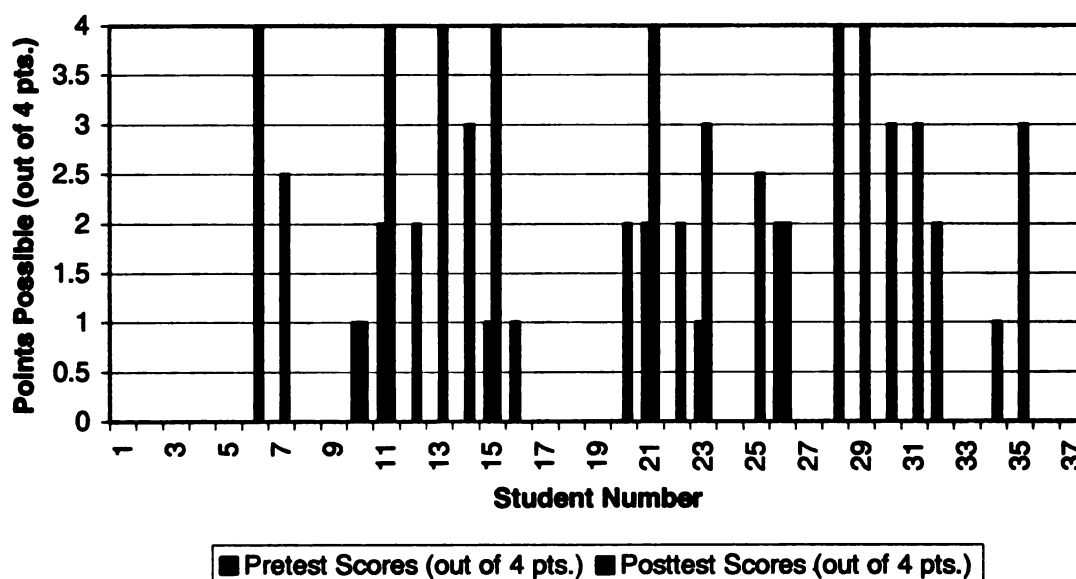
3) Question number three asked, "What factors/occurrences affect environmental change over time?" This question required students to think of three or more biotic or abiotic factors that affect the environment. They hear about one biotic factor that is relentlessly affecting the environment, ourselves (humans), and were able to list other factors from their prior knowledge. A large number of students received 2 or 3 points out of 3 points on the pretest, and did not leave too much room for improvement on the posttest. Some students did not improve, and others left one or both of the assessments incomplete. The scientific conceptual knowledge needed to answer this question was not improved based on the statistical analysis. Students showed no statistically significant difference, as indicated by a paired t-test, resulting in a t-value of 0.865 and a p-value of 0.393. Some students gave more detailed posttest answers using the new concepts learned from the unit. One student left the question blank on the pretest, but wrote, "Variations in weather, pollutions, and amount of people in the certain area" on the posttest. Although lacking concepts from the unit, it shows some improvement in ecological cognition. The pre- and posttest question 3 results are shown in Figure 4.

Figure 4. Dune Ecology Unit Pretest and Posttest Student Scores for Question 3



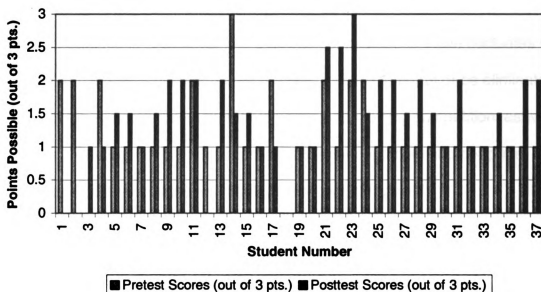
4) Question number four said, "Describe the content of soil typically found in Michigan." I was looking for four answers: gravel, sand (coarse/fine), silt, and clay. The question was worth four points, each point given for one of the components. Many students replied with, "dirt" on the pretest or were baffled. Roughly half of the students were able to list two or more components of soil on the posttest. Some students did not complete one or both of the assessments, and apparently skipped the question due to its difficulty or their lack of understanding. Students showed a statistically significant improvement, as indicated by a paired t-test, resulting in a t-value of 4.67 and a p-value of 0.0001. The pre- and posttest question 4 results are shown in Figure 5.

Figure 5. Dune Ecology Unit Pretest and Posttest Student Scores for Question 4



5) Question number five asked students to, “Explain why geological features (e.g. mountains, valleys, sand dunes, etc.) change over time.” The question was worth three points, and I was looking for answers referring to abiotic/biotic factors, climate patterns (e.g. wind/water currents, weathering), Earth’s composition (e.g. tectonic plate movement), or glaciation. The data suggest that they did not gain much knowledge regarding this question, or were unsure how to answer it. Students showed no statistically significant difference, as indicated by a paired t-test, resulting in a t-value of 1.42 and a p-value of 0.165. Some students were able to include biotic/abiotic factors in their posttest answers, such as, “Wind, weather, erosion, heat, cold, people, animals- they can all do something to effect an area.” Students were generally able to increase their score by 1 point from pretest to posttest. The pre- and posttest question 5 results are shown in Figure 6.

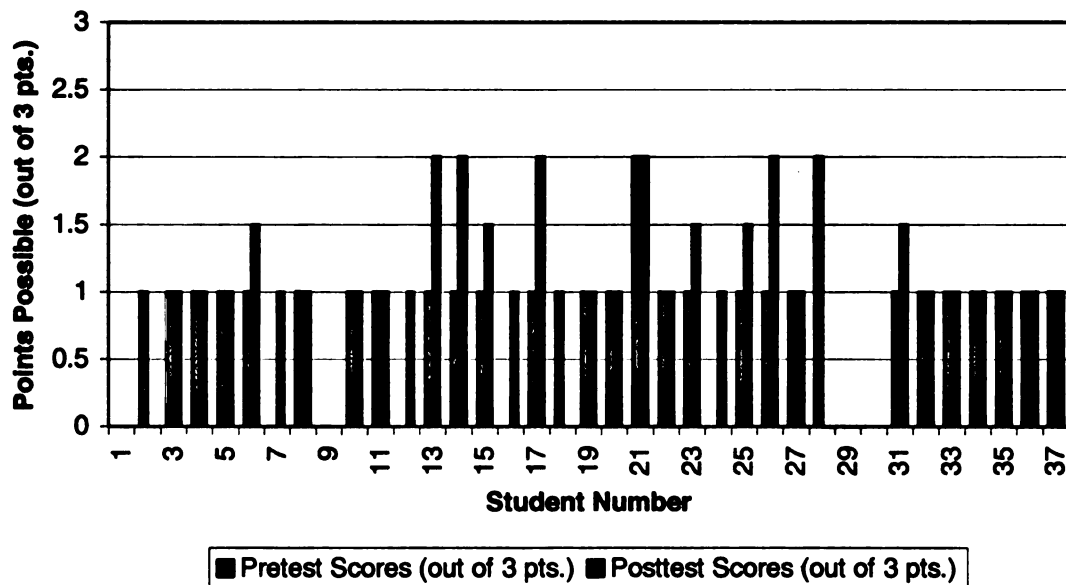
Figure 6. Dune Ecology Unit Pretest and Posttest Student Scores for Question 5



6) Question six asked, "How do populations of organisms affect change over time?" Students were expected to identify at least three population concepts like growth (e.g. change in number, evolve), predator/prey relationships, competition, disease, dispersal, predation/parasitism, or human impacts. Students struggled in answering this question, possibly due to its complex ecological underpinnings of "change over time." Some improvement in conceptual knowledge was evident, although not statistically significant. Use of population vocabulary was lacking in many posttest answers. Some students did not improve their answers, or left one or both of the assessments blank. Students showed no statistically significant difference, as indicated by a paired t-test, resulting in a t-value of 1.71 and a p-value of 0.096. A highly motivated learner answered the pretest in this way, "If one species population becomes too

large, it can upset the balance of an environment by using organisms essential to other species.” They received a point for identifying population growth as a factor affecting change over time. The same student wrote the following on the posttest, “Populations of organisms are all interconnected, so if one fluctuates it affects all the others. Competition also causes species to adapt or be eliminated over time.” They showed some improvement by suggesting competition, as well as growth (fluctuations), in the posttest and therefore received another point. The pre- and posttest question 6 results are shown in Figure 7.

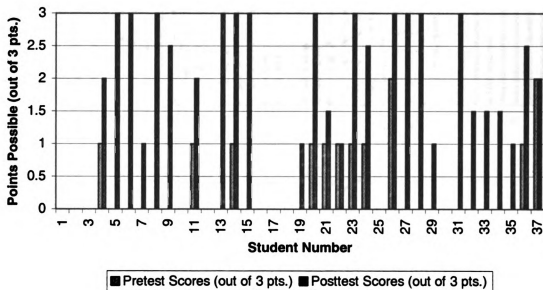
Figure 7. Dune Ecology Unit Pretest and Posttest Student Scores for Question 6



7) The next two questions, seven and eight, covered crucial ecological concepts in relation to the sand dunes. Many students excelled at answering one or both questions post instruction. A statistically significant difference comparing pre- to posttest answers suggested the development and attainment

of knowledge regarding the concepts. Question seven required students to, "Define Pioneer Species." It was worth three points, and their answers required the words or phrases: first species, colonize, and new habitat for all three points. Twelve out of 37 students received all the points, and a handful of others received a 2 or above on the posttest. Some of the students did not complete one or both of the assessment instruments. Many students showed a statistically significant improvement, as indicated by a paired t-test, resulting in a t-value of 6.78 and a p-value of 0.0001. The pre- and posttest question 7 results are shown in Figure 8.

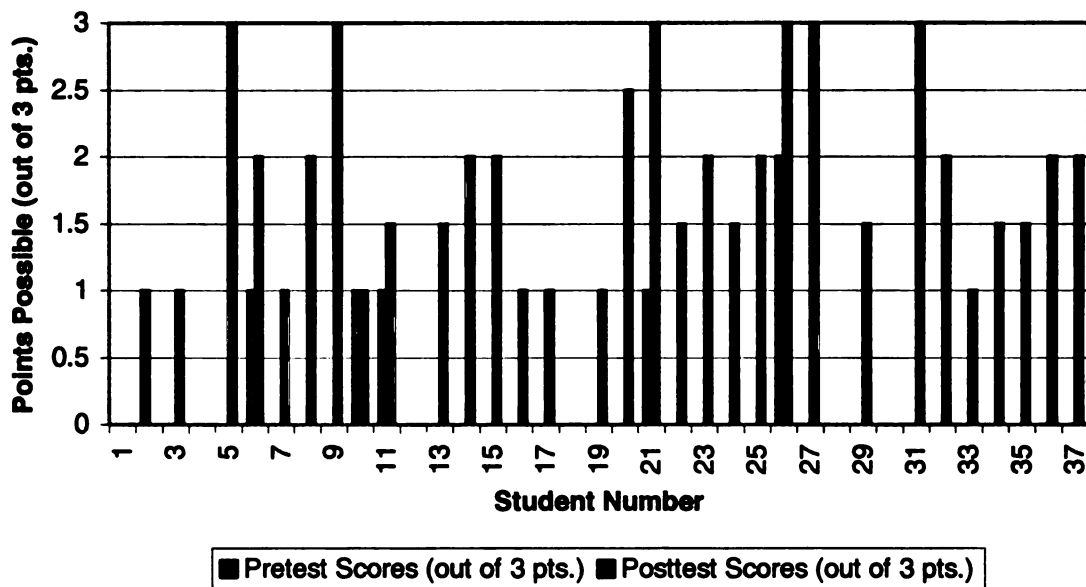
Figure 8. Dune Ecology Unit Pretest and Posttest Student Scores for Question 7



8) Question eight was, "What is succession?" Again, three key concepts or phrases led to three total points on this question. The three key components of the answer were: predictable, sequential, replacement of populations, and

ecosystem/community. Almost half of the students answered the posttest with two or more of the above components. Posttest responses were significantly better than pretest responses. A majority of students showed a statistically significant improvement, as indicated by a paired t-test, resulting in a t-value of 8.04 and a p-value of 0.0001. The pre- and posttest question 8 results are shown in Figure 9.

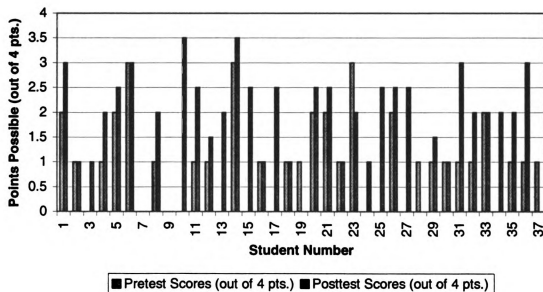
Figure 9. Dune Ecology Unit Pretest and Posttest Student Scores for Question 8



9) Questions nine and ten were developed to assess the knowledge obtained from learning and studying ecological concepts in relation to plants on the sand dunes. Question nine asked, "Explain how plant species are affected by the living and non-living portions of their environments." Students were expected to include the abiotic and biotic factors they read or heard about in

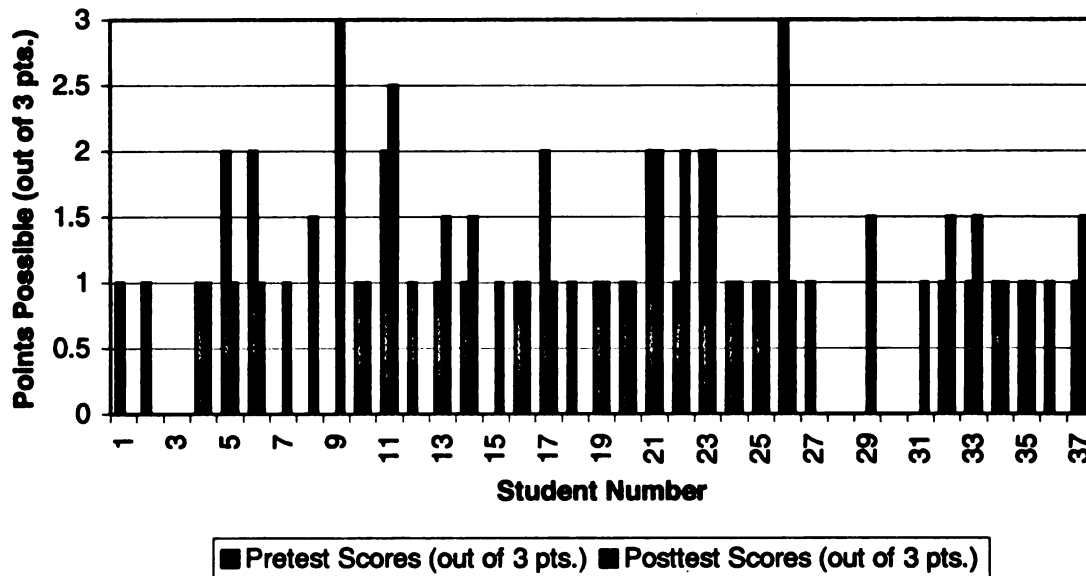
lecture or lab. They were expected to explain four effects like wind, water, chemical composition of soil, temperature of soil, disease, or herbivory. A majority of students that explained one effect on the pretest explained two or three effects on the posttest. Some students did not answer, or answered incorrectly on one or both of the assessments. Students showed a statistically significant improvement from pretest to posttest as indicated by a paired t-test resulting in a t-value of 4.35 and a p-value of 0.0001. One student showed a significant improvement from pretest to posttest answers. They left the pretest blank, while writing, "The living could pollute them or kill them. They could burn them down or use them for things. The non-living, there could be too much sunlight, rain, and natural fires." Even though they did not use explicit ecological terminology, at least three biotic or abiotic factors were explained. The pre- and posttest question 9 results are shown in Figure 10.

Figure 10. Dune Ecology Unit Pretest and Posttest Student Scores for Question 9



10) Question ten asked students to, "Explain how existing plants (e.g. grasses, flowers, shrubs, and trees) in a field or sand dune can facilitate or inhibit the growth of new plants." I was looking for answers to include concepts such as: provide biomass (fertilizer), block effects due to abiotic/biotic factors, competition, or resource in-/availability. Students had difficulty with this question probably in understanding the terms "facilitate" and "inhibit." The statistical analysis showed little, if any, attainment of conceptual knowledge regarding this question. Many students did not complete one or both of the assessments, or improve upon their answers to the pretest. Some students made an improvement from pretest to posttest answers, but few received all 3 points. Students showed no statistically significant improvement, as indicated by a paired t-test, resulting in a t-value of 0.349 and a p-value of 0.729. One student did not answer the pretest, but wrote, "Existing plants facilitate the growth of new plants by dispersing seeds, giving nutrients through the soil. They inhibit plant growth by taking water, sunlight, and not giving area to grow" on the posttest. It showed a general acquisition of knowledge regarding biotic/abiotic relationships that elicit community change over time. The pre- and posttest question 10 results are shown in Figure 11.

Figure 11. Dune Ecology Unit Pretest and Posttest Student Scores for Question 10



Ecology Unit Survey Analysis

Consenting students were asked to complete an *“Ecology Unit Survey”* (Appendix B4) at the end of each week to assess the strengths/weaknesses of the unit. The survey had 5 questions focusing on what they learned, any beneficial teaching methods used, likes/dislikes, suggestions, and the overall rating for the week. I perused the answers and developed ideas regarding the unit’s strengths and weaknesses, and will consider these when developing future unit revisions of pedagogical techniques. Many students listed or explained what was learned during the week for question 1 in the survey. They frequently wrote that lecture and note-taking were not as beneficial of teaching strategies as cooperative, student-driven learning activities or labs. They were not enthused about writing up the labs or taking notes. They did enjoy doing the labs/activities,

watching films, answering book questions to review the material, and getting “hands on” experience. Some students felt they did not need to change anything to be more successful at learning the concepts. Others blamed themselves for not studying, reading, taking notes, or doing the assignments/activities to learn the concepts. Students sometimes felt detached from the learning when we covered the material too quickly (e.g. vocabulary, notes), or when we did not review or reinforce the concepts enough. The modification of the labs, whereby I set up the lab procedure and/or demonstrated them, was not deemed beneficial by the students. They preferred to complete the labs themselves within lab groups. Overall, they desired more cooperative, “hands-on,” student-centered learning experiences as opposed to inductive activities of reading and note-taking. They preferred more activities or assignments that make the subject “real,” “exciting,” and “enjoyable.” The dune visit on June 3rd was one activity they really enjoyed during the unit, as one student mentioned, “It was pretty awesome. It was a lot easier to learn what the plants looked like in person. I had a lot of fun.”

Overall Assessment Techniques/Results

The key concepts and principles were assessed throughout the unit by weekly quizzes, labs, assignments, and the two tests in addition to the pre- and posttest questions. Overall quiz and test percentages, and the statistical results of the pretest and posttest questions are listed in *“Ecology Unit Assessment Results”* (Appendix B5). Each student had to collect data, make observations, answer analysis questions, and write a conclusions section for each lab. This enabled students to reinforce the key vocabulary, concepts, and ideas while

relating them to biotic/abiotic factors affects on different plant species. I scanned through each lab to check for its correct completion and any misconceptions regarding content. Weekly quizzes provided a formative assessment technique for students to learn the new vocabulary and concepts. Their mistakes and misconceptions on the quizzes could be corrected before the test. Assignments were given almost daily in the form of inductive pedagogical strategies- reading, writing vocabulary, or answering book questions. Some assignments were given in class, so as to gauge the students' learning and provide help for the struggling learners. All homework assignments were graded in class to reinforce the terms and ideas from each section. Students were ultimately assessed on the two unit tests titled, *"Introduction to Ecology/Geology of the Great Lakes Region"* (Appendix B2a) and *"Populations/Communities"* (Appendix B2b). These tests contained the previously mentioned posttest questions, but also consisted of numerous matching, true/false, multiple choice, and short answer, analytical and applicatory type essay questions.

DISCUSSION AND CONCLUSION

The results/evaluation data suggests that students made some gains in their overall knowledge of ecological concepts during this unit. Students showed significant improvements on questions 1, 4, and 7-9 from pretest to posttest, but only slight to no knowledge gains on questions 2-3, 5-6, and 10. Questions 1, 4, and 7-9 assessed the main ideas/concepts of the unit by asking students to, "Define Ecology," "Describe the content of soil typically found in Michigan," "Define Pioneer Species," "What is Succession?," and "Explain how plant species are affected by the living and non-living portions of their environments." These student gains suggest an overall success in teaching the concepts of ecology, soil composition, pioneer species, succession, and abiotic and biotic factors. Consequently, these topics were stressed and reinforced the most throughout the unit. Questions 2-3, 5-6, and 10 most likely caused problems due to their ambiguity, vocabulary content, and the "open-ended" application type responses they required. Although reflecting a low percentage (50-60%), students' average test scores improved from pretest to posttest, as displayed in the *"Ecology Unit Assessment Results"* (Appendix B5). The primary goal of improving the learning of ecology by focusing on the students' interests, life experiences, and prior knowledge was evident through student observation and oral evaluations/discussions. Students seemed enthused when the term "sand dune" became a part of a lecture or activity, and some students openly expressed their excitement regarding the study of dune ecology. Enhanced teaching methods and modified student activities most definitely led to the unit's improvement over

past years. The goal of facilitating the learning of ecological concepts by using a local resource - the sand dunes - was achieved, while the increase of “hands on”, cooperative learning laboratory activities was partially achieved. Revisions to the unit’s design and implementation will foster future improvement and continued success. The unit’s overall effectiveness will most likely improve when four factors affecting its implementation are addressed, including, unit design/length, use of labs (revised or new), assessment strategies, and student involvement (enthusiasm).

The unit was specifically developed to enhance the teaching of Ecosystems benchmarks within the Michigan Curriculum Framework of Science Benchmarks (2000). Pre- and posttest questions, developed before the unit’s implementation, were aligned with the following benchmarks to gauge the unit’s success:

- (LEC) III.5.1: Describe common ecological relationships between and among species and their environments. (Pre-/Posttest Items: 1-3, 5-10)
- (LEC) III.5.3: Describe general factors regulating population size in ecosystems. (Items: 1-3, 5-10)
- (LEC) III.5.4: Describe responses of an ecosystem to events that cause it to change. (Items: 1-3, 5-10)
- (LEC) III.5.5: Describe how carbon and soil nutrients cycle through selected ecosystems. (Items: 2-10)

Students were also assessed based on these objectives developed by me:

- Explain how organisms/ecosystems change over time. (Items:1-3, 5-10)
- Analyze plant physiological adaptations to their environment. (Items: 1-3, 5-10)

- Identify numerous plants found in the sand dunes.
(Populations/Communities Test, Items: 96-119)

The unit was designed to modify and improve previous years pedagogical techniques generally requiring students to read the book, take notes, and answer questions from the book or worksheets. The revised unit used the book as a resource for learning key ecological concepts and background knowledge. This information was then reinforced using relevant, designed labs, activities and assessments linking the concepts to the sand dunes of Southwestern Michigan.

The *“Physical Factors of Soil”* lab was the first designed lab/activity implemented. It compared the amounts of various soil particle types in three different samples (forest, dune, and field). My plan of providing a “grandiose picture” of abiotic/biotic factor relationships affecting plant growth in the dunes started with a glimpse of the soil's properties. Student's showed an improved understanding of this relationship in their answers to posttest questions: 4 and 7-9. At this point in the unit though, students just gathered and analyzed data regarding the soil's composition. The lab demonstration/discussion, student's responses assessed within the lab write-up, and improved gains shown on question 4 of the posttest suggest the successful attainment of knowledge regarding soil composition. As the unit's lab activities progressed, they were expected to connect soil composition differences to affects on plant species germination, growth, and frequency. Unfortunately, germination and growth observations were hindered because some future unit labs provided inconclusive results.

The *“Abiotic Factors of Soil”* activity was intended to foster further connections between the soil content in different sections of the dune, and plants that can be found there. Students conducted several tests on soil from the foredune, interdune, and backdune. They determined the moisture content, water-holding capacity, and pH of all of the soil samples. This lab posed some problems for students due to its length, detail, and the experimental tests involved. A lot of sand and soil was spilled on desktops, as students enthusiastically attempted this “hands-on” experience. Many students were forced to complete the lab outside of class time. The acquisition of this lab’s concepts was evident in some students’ gains on question 9 of the posttest. One student wrote, “Because of sun, water, and nutrients in the soil.” Answers within the lab’s analysis section also displayed students’ correct application of the data and observations collected.

As we moved into studying populations, I developed the “Plants of the Southwestern Michigan Sand Dunes” PowerPoint handout for students to learn the most common dune plants. Using the dune plant Sea Rocket (Cakile edentula) they would next apply the abiotic factors of soil to differing plants in the *“How do Abiotic Factors Affect Different Plant Species?....”* lab. The abiotic factor affects on Sea Rocket were compared to Fast Plants® (Brassica rapa) and Garlic Mustard (Cakile edentula). These plants are all in the Mustard family. Unfortunately, the Sea Rocket and Garlic Mustard seeds did not grow in either the potting soil or sand, while the Fast Plants® only grew in the potting soil. This lab’s design, set-up, and demonstration also inhibited students’ ability to learn

within a “hands-on,” cooperative group setting. Students retained some knowledge regarding abiotic factors affects on plants, as evidenced in responses to question 9 of the posttest. One student answered by saying, “An organism’s water [sic] light [sic] and pH level will affect it.” Most students did poorly on the dune plant identification portion of the posttest.

Students next determined whether nitrogen, phosphorus, and potassium were limiting nutrients for the growth of Fast Plants®, Garlic Mustard, and Sea Rocket. They identified the affects these nutrients had on plant growth while completing the *“Identifying Limiting Nutrients....”* lab. Again, only the Fast Plants® germinated, but students were able to observe, measure, and analyze the effect fertilizer and nutrients had on this plant’s growth. This demonstration lab prevented students from gaining knowledge through group interaction and discussion, most likely limiting knowledge “transfer.”

The next four activities were designed to instill a sense of the abiotic/biotic factors plants encounter within communities through space and time. They coincided with the classroom lectures focused on community concepts.

“Intraspecific Competition in Plants” and *“Interspecific Competition in Plants”* activities required observing and measuring the effects of overcrowding on radish plants, and observing and measuring the effects of growth interactions between radish and sunflower plants, respectively. Dune plants were not used, unfortunately, because they required more temperamental growth conditions over a longer period of time. Students were expected to infer the observed patterns of competition with similar patterns that occur to plants on the dunes.

Again, these demonstration labs were most likely ineffective because they lacked student “hands-on” activity. Students also showed no significant improvement in the “transfer” of this lab’s conceptual knowledge from responses to pretest and posttest question 10.

The *“Biotic/Abiotic Factors of an Old Field”* lab was intended to introduce students to ecological field testing methods. They systematically sampled biotic factors and calculated quantitative data regarding plant types found in an old field. Unfortunately, students collected the data from a pre-designed hypothetical belt transect map of a typical old field in Michigan. They were able to apply ecological field sampling techniques of organisms using these transects, even though they were not in a “real” field. This most likely detracted from making the learning “real” for the students. However, some students were able to apply a similar procedure, at the sand dunes, in the final culminating activity,

“Biotic/Abiotic Factors of a Lake Michigan Sand Dune.”

This last lab was designed to incorporate all of the concepts learned regarding species, populations, and community dynamics of the dunes. Students were expected to collect evidence describing the primary succession of plant species in the area. We traveled to the sand dunes at Oval Beach in Saugatuck to complete this lab. Students again systematically sampled biotic factors (plant types/abundance) along with measuring abiotic factors (light intensity, wind velocity, air temperature, soil temperature). They combined these measured abiotic factors with those discovered in the previous *“Abiotic Factors of Soil”* lab. This ultimately forced them to analyze all of the conditions affecting the growth

and survival of dune plants. Only 10 students completed this lab, and were unable to share their findings with classmates hindering the overall application of the unit concepts. Like the other modified labs, this incomplete lab most likely detracted from students' conceptual knowledge gains during the unit. In fact, it was completed after the posttest was given, so students' could not have applied their knowledge learned anyway.

The other lab designed to teach succession, *"Observing Succession in Aged Tap Water"* was unable to be implemented due to time constraints.

In principle, these modified lab activities were optimal for reinforcing the ecological concepts taught in class. The realities of inadequate time, space, materials, and student enthusiasm affected their eventual implementation. Students copied these activities, which were quite lengthy at times, into their lab composition books. This provided a means by which students could review the lab before completing it, but it was not a totally worthwhile idea. Students lost their excitement and anticipation when copying the entire lab before completing it. Some of the labs were delayed as we waited for the plants to germinate, and this coupled with the time needed for their eventual completion caused the unit itself to lengthen.

Materials and space needed for all students to complete the labs were at times unavailable. Most of the labs were demonstrated or modified to account for lacking materials and space, and to shorten the time needed for the unit's complete implementation. This was detrimental toward my goal of increasing "hands-on", cooperative learning lab activities. Although they were completed,

students were not always able to take ownership of labs by completing them within a group setting.

As observed, students were excited about learning ecology and being able to link textual concepts to their natural occurrence in the dunes. The modification, implementation, and completion of some cooperative lab activities helped to make this a reality. Students' affective and cognitive realms of knowledge regarding this local natural resource made the unit "real." At times though, students complained about too much writing whether with labs or during lecture (note-taking). The direct "transfer" of knowledge regarding dune plants, geology, and the ecological concepts associated with species, populations, and communities sometimes took too long. Some students became "uninspired" by the plethora of notes given, and craved more group discussions or activities. Labs meant to evoke and engage analytical, critical thinking of the key ecological concepts sometimes decreased student enthusiasm due to their detail and length. Future revisions will take these student responses into consideration.

Revisions to portions of the unit will continue engaging students in the teaching of ecology using a local natural resource – the dunes. Although I liked the lab designs and objectives, the write-ups can be shortened by not requiring students to write out the entire procedure sections. Plants used in the labs can be planted earlier, and better germination results could be gained from added research on my part. If possible, more materials can be purchased over the years to allow for more group lab activities. The last lab at the dunes was wonderful, but future students involved will present their data and experiences to

classmates upon their return. These alterations can allow students to finish the lab exercise concepts before they are assessed on quizzes and tests. The acquisition of student computers, in my class this year, could enhance current unit activities and provide for new ones. Students could complete portions of their lab data using Microsoft Excel, study successional change using the Internet, or complete any other wide range of computer-aided activity regarding the dunes and ecology. Some concepts from sections in the book can be modified to comprise examples related to the unit, or omitted based on their lack of connection to the key concepts. I believe, though, that the PQ3R reading strategy implemented to preview, question, read, recite, and review these sections of text helped students divulge meaning from numerous concepts. I observed the engagement of students' minds as we read, and will continue to practice this technique during future class readings. Book questions, given as assignments, can also be modified to match the unit's content. The quizzes and tests can be edited to reflect the assessment of more concise conceptual objectives. Overall, more time spent with less content, and with shorter, more concise labs, lectures, textual background information/references, and assessments might increase the learning of unit objectives. Future considerations for new labs and activities will be acquired by researching pedagogical techniques tried by other teachers, similar to those discussed in the literature review.

Students can research and present ecological data (i.e. biotic/abiotic factors) regarding a particular dune plant. I can incorporate problem-based

ecological scenarios, like Jack Tessier's (2004) idea of developing environmental consultant teams, to research the repercussions of land development on or near the sand dunes. Fictitious town government issues could be developed, and students could apply their knowledge of the dune and abiotic/biotic factors toward solving the problem (Singletary, 2000). The production of dune models or even aquariums could allow students to review the unit's concepts. Students can learn about transects, sampling techniques, and field research methods through a "TRASH" ecology project (Lind, 2004). They can develop ecological learning activities to teach elementary students about the environment and the dunes. Also, ecological games, simulations (Lauer, 2003) or scenarios can be developed to replace the monotonous, traditional vocabulary exercises and lectures. Assessments can become more authentic and reflective of the diverse learning styles from added research. Current pretest and posttest questions can be revised or kept the same, while new questions are amended.

A statistical analysis of the 10 pretest and posttest questions from this unit, provided by a paired t-test, suggested students gained knowledge. Thirty-seven data points, each representing a student's pretest and posttest total scores out of 32 points, were entered into the t-test. The mean difference between the two tests was calculated as 7.15 with a 95% confidence interval. The t-value was 8.20 with 36 degrees of freedom and a probability (p-value) of 0.0001. These results provide statistically significant data suggesting the successful teaching of the key concepts.

Average overall scores were calculated for both the pretest and posttest questions. Thirty-seven students averaged 8.05 points out of 32 possible points (25.2 % correct) for the 10 pretest questions. The same students averaged 15.2 out of 32 possible points (47.5%) for the same posttest questions.

These low assessment percentages could have been influenced by a number of factors affecting the test design. Many of the test questions were open-ended, subjective, application-type questions that perplex high school students. Some of the vocabulary in the questions or statements may have been too ambiguous. Many students did not answer either questions on the pretest or posttest. These students were either absent and didn't make-up the test, or skipped a question entirely. The rigorous, high standards I applied when correcting the answers, using *"Ecology Unit Pretest/Posttest Rubric,"* may have caused me to overlook sufficient answers. Only ten questions were measured in the pretest and posttest. A more diverse grouping of questions will be added in future revisions. The tests were very long. Shorter, more concise tests could cause students to answer all questions instead of omitting some. The final test needs to be implemented after the final culminating unit activity – dune visit. Concepts found on the pretest, quizzes, and other assessment techniques need to be reinforced to increase students' knowledge before the test. This includes implementing formative assessment techniques whereby students' papers are returned promptly to alter any misconceptions. Assignment and assessment results were not always efficiently returned to students. The tests included many multiple-choice type questions and were worth forty percent of their grade.

This could have encouraged students to excel at the tests, while not worrying about the pretest, quiz scores, or other assessment techniques (roughly 15-20% of their grade).

Students were also assessed throughout the unit using weekly quizzes, homework assignments, labs/activities, and other test questions. The results of these assessments showed a marked increase in conceptual learning, as opposed to the results of the direct learning (e.g. lecture, assignment and testing) teaching methods that were imposed during this unit in the past. Results of these assessments are found in *"Ecology Unit Assessment Results."*

Some students verbally commented about their appreciation for the unit design, their personal connection to the topic – the dunes, and the overall acquired or renewed interest they had for the subject of ecology.

The previously listed objectives were successfully implemented except:

- (LEC) III.5.5: Describe how carbon and soil nutrients cycle through selected ecosystems.
- Analyze plant physiological adaptations to their environment.

The first objective is generally taught while covering ecosystems. This was not covered until after the unit in January. Nutrient availability needed for plant growth was analyzed, but the particular nutrient cycles were not a part of the unit. The second objective of physiological adaptations was not covered in depth due to the complexity of the subject. However, students were able to identify the results of these adaptations in the dune plants.

All other objectives were taught, but will benefit from future revisions to the unit aiming to converge their content, strengthen their teaching “transfer,” and increase their retention in students’ minds. The modification of these objectives may also be necessary to facilitate the new mandatory state exam, administered by ACT, Inc, and taken by students in this core general biology class. This exam, similar to the MEAP, will most likely endorse future passing students’ graduation diplomas.

The production, inception, and implementation of this ecology unit in my general biology class has renewed my vigor as a biology teacher. I have witnessed the success and affective response inspired by interactive cooperative learning activities applied to a “real world” natural setting – the dunes. The joyful experiences I had contemplating nature during youth, secondary schooling, and throughout college are now self-realized and shared with my students. This allows me to “teach who I am” through the content that I love – biology and ecology. I plan on continuing to share myself through this subject matter, and to instill my passion within the classroom and beyond. I will research, develop, and utilize progressive teaching methods in the classroom to ignite my optimistic spirit. This will be transferred to students to positively facilitate learning. The beginnings of this “Utopian classroom” were observed through the initial implementation of this ecology unit. I will continue to incorporate “hands on”, cooperative, and critical thinking teaching methods within a “real-world” context to facilitate my students’ development into educated, informed, and “generative” citizens.

Appendix A

Parent/Student Consent Form

Re: Data Collection for Master's Thesis

Date: September 7, 2004

Dear Parents/Guardians and Students,

During the past three years, I have been working on my Master's Degree in the Program for Biological Science Teachers within the Division of Science and Mathematics Education at Michigan State University (MSU). An important degree requirement includes writing and submitting a thesis based on the implementation, analysis, and evaluation of a unit taught in class. The ecology unit I developed over the summer addresses portions of the State of Michigan science benchmarks regarding ecosystems. It contains classroom labs/activities, homework assignments, quizzes, and pre-/post-tests that emphasize and utilize the environment in close proximity to South Haven High School (i.e. fields, sand dunes, etc.). The unit will cover approximately 6-8 weeks from the beginning of school. With your permission, I will be collecting data from the aforementioned assessments, and from students' reflections and opinions expressed on surveys postulating the unit's effectiveness. I also would like to include pictures of the students performing activities during the unit.

At no time will the students' names be used in, or attached to, any work or pictures included in the thesis paper. Your privacy will be protected to the maximum extent allowable by law. There is no penalty for denying or revoking consent, and your decision *will not* affect the student's grade in any way. The assignments developed for the unit will be assessed whether or not your permission is given. Declining simply means that data from the student's work will not be included in my thesis. You may request your student's work not be included in the thesis at any time during its implementation.

If you have any questions about this study, please contact me at phone number (269) 637-0500, or by e-mail at MWoolcock@shps.org. If you have any questions or concerns regarding your rights as a student participant, or are dissatisfied at any time with any aspect of this study, you may contact - anonymously, if you wish - Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517) 355-2180, fax: (517) 432-4503, e-mail: ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

Sincerely,

Mark W. Woolcock
Science Teacher
South Haven High School

Parent/Student Consent Form
Re: Data Collection for Master's Thesis
Date: September 7, 2004

Please read the following carefully, mark all that apply, and provide names/signatures where appropriate. Please return this form to me by Wednesday, September 8th, 2004.

_____ (✓) I voluntarily agree to have _____
participate in this unit. (print student name)

_____ (✓) I voluntarily agree to allow the above named student's picture to be
taken during the unit.

Parent/Guardian Signature

Date

_____ (✓) I voluntarily agree to participate in this unit.

Student Signature

Date

Name:
Hour:

Ecology Unit Pretest

Directions: Answer the following questions/statements using any existing prior knowledge you have regarding ecology. Please be descriptive and thorough when answering these questions/statements.

1. Define Ecology.
2. People, communities, and cities change in function and appearance over time. How can you tell if something in the environment changes over time?
3. What factors/occurrences affect environmental change over time?
4. Describe the content of soil typically found in Michigan.
5. Explain why geological features (e.g. mountains, valleys, sand dunes, etc.) change over time.
6. How do populations of organisms affect change over time?
7. Define Pioneer Species:
8. What is succession?
9. Explain how plant species are affected by the living and non-living portions of their environments.
10. Explain how existing plants (e.g. grasses, flowers, shrubs, trees) in a field or sand dune can facilitate or inhibit the growth of new plants.

Appendix B2a

Mr. Woolcock

Introduction to Ecology/ Geology of the Great Lakes Region Test

Name:
Hour:

Matching: Write the correct letter in the blank before each numbered term.

- | | |
|------------------------------|---|
| _____ 1. community | a. where an organism lives |
| _____ 2. generalist | b. phenomenon that insulates Earth from the freezing temperature of space |
| _____ 3. stabilized dune | |
| _____ 4. resources | c. members of a single species living in one place at a time |
| _____ 5. habitat | |
| _____ 6. population | d. organisms interacting in a specific area |
| _____ 7. greenhouse effect | e. increase in average global temperature due to trapped excess greenhouse gases |
| _____ 8. global warming | |
| _____ 9. inland dune | f. a species with a broad niche |
| _____ 10. interdune | g. study of the interactions between organisms and their environment |
| _____ 11. coastal dunes | |
| _____ 12. blowout | h. energy and materials needed by a species |
| _____ 13. longshore currents | i. the upper portion of an open lake |
| _____ 14. foredune | j. a low trough in the dunes between a foredune and a stabilized dune |
| _____ 15. fetch | |
| _____ 16. spit | k. a dune covered with vegetation |
| _____ 17. lower beach | l. a structure that is formed when a long shore current carries sediment out of a bay |
| _____ 18. upper beach | m. younger than the inland dunes |

n. part of the beach closest to the water

q. currents that pass along the shoreline of Lake Michigan

o. part of the beach distinguished by the presence of marram grass

r. ridges that are low dunes (30 to 50 feet high), closer to the water's edge

p. generally the oldest dunes

s. a reactivated dune, parabolic shape, caused by the absence of vegetation

True-False: If a statement is true, write T in the blank. If a statement is false, write F in the blank, and then in the space provided, explain why the statement is false.

_____ 19. The world's population tripled from 1 billion to 3 billion people in just 33 years.

_____ 20. The greenhouse effect is a natural phenomenon caused by trapped heat and solar radiation within the Earth's lower atmosphere.

_____ 21. A tolerance curve shows the range of a certain environmental factor that a species cannot tolerate.

_____ 22. Conformers change their internal conditions as their environment changes.

_____ 23. The realized niche of a species is the range of resources it could use.

_____ 24. Glaciers covered the entire Great Lakes region approximately 10,000 to 12,000 years ago.

_____ 25. During the Algonquin Epic, Lake Michigan was at its highest level in geological history.

_____ 26. There were five major epics that evoked dune formation in the vicinity of Lake Michigan.

_____ 27. Till and debris deposited at the receding edge of the glaciers formed end moraines.

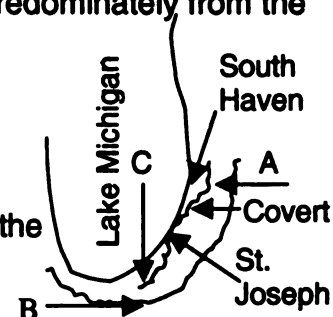
- _____ 28. The lake border moraine prevents the formation of inland dunes.
- _____ 29. During glaciation, inland dunes were formed when lake levels were high.
- _____ 30. During the Algoma Epic, the lake drained through the Kalamazoo River Valley.
- _____ 31. While an understanding of the interactions between organisms and their environment was very important to early hunter and gatherer humans, it is even more important today because humans are having significant effects on the environment.
- _____ 32. The world's climate is warming as large amounts of CO₂ are released into the atmosphere.
- _____ 33. An organism's range can be determined by its tolerance to only one environmental variable.
- _____ 34. An organism's niche includes its habitat.

Multiple Choice: Write the letter of the most correct answer in the blank.

- _____ 35. The three necessities for coastal dune formation include
- a. sand, wind/water, and the absence of a lake border moraine.
 - b. sand, plants, and Lake Michigan.
 - c. sand, wind/water, and the presence of large trees.
 - d. wind/water, lake currents, and the presence of a lake border moraine.

- _____ 36. Winds that blow across Lake Michigan flow predominately from the
- a. east.
 - b. west.
 - c. southwest.
 - d. northwest.

- _____ 37. In the figure to the right, letter "A" represents the
- a. the Covert ridge (lake border moraine).
 - b. Valparaiso moraine.
 - c. Kalamazoo moraine.
 - d. Saugatuck moraine.

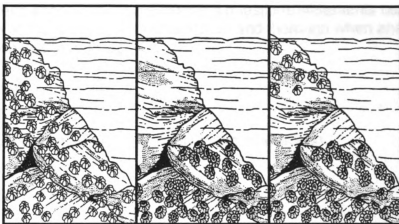


- _____ 38. In the figure to above, letter "B" represents the
- lake border moraine.
 - Valparaiso moraine.
 - Kalamazoo moraine.
 - Covert moraine.
- _____ 39. In the figure above, letter "C" represents
- an area where dunes can form.
 - an area where dunes cannot form.
 - the Covert ridge, another name given to the lake border moraine.
 - Lake Michigan.
- _____ 40. The areas of a tolerance curve that lie at the extreme high or low for the environmental variable represent the
- optimal range of an environmental variable for an organism.
 - zones of physiological stress of an environmental variable for an organism.
 - zones of physiological intolerance of an environmental variable for an organism.
 - None of the above
- _____ 41. Which of the following is not an adaptation for avoiding unfavorable conditions?
- acclimation
 - body temperature regulation
 - dormancy
 - migration
- _____ 42. When two species compete, the niche that each organism ultimately occupies is its
- competitive niche.
 - realized niche.
 - fundamental niche.
 - exclusive niche.
- _____ 43. If the niches of two organisms overlap,
- the organisms may have to compete directly.
 - the two organisms will always form a symbiotic relationship.
 - both organisms will disappear from the habitat.
 - one organisms usually migrates to a new habitat.



- _____ 44. Which of the figures above depicts a regulator?
- A
 - B
 - C
 - B and C
- _____ 45. The small percentage of ultraviolet radiation that strikes the Earth from the sun is the cause of
- climate changes.
 - sunburns and skin cancer.
 - global warming.
 - the greenhouse effect.
- _____ 46. The lowest, most definitive level of organization in ecology is
- an ecosystem.
 - an organism.
 - a population.
 - the biosphere.
- _____ 47. When organisms affect and are affected by other organisms in their surroundings and with the non-living parts of their environment, it is called
- ecology.
 - disturbances of the ecosystem.
 - interdependence.
 - modeling.
- _____ 48. An example of an abiotic factor is
- water.
 - sunlight.
 - temperature.
 - all of the above.

- _____ 49. Some organisms adjust their tolerance to abiotic factors through
- a. dormancy.
 - b. acclimation.
 - c. migration.
 - d. all of the above.
- _____ 50. Conformers are organisms that
- a. use energy to control internal conditions.
 - b. change over many generations.
 - c. do not regulate internal conditions.
 - d. none of the above
- _____ 51. A long term strategy to avoid unfavorable conditions by moving to another, more favorable habitat is called
- a. dormancy.
 - b. migration.
 - c. hibernation.
 - d. all of the above.
- _____ 52. A species' fundamental niche is
- a. the range of resources it can potentially use.
 - b. the range of conditions it can potentially tolerate.
 - c. where it probably competes for resources.
 - d. all of the above
- _____ 53. The range of resources a species actually uses is called
- a. an abiotic factor.
 - b. fundamental niche.
 - c. a realized niche.
 - d. a regulator.
- _____ 54. An ecosystem consists of
- a. a community of organisms.
 - b. energy.
 - c. the soil, water, and weather.
 - d. all of the above
- _____ 55. The physical location of an ecosystem in which a given species lives is called
- a. habitat.
 - b. tropical level.
 - c. community.
 - d. food zone.



A. The barnacle *Chthamalus stellatus* can live in both shallow and deep water on a rocky coast.

B. The barnacle *Balanus balanoides* prefers to live in deep water.

C. When the two live together, *Chthamalus* is restricted to shallow water.

The following questions refer to the diagrams above illustrating experiments performed with two species of barnacles that live in the same area.

- _____ 56. Diagram "A" indicates that the barnacle *Chthamalus stellatus* can live in both shallow and deep water on a rocky coast. This is the barnacle's
- competitive niche.
 - realized niche.
 - fundamental niche.
 - exclusive niche.
- _____ 57. Diagram "B" indicates that the barnacle *Balanus balanoides* prefers to live in deep water. Deep water is the barnacle's
- competitive niche.
 - realized niche.
 - fundamental niche.
 - exclusive niche.
- _____ 58. Diagram "C" indicates that when the two barnacles live together, *Chthamalus* is restricted to shallow water. Shallow water is the barnacle's
- competitive niche.
 - realized niche.
 - fundamental niche.
 - exclusive niche.
- _____ 59. An organism's niche includes
- what it eats.
 - where it eats.
 - when it eats.
 - all of the above

Extended Response: Answer the following questions/statements using your knowledge of ecology. Please be descriptive and thorough when answering these questions/statements.

60. Define Ecology.

61. Describe the content of soil typically found in Michigan.

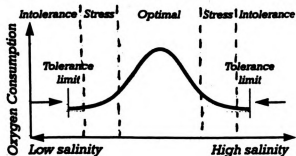
62. Explain how plant species are affected by the living and non-living portions of their environments.

63. Briefly explain three environmental problems caused by humans.

64. List three biotic and three abiotic factors found in the picture below.



65. Refer to the drawing below as you answer a-c.



- a. What kind of graph is shown above? What does it measure?
- b. What are the optimal conditions of salinity and oxygen consumption according to the graph?
- c. Could an organism with a low tolerance to salt in an oxygen rich environment survive in these conditions? Why or why not?

66. Soil from a field is mixed with water in a jar, shaken, and allowed to settle over a 24 hour period. Draw a picture of the observations you would make the following day. Label all of the horizons (5) and then answer letters a and b.

- a. Which type of soil was the most closely packed and why?
- b. Which type of soil was the least tightly packed, excluding gravel, and why?

67. Draw and label the different portions of a sand dune extending away from the shoreline (label: interdune, foredune, lower beach, middle beach, upper beach, stabilized dune, blowout). Place the appropriate drawings of vegetation or objects found in each area.

68. A plant disease infects most of the vegetation in a particular area, destroying it. How might the destruction of this vegetation affect the animal life in the area?

69. Which type of organisms are most likely to survive, those that have a narrow ecological niche or those that have a broad niche? Explain.

Appendix B2b

Mr. Woolcock

Populations/Communities Test

Name:
Hour:

Matching: Write the correct letter in the blank before each numbered term.

- | | |
|-------------------------------------|--|
| _____ 1. limiting factor | a. each species uses only part of the available resources |
| _____ 2. carrying capacity | b. one species is eliminated from the community due to competition for scarce resources |
| _____ 3. density-dependent factor | c. the sequential replacement of populations in a disrupted habitat |
| _____ 4. density-independent factor | d. the first species to colonize a new habitat |
| _____ 5. exponential growth | e. food shortages and living space |
| _____ 6. logistic growth | f. restrains growth of a population |
| _____ 7. population density | g. two dissimilar species live together in close association |
| _____ 8. growth rate | h. a harmless species resembles a poisonous or distasteful species |
| _____ 9. commensalism | i. the number of individuals per unit area |
| _____ 10. resource partitioning | j. a variable that affects population size regardless of population density |
| _____ 11. symbiosis | k. stable end point of succession |
| _____ 12. character displacement | l. the sequential replacement of populations in an area that has not previously supported life |
| _____ 13. mimicry | m. population size the environment can support for a long time |
| _____ 14. parasitism | n. cooperative relationship in which both species benefit |
| _____ 15. competitive exclusion | |
| _____ 16. mutualism | |
| _____ 17. species-area effect | |
| _____ 18. species diversity | |
| _____ 19. species richness | |
| _____ 20. climax community | |

- | | |
|--|--|
| _____ 21. primary succession | o. an index combining the number and relative abundance of different species in a community |
| _____ 22. secondary succession | |
| _____ 23. succession | p. the amount by which a population's size changes in a given time |
| _____ 24. pioneer species | q. species interaction where one organism is harmed while the other benefits |
| r. a pattern of species disruption in which larger areas contain more species than smaller areas | s. a population is at its carrying capacity, the birth rate equals the death rate and growth stops |
| t. the larger a population gets, the faster it grows | u. evolution of anatomical differences that reduce competition between spp. |
| v. interaction in which one species benefits and the other is unaffected | w. the number of different species in a community |
| x. the predictable, sequential replacement of populations in an ecosystem | |

True-False: If a statement is true, write T in the blank. If a statement is false, write F in the blank, and then in the space provided, explain why the statement is false.

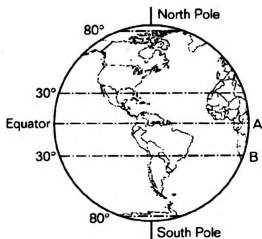
- _____ 25. Population growth is determined by total births, deaths, immigration and emigration.
- _____ 26. Two major properties of populations include their inability to change in number and evolve over time.
- _____ 27. Overlapping generations are present when parents and offspring are in different populations as reproductive adults.
- _____ 28. Discrete generations occur when one generation lives and dies before the next generation lives and dies.
- _____ 29. Exponential growth occurs in populations with overlapping generations and continuous reproduction.

- _____ 30. Predation is an example of a symbiotic relationship.
- _____ 31. Mimicry results in confusion on the part of a predator, resulting in the predator eating both harmless and poisonous species.
- _____ 32. When two species compete for limited resources, competitive exclusion is sure to take place.
- _____ 33. Mutualism is a symbiotic relationship in which only one party benefits.
- _____ 34. When two dissimilar species live together in a close association, they are part of a symbiotic relationship.
- _____ 35. A measure of the number of tree species in a community is a measure of the species diversity of trees in that community.
- _____ 36. Larger land areas usually include a greater diversity of climates than smaller land areas and can therefore support more species.
- _____ 37. Grasses are common pioneer species because they secrete acids that dissolve rock, releasing minerals for plant growth.
- _____ 38. Climate is not a factor in determining the ecosystem types found in the United States.
- _____ 39. Secondary succession typically proceeds from deciduous trees to shrubs and then finally grasses.
- _____ 40. Clumped population distributions result from organisms seeking clumped resources.
- _____ 41. In a stable community, effects of a disturbance are apparently dispersed because of the large number of links that exist between the large number of species present.

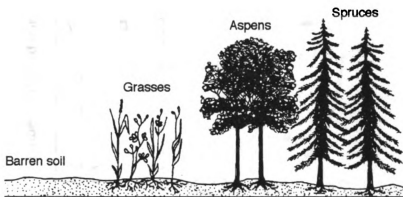
- _____ 42. The major difference between primary succession and secondary succession is that primary succession occurs only on land and secondary succession occurs in ponds and lakes.
- _____ 43. When succession takes place where there has been previous growth, it is called secondary succession.
- _____ 44. The critical resource required for plant growth that is usually absent in newly formed habitats is water.

Multiple Choice: Write the letter of the most correct answer in the blank.

- _____ 45. Pioneer species
- a. disperse many seeds over a large area.
 - b. are usually small plants.
 - c. are usually fast-growing.
 - d. All of the above
- _____ 46. In the process of succession,
- a. an unchanging climax community is the final stage.
 - b. organisms change the environment so that it can support the growth of other species.
 - c. progress toward a climax community cannot be altered by further disturbances.
 - d. grasses are present in primary succession but absent in secondary succession.
- _____ 47. Which of the following is a characteristic of a stable community?
- a. good resistance to insect pests
 - b. the ability to recover rapidly from a drought
 - c. a high species richness
 - d. a low number of predators
- _____ 48. Which of the following types of succession would most likely occur following a forest fire?
- a. primary succession
 - b. old field succession
 - c. secondary succession
 - d. lake succession
- _____ 49. Which of the following is not a characteristic of pioneer species?
- a. They are small.
 - b. They grow quickly.
 - c. They reproduce slowly.
 - d. They disperse many seeds.

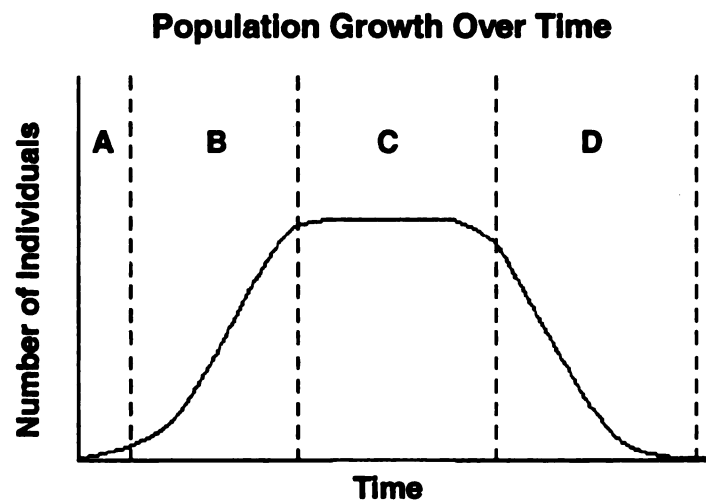


50. Refer to the illustration above. An ecosystem located along latitude "A" would
- have a shorter growing season than an ecosystem on latitude "B."
 - probably contain fewer species than an ecosystem at lat. "B."
 - probably be more diverse than an ecosystem at lat. "B."
 - probably have less rainfall than an ecosystem at lat. "B."



51. Refer to the illustration above. The process shown in the diagram is known as
- competitive exclusion.
 - succession.
 - symbiosis.
 - oligotrophy.
52. The end stage of primary succession in a northern latitude would be characterized by the predominance of
- lichens.
 - needle-leaved evergreen trees.
 - small plants and shrubs.
 - grasses.

- _____ 53. Common types of plants found in areas in the early stages of secondary succession are
- a. shrubs.
 - b. lichens.
 - c. grasses.
 - d. trees.
- _____ 54. As a population reaches its carrying capacity, there is an increase in competition for
- a. food.
 - b. shelter.
 - c. mates.
 - d. all of the above.
- _____ 55. Which of the following is a density-independent regulatory factor?
- a. food
 - b. water
 - c. temperature
 - d. number of nesting sites

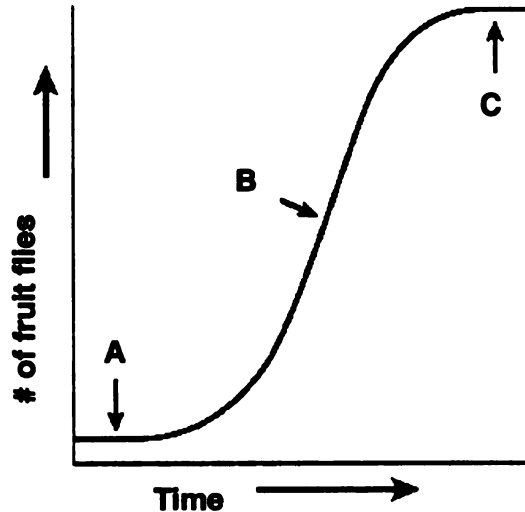


- _____ 56. Refer to the illustration above. During which time period are the birth rate and death rate equal?
- a. period "A"
 - b. period "B"
 - c. period "C"
 - d. period "D"
- _____ 57. Refer to the illustration above. The rate of growth of a population is represented by r . During which time period will $r=0$?
- a. period "A"
 - b. period "B"
 - c. period "C"
 - d. period "D"

- _____ 58. Refer to the illustration above. The time period during which r would have a negative value is
- period "A"
 - period "B"
 - period "C"
 - period "D"
- _____ 59. Which population might be least likely to be devastated by a disease outbreak?
- a small population who are all offspring of healthy, related parents
 - a large, genetically-diverse population
 - a small, genetically-uniform population
 - a few strong, healthy individuals
- _____ 60. A population of organisms grows
- with no natural restrictions except the availability of food.
 - when the birth rate exceeds the death rate.
 - only in the absence of predators or natural diseases.
 - all of the above
- _____ 61. When the birth rate and the death rate of a population are equal,
- the population is growing in size.
 - the population is remaining constant in size.
 - the population is decreasing in size.
 - the life expectancy of individuals in the population is very great.
- _____ 62. In the exponential model of population growth, the birth rate
- increases while the death rate remains constant.
 - remains constant while the death rate increases.
 - and the death rate remain constant.
 - and the death rate increase.
- _____ 63. During exponential growth,
- populations grow very slowly.
 - an increasing number of individuals in the population will lead to decreased growth.
 - a population always grows at a maximal rate unaffected by density-independent factors.
 - a population always grows at a maximal rate unaffected by density-dependent factors.
- _____ 64. The letter "K" on a logistic growth curve symbolizes the
- death rate.
 - carrying capacity.
 - birth rate.
 - vital capacity.

- _____ 65. Which of the following is a density-dependent regulatory factor?
- a. food shortages
 - b. decreased nesting sites
 - c. decreased territories
 - d. all of the above
- _____ 66. Logistic growth is evident in a population when
- a. the population increases until it reaches its carrying capacity.
 - b. the population increases forever.
 - c. the population increases, then decreases dramatically.
 - d. all of the above
- _____ 67. Populations are mostly regulated by
- a. density-dependent factors.
 - b. the amount of food resources.
 - c. the amount of space.
 - d. all of the above
- _____ 68. Predation occurs when
- a. a predator captures and wounds its prey.
 - b. a predator captures, kills, and consumes its prey.
 - c. a predator lets its prey escape.
 - d. all of the above
- _____ 69. Parasitism is a form of predation where
- a. one individual is harmed and the other is killed.
 - b. one individual is not harmed and the other benefits.
 - c. one individual is harmed and the other benefits.
 - d. one individual is harmed and benefits from it.
- _____ 70. Populations may be regulated by density-dependent factors like
- a. competition.
 - b. disease.
 - c. dispersal.
 - d. all of the above
- _____ 71. A tick feeding on a human is an example of
- a. parasitism.
 - b. mutualism.
 - c. competition.
 - d. predation.
- _____ 72. Which of the following is an example of mimicry?
- a. a poisonous species that resembles a harmless species.
 - b. coloration that causes an animal to blend in with its habitat.
 - c. a harmless species that resembles a poisonous species.
 - d. similarly colored body parts on two poisonous species.

- _____ 73. Characteristics that enable plants to protect themselves from herbivores include
- a. thorns and prickles.
 - b. sticky hairs and tough leaves.
 - c. chemical defenses.
 - d. All of the above

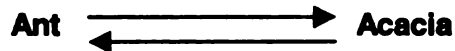


The following questions refer to the graph shown above.

- _____ 74. Point "A" indicates
- a. fast growth.
 - b. a population crash.
 - c. steady growth.
 - d. the carrying capacity (K).
- _____ 75. Point "B" indicates
- a. fast growth.
 - b. a population crash.
 - c. steady growth.
 - d. the carrying capacity (K).
- _____ 76. Point "C" indicates
- a. fast growth.
 - b. a population crash.
 - c. steady growth.
 - d. the carrying capacity (K).
- _____ 77. Which of the following usually results when members of the same species require the same food and space?
- a. primary succession
 - b. competition
 - c. secondary succession
 - d. interspecific competition

- _____ 78. Competitive exclusion occurs when
- a species is eliminated from a community because of competition.
 - new species enter an ecosystem.
 - species reproduce.
 - a species occupies a fundamental niche.

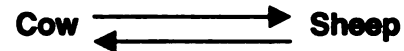
The ant keeps predators away from the acacia tree.



The acacia provides shelter and food for the ant.

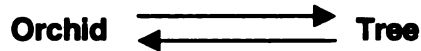
1

The cow eats grass.



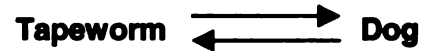
The sheep eats same grass.

2



The tree provides nutrients and a sunlit location for the orchid living on it.

3



The dog provides nutrients and shelter for the tapeworm living in its intestines.

4

- _____ 79. Refer to the illustration above. The relationship shown in diagram "4" above is
- commensalism.
 - competition.
 - mutualism.
 - parasitism.
- _____ 80. Refer to the illustration above. The relationship shown in diagram "2" above is
- commensalism.
 - competition.
 - mutualism.
 - parasitism.
- _____ 81. Refer to the illustration above. The relationship shown in diagram "1" above is
- commensalism.
 - competition.
 - mutualism.
 - parasitism.

- _____ 82. Refer to the illustration above. The relationship shown in diagram "3" above is
- a. commensalism.
 - b. competition.
 - c. mutualism.
 - d. parasitism.

Extended Response: Answer the following questions/statements using your knowledge of ecology. Please be descriptive and thorough when answering these questions/statements.

83. Define Ecology.

84. People, communities, and cities change in function and appearance over time. How can you tell if something in the environment changes over time?

85. What factors/occurrences affect environmental change over time?

86. Explain how plant species are affected by the living and non-living portions of their environments.

87. Explain why geological features (e.g. mountains, valleys, sand dunes, etc.) change over time.

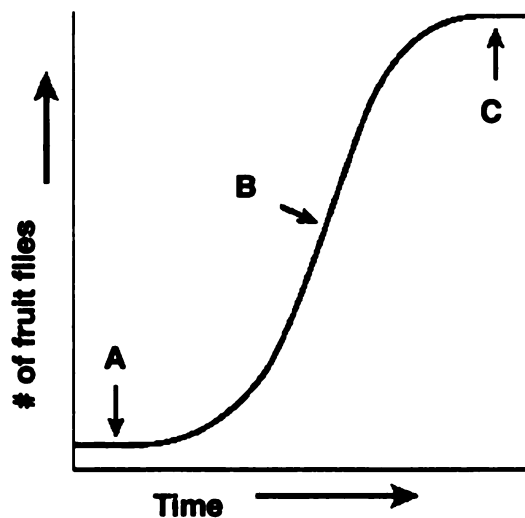
88. How do populations of organisms affect change over time?

89. Define Pioneer Species:

90. What is succession?

91. Explain how existing plants (e.g. grasses, flowers, shrubs, trees) in a field or sand dune can facilitate or inhibit the growth of new plants.

92. The graph below depicts the growth of a population of fruit flies over time.



a) Why does the population stop increasing after it reaches the point on the curve labeled "C"?

b) Would a density-dependent limiting factor have a greater impact on the population at point "A," "B," or "C" on the curve? Why?

c) Name one density-independent limiting factor that could affect this population of fruit flies. Would you expect this limiting factor to have a greater impact on the population at any particular point on the curve, and if so, which one?

Write your answers in the space below.

93. Why is species diversity a more meaningful measure than species richness?

94. What is the difference between primary and secondary succession?

95. The data in the table shown below were taken during a study of an abandoned southwestern Michigan sand dune. Ecologists counted the number of different kinds of grasses, shrubs, and trees present in three separate belt transects of the foredune, interdune, and backdune. Data was collected one, 25, and 50 years after it had been abandoned.

Time after abandonment of the sand dune.

	<u>1 year</u>	<u>25 years</u>	<u>50 years</u>
Number of grass species	2	4	7
Number of shrub species	0	7	12
Number of tree species	0	6	13
Total number of species	2	17	32

- a) In the space below, write three conclusions that you can draw from these data.
b) Make a prediction of the relative numbers of grasses, shrubs, and trees, and the total number of plant species that you would expect to see 100 years after abandonment of the sand dune.

Dune Plant Identification: Identify the common name of the plants shown on the computer display projector. (30 seconds per plant, repeats at the end)

- | | | |
|------|------|------|
| 96. | 106. | 116. |
| 97. | 107. | 117. |
| 98. | 108. | 118. |
| 99. | 109. | 119. |
| 100. | 110. | |
| 101. | 111. | |
| 102. | 112. | |
| 103. | 113. | |
| 104. | 114. | |
| 105. | 115. | |

Appendix B3

Ecology Unit Pretest/Posttest Rubric

1. Define Ecology. (3 points – 1 pt. per underlined word/phrase)
-the study of interactions between organisms and the living (biotic) and non-living (abiotic) components of their environment
2. People, communities, and cities change in function and appearance over time. How can you tell if something in the environment changes over time? (3 points – 1 pt. per example given)
examples: physical appearance, social interactions, chemical analysis, # of species, presence/absence of abiotic/biotic factors, etc.
3. What factors/occurrences affect environmental change over time? (3 points – 1 pt. per factor listed)
abiotic (wind, water, temperature)/biotic (interspecies relationships, etc.) factors, people, organisms, etc.
4. Describe the content of soil typically found in Michigan. (4 points – 1 pt. per component listed)
gravel, sand(coarse/fine), silt, clay
5. Explain why geological features (e.g. mountains, valleys, sand dunes, etc.) change over time. (3 points – 1 pt. per example given)
abiotic/biotic factors, Earth's composition/geological features, geological functions, climate, interrelationship of objects in space and time, etc.
6. How do populations of organisms affect change over time? (3 points – 1 pt. per example given)
population growth (change in #, evolve), predator/prey relationships, competition, disease, dispersal, predation/parasitism, human impacts, etc.
7. Define Pioneer Species: (3 points – 1 pt. per underlined word/phrase)
-the first species to colonize a new habitat
8. What is succession? (3 points – 1 pt. per underlined word/phrase)
-the predictable, sequential replacement of populations in an ecosystem
9. Explain how plant species are affected by the living and non-living portions of their environments. (4 points – 1 pt. per example given)
wind, water, chemical components of soil, soil composition, temperature, disease, predation, infection, etc.
10. Explain how existing plants (e.g. grasses, flowers, shrubs, trees) in a field or sand dune can facilitate or inhibit the growth of new plants. (3 points – 1 pt. per example given)
provide biomass, bio-/abiotic factor effects, competition, resource use, etc.

Appendix B4

Ecology Unit Survey

Directions: Answer the following questions/statements regarding the ecology unit over the past week. Please be descriptive, thorough, and honest when answering these questions/statements.

- 1. Did you learn anything about ecology over the week? If so, explain.**

- 2. Was the method of teaching beneficial for your learning? Explain why or why not.**

- 3. List some aspects of the week that you enjoyed or did not enjoy.**

- 4. Was there anything you could have changed to be more successful at learning this week? Was there anything that you would keep the same?**

- 5. Give an overall rating for the week with a ten (10) being very satisfied and a one (1) being unsatisfied. Provide comments about your rating, if desired.**

1-----2-----3-----4-----5-----6-----7-----8-----9-----10

Comments:

Appendix B5

Ecology Unit Assessment Results

Tests	Students' Average Scores (percent correct out of 100)				
Ecology Unit Pretest	Entire Test	Pretest Questions			
	25.2%	1. 25.2%			
		2. 31.5%			
		3. 47.7%			
		4. 8.1%			
		5. 40.5%			
		6. 27.9%			
		7. 11.7%			
		8. 6.3%			
		9. 25.7%			
		10. 32.4%			
Introduction to Ecology/Geology of the Great Lakes Region	Entire Test	Posttest Questions	t-test results per question	t-value	p-value (0.05 cutoff)
	60.9%	1. 78.8%	Question 1	11.2	0.0001
		4. 39.2%	" 4	4.67	0.0001
		9. 45.6%	" 9	4.35	0.0001
Populations/Communities	Entire Test	Posttest Questions			
	56.2%	2. 40.5%	" 2	2.31	0.027
		3. 54.1%	" 3	0.865	0.393
		5. 47.3%	" 5	1.42	0.165
		6. 33.8%	" 6	1.71	0.096
		7. 54.5%	" 7	6.78	0.0001
		8. 50.5%	" 8	8.04	0.0001
		10. 34.2%	" 10	0.349	0.729

Quizzes	Students' Average Scores (percent correct out of 100)
Introduction to Ecology	66.8%
Geology/Glaciation of the Great Lakes Region	54.5%
Populations	61.9%
Community-Interactions	63.6%
Properties of Communities/Succession	61.3%

Appendix C1

Physical Factors of Soil

Problem: What are the physical factors of the soil? How can soil influence the survival of many living things?

Purpose: Compare the amounts of various particle types in three different soil samples (forest, dune, field).

Materials (per group):

3 specimen jars with lids
water
metric ruler

pen/pencil
white labels
soil samples

Procedure:

Particle Types

1. Label three specimen jars with the locations of the soil samples using the white labels. Write the location in Table 1. Fill each jar halfway with soil. Add water, allowing it to soak into the soil, until the jars are full.
2. Cover the jars with lids and shake until any large soil particles break apart. Set the jars aside and let the particles settle overnight.
3. Using a ruler, measure in millimeters the depth of each particle type in each jar. See Figure 1.
4. Record in Table 1 the depths of the gravel, coarse sand, fine sand, silt, and clay layers in the settled soil samples.

Data and Observations

Table 1.

Depth of each particle type (mm)

Soil Location	Gravel	Coarse sand	Fine sand	Silt	Clay
1.					
2.					
3.					

Analysis

1. Which type of soil particle made up:
 - a. the greatest amount of each soil sample?
 - b. the least amount?
2. Which type of soil was:
 - a. most closely packed? Explain.
 - b. least closely packed? Explain.
3. What soil sample contains the most soil horizons? Why do you think this sample has the most horizons?
4. Analyze and explain the similarities and differences between the three soil samples.
5. Which soil sample do you believe is the most conducive to plant growth?

Conclusion

Appendix C2

Abiotic Factors of Soil

Problem: What are some abiotic factors that affect dune plant growth? How are abiotic factors tested or determined?

Purpose: Examine the abiotic soil factors that affect populations of sand dune plants. Conduct several tests used to determine moisture content, water-holding capacity, and pH of soil samples.

Materials (per group):

pen/pencil	2 Large, shallow pans
Wire screen	3 250-mL beakers
Distilled water	Laboratory balance
Paper towels	3 soil samples (fore-, inter-, backdune)
6 100-mL beakers	3 small juice cans
4 plastic spoons	3 pieces of filter paper
pHdriion paper (pH range 1-11)	Hydrogen peroxide
(12.5 cm diameter)	Black Sharpie marker
3 rubber bands	masking tape
white labels	timer (clock or watch)
plastic pipet	

Procedure:

Part A-Moisture Content of Soil

1. Using a pen/pencil and the white labels identify three 250 mL beakers as A,B, and C. Find the mass of each empty beaker, and record the masses in Table 1 of the data section.
2. Soil samples, in the 1000 mL beakers on the lab tables, were previously collected from each area of the dunes. Fill each of your marked beakers to the 100 mL mark with a different soil sample. In beaker A, place 100 cm³ of foredune soil. In beaker B put 100 cm³ of interdune soil. In beaker C put 100 cm³ of backdune soil.
3. Find the mass of each beaker with its soil sample, and record the masses in Table 1.
4. Place the beakers and soil in an oven at 100° C (212° F) for 24 hours.
Note: Allow the soil samples to cool after taking them out of the oven.

5. Find the mass of each beaker and its dried soil. Record your findings in Table 1.

6. Calculate the percentage of moisture in each sample by using the following formulas.

$$(\text{Mass of beaker} + \text{original soil}) - \text{Mass of beaker} = \text{Mass of soil sample before drying}$$

$$(\text{Mass of beaker} + \text{dried soil}) - \text{Mass of beaker} = \text{Mass of dried soil}$$

$$\text{Mass of soil sample before drying} - \text{Mass of dried soil} = \text{Mass of water in soil sample}$$

$$\frac{\text{Mass of water in soil sample}}{\text{Mass of dried soil}} \times 100 = \text{Percentage of moisture in the soil sample}$$

Record the results in the appropriate places in Table 1.

Part B-Water-Holding Capacity of Soil

1. Obtain three small soup cans with both ends removed. Cover one end of each can with a piece of filter paper. Secure the filter paper with a rubber band. Label the cans A, B, and C.

2. Find the mass of each can with its filter paper and bands. Record all the masses in Table 2 of the data section.

3. Place dried soil sample A into can A. Find the combined mass of can A and the soil it holds. Record the mass in Table 2. Repeat this step for samples B and C.

4. Moisten the entire piece of filter paper by wetting your finger and spreading water over the filter paper. Find the mass of each can with the wet filter paper and the dried soil. Record the masses in the appropriate column in Table 2.

5. Put the cans, filter paper side down, in a pan of distilled water so that the lower half of the can is below water level. Soak the cans and soil samples overnight.

6. Remove the cans from the water and let them drain on a screen overlaying a pan for 30 minutes.

7. Dry the surface of each can with a paper towel and find its mass. Record the masses in the appropriate sections of Table 2.

8. Calculate the percentage of water-holding capacity in each sample by using the following formulas.

(Mass of water-soaked soil + can) - (Mass of oven-dried soil + can + wet paper) = Mass of water in soil

(Mass of dry can + oven-dried soil) - Mass of dry can = Mass of oven-dried soil

$$\frac{\text{Mass of water in soil}}{\text{Mass of oven-dried soil}} \times 100 = \text{Percentage of water-holding capacity of the soil}$$

Record the results in the appropriate places in Table 2.

Part C-Soil pH

1. Rinse 3 100 mL beakers with distilled water.
2. Using a plastic spoon, put a level spoonful of soil sample A into one of the clean beakers. Add either 20 mL of distilled water or enough water to thoroughly wet the sample.
3. Get a 4 to 5 cm strip of pHydron paper, and immerse one end of the paper in the soil-water mixture.
4. Remove the strip of paper quickly. Compare the color of the pHydron paper with the colors on the dispenser and record the results in Table 3 of the data section.
5. Repeat steps 2 through 4 for samples B and C.

Part D-Organic Content of Soil

1. Clean the three 100 mL beakers used in Part C. Rinse them with distilled water, then label them A-1, B-1, and C-1 with the white labels and a pen/pencil. Label three other beakers as A-2, B-2, and C-2.
2. Add some of soil sample A to beaker A-1 and some to beaker A-2. Do the same for samples B and C. Fill each beaker to the 25 mL mark being careful not to touch the contents.
3. To beakers A-1, B-1, and C-1, add enough water to cover the soil. To beakers A-2, B-2, and C-2, add enough hydrogen peroxide to cover the soil. Hydrogen peroxide oxidizes the carbon compounds in humus (decayed organic matter). If a reaction occurs, wait until it finishes before you proceed.

4. Add 10 to 15 mL of distilled water to each beaker. Let the soil settle.
5. Compare beakers A-1 and A-2. Do the same with the other pairs of beakers. Then compare beakers A-2, B-2, and C-2 with one another.

Part E-N•P•K Soil Test

1. Obtain an N•P•K Soil test kit for your group.
2. Fill the round extraction tube to the 30 mL line with distilled water.
3. Add two Floc-Ex Tablets (5504). Cap the tube and mix until the tablets have disintegrated.
4. Remove the cap. Add one heaping teaspoon of soil from sample A (foredune). Pick out any leaves, stones or sticks and crush any lumps.
5. Cap the tube and shake for one minute.
6. Let the tube stand until the soil settles out. The clear solution above the soil will be used for the Nitrate, Phosphorus, and Potassium tests.

Nitrogen Test

7. Use a plastic pipet to transfer the clear solution above the soil to a test square tube until it is filled to the shoulder.
8. Add one Nitrate WR CTA Testab (3703). Cap and mix until the tablet disintegrates.
9. Wait 5 minutes for the color to develop. Compare the pink color of the solution to the Nitrogen Color Chart.
10. Record your results in Table 4 of the data section.

Phosphorus Test

11. Use the pipet to transfer 25 drops of the clear solution above the soil to a square test tube.
12. Fill the tube to the shoulder with distilled water.
13. Add one Phosphorus Tablet (5422). Cap and mix until the tablet disintegrates. Wait 5 minutes for the color to develop.
14. Compare the blue color of the solution to the Phosphorus Color Chart.

15. Record your results in Table 4 of the data section.

Potassium Test

16. Use the pipet to transfer the clear solution above the soil to a square test tube until it is filled to the shoulder.

17. Add one Potassium Tablet (5424). Cap and mix until the tablet disintegrates.

18. Compare the cloudiness of the solution in the test tube to the Potassium Color Chart. Hold the tube over the black boxes in the left column and compare it to the shaded boxes in the right column.

19. Record your results in Table 4 of the data section.

20. Thoroughly rinse and clean all of the testing materials with distilled water.

21. Repeat steps 2-17 with soil sample B (interdune) and C (backdune).

Data and Observations

Table 1.

Masses/Percentages	A	B	C
Mass of beaker			
Mass of beaker + original soil			
Mass of soil sample			
Mass of beaker + dried soil sample			
Mass of dried soil			
Mass of water in soil sample			
Percentage of moisture in soil sample			

Table 2.

Soil sample	Mass of can	Mass of dry soil + can	Mass of dry soil, wet paper + can	Mass of water-soaked soil + can	Water-holding capacity (percentage)
A					
B					
C					

Table 3.

Soil sample	pH Hydron paper color change	pH	Acidic or basic
A			
B			
C			

Table 4.

Soil sample	Nitrogen content	Phosphorus content	Potassium content
A			
B			
C			

Analysis

Part A

1. a. Which soil sample has the greatest amount of moisture?

b. Which soil sample do you assume has the greatest humus content?
2. Which soil sample do you expect to support the most living things? Why would this soil sample have the most living things?

Part B

1. Which soil sample holds the most water? The least?
2. Why are some soil samples not able to absorb large amounts of water?

Part C

1. Which soil samples are acidic? Which are basic?
2. Which sample do you expect to contain the most nutrients? Why?

Part D

1. What is the purpose of beakers A-1, B-1, and C-1?
2. What evidence is there of a chemical change? In which beakers does a chemical change occur?
3. Which beaker appears to contain the most decayed organic matter in the soil (humus)? Compare these results with your answer in Part A, question 1b.
4. List any changes in the color of the soil.

Part E

1. Was the NPK content of each soil sample different? If so, what were the differences?

2. Why do you think the NPK content of the soil samples would be similar or different? Use the location of the soil to deduce your answer.

3. What is the usefulness of each of the nutrients in the soil?

4. How did your results compare to those of other groups?

Conclusion

How do Abiotic Factors Affect Different Plant Species? (Fast Plants®-Brassica rapa, Garlic Mustard- Alliaria petiolata, and Sea Rocket-Cakile edentula)

Problem: Do Fast Plants®, Garlic Mustard, and Sea Rocket grow best in sand or potting soil? Which of these soil types is more conducive to growth and why?

Purpose: Determine whether Fast Plants®, Garlic Mustard, and Sea Rocket grow best in sand or potting soil. Analyze and identify the optimal growth media for each of these plant species.

Materials (per group):

pen/pencil	plant fertilizer
white labels	Fast Plant® seeds
distilled water	Sea Rocket seeds
fluorescent lamp	Garlic Mustard seeds
sand	potting soil
6 paper cups	

Procedure:

1. Use a pencil to punch three holes in the bottom of each cup. Fill 3 cups with equal amounts of sand and 3 cups with the same amount of potting soil.
2. Plant 5 Fast Plant® seeds in one sand-filled cup and 5 seeds in one soil-filled cup. Plant 5 seeds from each of the other two plants in the other 4 cups (e.g. 5 Sea Rocket seeds in one sand-filled cup and 5 seeds in one soil-filled cup). Label each cup with the type of seed and soil it contains.
3. Place all of the cups under the grow light bank. Each day for 3 weeks, water the cups equally and record your observations of any plant growth.
4. Record in Table 1 any observations you make over the weeks.
5. Clean up your lab station and wash your hands with soap and warm water.

Data and Observations

Table 1.

Growth observations per day

Plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fast Plant®/soil															
Fast Plant®/sand															
Sea Rocket/soil															
Sea Rocket/sand															
Garlic Mustard/soil															
Garlic Mustard/sand															

Analysis

1. In which medium did the Fast Plants® grow best-sand or soil? Which was the better medium for the growth of Sea Rocket and Garlic Mustard?

2. Soil retains more water than sand, providing a moister environment. What can you infer from your observations about the kind of environment that favors the growth of Fast Plants®? ...growth of Sea Rocket? ...growth of Garlic Mustard?

3. Which would compete more successfully in a dry environment-Fast Plants®, Sea Rocket, or Garlic Mustard? In a moist environment?

Conclusion

Identifying Limiting Nutrients of Fast Plants® (Brassica rapa), Garlic Mustard (Alliaria petiolata), and Sea Rocket (Cakile edentula)

Problem: Does the supply of nitrogen, phosphorus, and potassium limit the growth of Fast Plants®, Garlic Mustard, and Sea Rocket?

Purpose: Determine whether nitrogen, phosphorus, and potassium are limiting nutrients for the growth of Fast Plants®, Garlic Mustard, and Sea Rocket. Analyze the affects of available nutrients on the growth of these plant species.

Materials (per group):

2 small plastic Tupperware containers	pen/pencil
large piece of felt	white labels
distilled water	12 film canisters (w/ holes)
fluorescent lamp	plant fertilizer
Sea Rocket seeds	Fast Plant® seeds
Garlic Mustard seeds	light bank

Procedure:

1. Obtain 2 Tupperware containers, 1 large piece of felt, and 12 film canisters with holes in the bottom.
2. Construct the growing apparatus to resemble the one shown to you by Mr. Woolcock, also resembling Fig. 1 below.

Fig. 1

3. Label one Tupperware container, "fertilizer", and the other, "control".
4. Label 4 film canisters "Fast Plant®" with the white labels and a pen/pencil, 4 "Garlic Mustard", and 4 "Sea Rocket".
5. Place the felt wicks up into the film canisters, and then fill the canisters with potting soil leaving approximately one cm of space at the top.

6. Make small holes, using a pen/pencil, of the depth specified for Fast Plants® in the first four film canisters. Put four pre-soaked Fast Plants® in those canisters. Put 4 pre-soaked Sea Rocket seeds of the same size in the next four, and 4 pre-soaked Garlic Mustard seeds of the same size in the last four. Two of each of the plants should be placed side by side on each of the Tupperware containers (see Fig. 2).

Fig. 2

7. Read the directions on the fertilizer container to make a liquid fertilizer (water and fertilizer) that is needed to fill one tupperware container 3/4 full. Remember to write down the amount of water and water/fertilizer mixture you add to each of the containers. Add the same amounts to each container over the duration of the experiment, when needed.

8. Place the containers underneath the light bank making sure the film canisters stay balanced on the top.

9. Measure and record your observations over a two week period in Table 1 of the data and observations section using techniques described in procedure 10.

10. To measure the average height of plants, average length of roots, total weight of plant tissue, and average weight of plant tissue do the following....

- a. Take the plants out of the soil one at a time.
- b. Fill a 250 mL beaker with water.
- c. Separate the soil from the roots by agitating the roots in the beaker of water.
- d. Measure the height of the upper growth and the root length for each of the growing conditions. Do not measure all of the plants, but use a representative population (e.g. 5-10) and then average your results.
- e. Take out the remainder of the plants from each tray and agitate the roots in water. Be careful not to separate or mix up the plants in each tray. Cut up all of the plant tissue from each tray (e.g. upper growth and roots). Determine the total weight of plant tissue by placing it on a triple beam balance.

Data and Observations

Table 1.

	Container 1			Container 2		
	Fast Plants®	Sea Rocket	Garlic Mustard	Fast Plants®	Sea Rocket	Garlic Mustard
Percent of plants surviving						
Avg. height of plants						
Avg. width of leaves at widest location						
Avg. length of roots						
Total weight of plant tissue						
Avg. weight of plant tissue						

Analysis

1. How did the added fertilizer affect the growth of each of the three plant species? Were there any noticeable differences in plant growth between the two containers?

2. Do your results indicate that nitrogen, phosphate, and potassium are limiting nutrients for each of these plants? Explain your response in regards to each plant species.

3. How could you tell which of the three nutrients is a limiting factor for each plant?

4. How do limiting nutrients affect plants?

5. Would different plant species in separate communities have similar limiting nutrients? Why or why not?

Conclusion

Intraspecific Competition in Plants

Problem: How does crowding affect the growth of radish seeds? How does this crowding effect relate to plants on the dunes?

Purpose: Observe and measure the effects of overcrowding on radish plant growth.

Materials (per group):

4 plastic planting trays	white labels
pen/pencil	radish seeds
ruler	potting soil
string and tape	triple beam balance

Procedure:

1. Place potting soil to a depth of at least 5 cm in the 4 planting trays. Smooth and gently pack the surface of the soil.

2. Use a ruler to lay out a grid system in one flat, crisscrossing the string with lines 10 cm apart. Tape each piece of string to the side of the planting tray (see Fig. 1).

Fig. 1

3. Place the grid lines 5 cm apart in the second flat, 3 cm apart in the third, and 1 cm apart in the fourth.

4. Make small holes, using a pen/pencil, of the same depth at the centers of all of the squares in the grid system. Consult the planting directions on the seed package for the proper depth.

5. Place one radish seed in each of the holes and cover it with soil. Make sure all of the radish seeds you use are similar in size.

6. Carefully water the plants with a beaker, being sure to give each of the plants the same amount of water (again...consult the planting directions). Place the flats underneath the light bank. All flats must have the same conditions of temperature, light, and moisture.

7. (Advisable) Germinate a few extra plants in another tray so that you will have seedlings to plant in the positions where a seed fails to germinate. We will more than likely plant a flat as a class.

8. Make sure to water the plants at the same time using the same amount of water for each tray.

9. Allow the plants to grow until the results of competition are obvious. Take measurements and observations necessary to complete Table 1 in the data and observations section.

10. To measure the average height of plants, average length of roots, total weight of plant tissue, and average weight of plant tissue do the following....

- Take the plants out of the soil one at a time.
- Fill a 1000 mL beaker with water.
- Separate the soil from the roots by agitating the roots in the beaker of water.
- Measure the height of the upper growth and the root length for each of the growing conditions. Do not measure all of the plants, but use a representative population (e.g. 5-10) and then average your results.
- Take out the remainder of the plants from each tray and agitate the roots in water. Be careful not to separate or mix up the plants in each tray. Cut up all of the plant tissue from each tray (e.g. upper growth and roots). Determine the total weight of plant tissue by placing it on a triple beam balance.

Data and Observations

Table 1.

	Tray 1	Tray 2	Tray 3	Tray 4
Percent of plants surviving				
Avg. height of plants				
Avg. width of leaves at widest location				

Avg. length of roots				
Total weight of plant tissue				
Avg. weight of plant tissue				

Analysis

1. Summarize the effects that crowding appears to have on plants. Account for these effects.
2. What advice do you have for gardeners as a result of this investigation?
3. Which do you think tells a farmer or ecologist more about a crop, the average weight or total weight of the plant/crop? Why?
4. What would have happened if you had selected different size seeds?
5. Why would intraspecific competition generally result in a strengthening of the species?

Conclusion

Interspecific Competition in Plants

Problem: How does the interaction between radish and sunflower seeds affect their growth? How does this crowding effect relate to plants on the dunes?

Purpose: Observe and measure the effects of overcrowding and interaction on radish and sunflower plant growth.

Materials (per group):

4 plastic planting trays	white labels
pen/pencil	radish seeds
sunflower seeds	ruler
potting soil	string and tape
triple beam balance	light bank

Procedure:

1. Place potting soil to a depth of at least 5 cm in the 4 planting trays. Smooth and gently pack the surface of the soil.
2. Use a ruler to lay out a grid system in all four flats, crisscrossing the string with lines 2 cm apart. Tape each piece of string to the side of the planting tray (see Fig. 1).
3. Make small holes, using a pen/pencil, of the same depth at the centers of all of the squares in the grid system. Consult the planting directions on the seed package for the proper depth.
4. In the first flat, plant one radish seed in each hole.
5. In the second and third flats, alternate the planting of radish and sunflower seeds (see Fig. 2).

Fig. 2

6. In the fourth flat, plant one sunflower seed in each hole. In all cases, select seeds of about the same size.
7. Carefully water the plants with a beaker, being sure to give each of the plants the same amount of water (again...consult the planting directions). Place the flats underneath the light bank. All flats must have the same conditions of temperature, light, and moisture.
8. (Advisable) Germinate a few extra plants in another tray so that you will have seedlings to plant in the positions where a seed fails to germinate. We will more than likely plant a flat as a class.
9. Make sure to water the plants at the same time using the same amount of water for each tray.
10. Allow the plants to grow until the results of competition are obvious. Take measurements and observations necessary to complete Table 1 in the data and observations section.
11. To measure the average height of plants, average length of roots, total weight of plant tissue, and average weight of plant tissue do the following....
 - a. Take the plants out of the soil one at a time.
 - b. Fill a 1000 mL beaker with water.
 - c. Separate the soil from the roots by agitating the roots in the beaker of water.
 - d. Measure the height of the upper growth and the root length for each of the growing conditions. Do not measure all of the plants, but use a representative population (e.g. 5-10) and then average your results.
 - e. Take out the remainder of the plants from each tray and agitate the roots in water. Be careful not to separate or mix up the plants in each tray. Cut up all of the plant tissue from each tray (e.g. upper growth and roots). Determine the total weight of plant tissue by placing it on a triple beam balance.

Data and Observations

Table 1.

(r) - radish (s)- sunflower

	Tray 1	Tray 2 (r)	Tray 2 (s)	Tray 3 (r)	Tray 3 (s)	Tray 6
Percent of plants surviving						
Avg. height of plants						

Avg. width of leaves at widest location						
Avg. length of roots						
Total weight of plant tissue						
Avg. weight of plant tissue						

Analysis

1. Summarize the effects that radish and sunflower plants have on one another. Account for these effects.

2. Was the faster growing species in the pure stands also the faster growing species in the mixed stands?

3. Suppose that a gardener wants to plant radishes next to sunflowers. Would this be a wise decision by the gardener? Why?

Conclusion

Biotic/Abiotic Factors of an Old Field

Problem: What plant types compose a typical old field in Michigan? What is the dominant plant type in this field?

Purpose: Systematically sample biotic factors and calculate quantitative data regarding plant types in an old field.

Materials (per group):

pen/pencil

calculators (in class)

Procedure:

1. Below is an explanation of the method used to collect abiotic/biotic factors in an old field. The data in this lab is fictional, but resembles data that could be collected in a typical Michigan old field.

Lay out a belt transect perpendicular to the road by placing two lines produced with the tape measure, each 20-30 m long, parallel to each other and 1 m apart. Put stakes in the ground at the beginning of each tape measure and at the ending point 20-30 m away (4 stakes altogether). Attach string to the stakes on both ends so the transect resembles Fig. 1 below. Make sure the string is taut with the ground. Close off each end with a 1 m length of string.

Divide each belt into equal-sized plots by using the meter sticks. Lay a meter stick across the belt at the 1 m mark and record the vegetation up to that point. Place a meter stick at the 2 m mark and record the vegetation in this area. The first meter stick is then moved to the 3 m mark, and this cycle continues till the end (see Fig. 2 below).

Fig. 1

Fig. 2

2. Identify and record each type of plant per meter interval of the belt transect in Table 1 of the data and observations section. Place a tally mark(s) in the appropriate area of the table for each plant type found per interval.

3. Add up the total number of each plant type and record the total number of plants from your belt transect in Table 2.

4. The heights of four to five plants of each type are listed on the board. Calculate the average height of each plant type. Record your measurements in Table 2 of the data and observations section.

5. Calculate the percentage of plants in your belt transect that constitute the most numerous plant type. Use the formula below:

$$\frac{(\text{number of most numerous plant type} + \text{total number of plants}) \times 100}{\text{percentage of the most numerous plant type}} =$$

Example: $(300 \text{ grasses} + 500 \text{ plants}) \times 100 = 60\% \text{ grasses}$

6. Record your results in Table 3 of the data and observations section. Record your data on line one and add each of the other groups data to the other lines.

7. Describe the appearance of your sampled belt transect in Table 4 of the data and observations section.

Data and Observations

Table 1. Intercept Intervals (1 m)

Plant type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
grasses															
forbs															
vines															
shrubs															
trees															

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total # of plants

Table 2.

Species	Total number of plants	Measurements of plant heights	Average height

Table 3.

Group	Most numerous plant type	Number of most numerous plant type	Total number of plants	Percentage of most numerous plant type

Table 4.

Description	Observations
Most numerous plant type	
Tallest plants (average height)	
Percent of ground shaded or covered by vegetation	
Percent of ground lacking vegetation	
Distribution of plants (even/uneven)	

Analysis

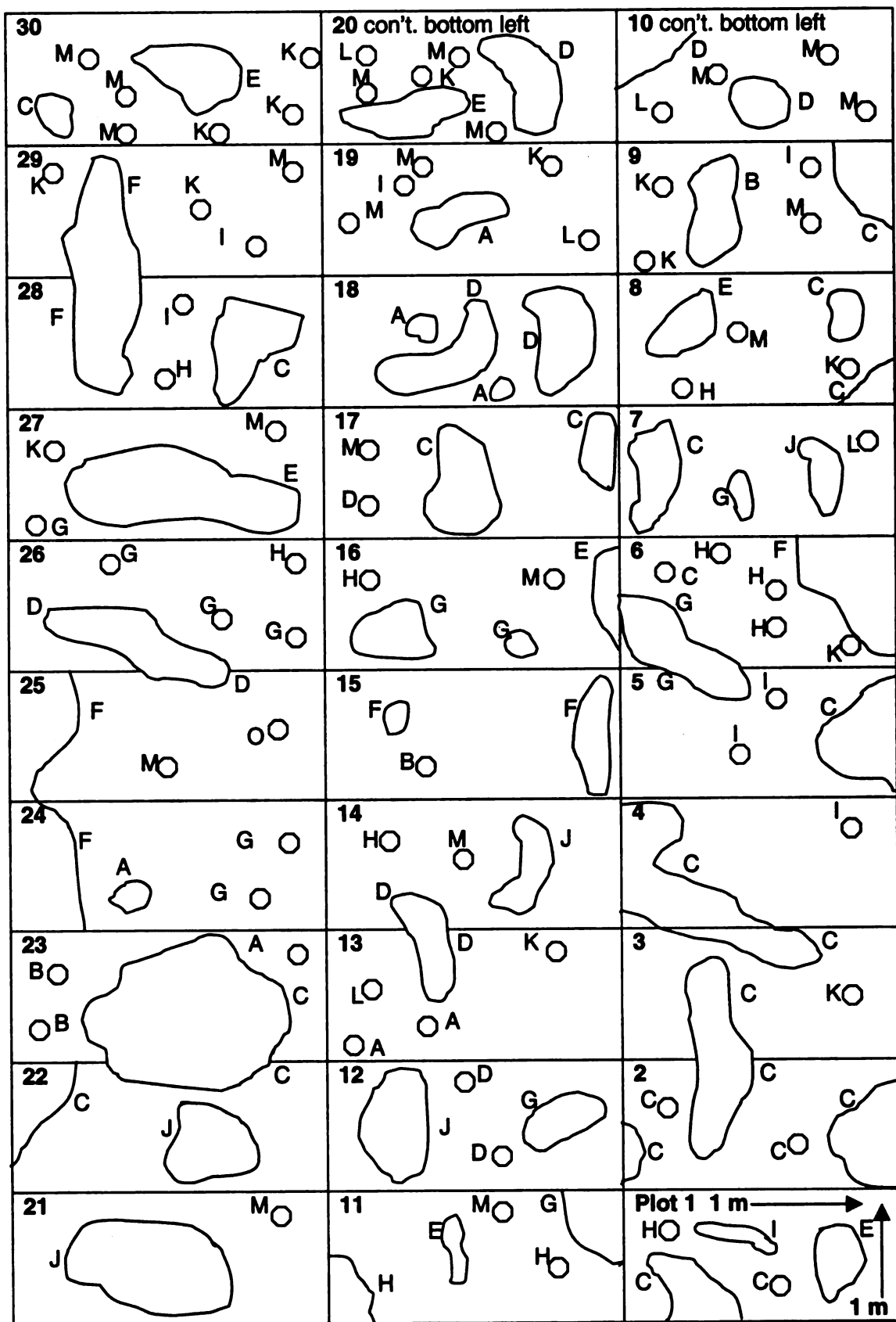
1. Write a general description of the plant community studied.
2. List the most numerous plant type and its percentage in decreasing order for your belt transect. Choose the dominant plant for the transect and support your selection.
3. What limiting factors could exist to limit the growth rate of one of the plants in your transect?

4. Would you describe the belt transect as well established? Cite evidence from your data and observations.

5. Make a sketch of your belt transect, using the symbols on the handout to represent plant types. Write the average height on one of each of the plant symbols.

6. Plot a line graph of your data with "Number of Plants" on the vertical axis and "Intercept Intervals" on the horizontal axis.

Conclusion



Biotic/Abiotic Factors of a Lake Michigan Sand Dune

Problem: What plant types compose the sand dune at Oval Beach in Saugatuck, MI? Is there an increase in species and detritus along a gradient perpendicular to the lake? Do the abiotic and biotic factors signify primary succession in this community?

Purpose: Systematically sample, using a belt transect, the abiotic and biotic factors and calculate quantitative data regarding plant types on the Lake Michigan sand dune in Saugatuck, MI.

Materials (per group):

pen/pencil	clipboard
2 meter sticks	field guide to dune plants
2 long tape measures	string
stakes	hammer
calculators (in class)	

Procedure:

1. Lay out a belt transect, parallel to the coastline, starting in the area identified by the teacher. Place two lines produced with the tape measure, each 20-30 m long, parallel to each other and 1 m apart. Put stakes in the ground at the beginning of each tape measure and at the ending point 20-30 m away (4 stakes altogether). Attach string to the stakes on both ends so the transect resembles Fig. 1 below. Make sure the string is taut with the ground. Close off each end with a 1 m length of string.

Fig. 1

2. Divide each belt into equal-sized plots by using the meter sticks. Lay a meter stick across the belt at the 1 m mark and record the vegetation up to that point. Place a meter stick at the 2 m mark and record the vegetation in this area. The first meter stick is then moved to the 3 m mark, and this cycle continues till the end (see Fig. 2 below).

Fig. 2

3. Identify and record each type of plant species per meter interval of your group's belt transect in Table 1 of the data and observations section. Place a tally mark(s) in the appropriate area of the table for each plant type found per interval.

4. Add up the total number of each plant type and record the total number of plants from your belt transect in Table 1.
5. Select 4-5 different plants from transect and measure their heights with a meter stick. Calculate the average height of each plant type. Record your measurements in Table 2 of the data and observations section. Estimate tree height by holding a protractor with a string attached to its middle with the curved side downward (see Fig. 3). Sight along the straight edge of the protractor to view the tree top. Walk away from and toward the tree until your lab partner(s) see the string hanging from the protractor at a 45° angle. Then add your height and your distance from the tree to obtain an estimated tree height.

Fig. 3

6. Measure the light intensity, wind velocity, air temperature, and soil temperature in the middle of the transect. Record your results in Table 3 of the data and observations section. Consult your "Abiotic Factors of Soil" Lab, when you return back to class, to record the moisture content, water-holding capacity, pH, organic content, and NPK calculations for the transect.

7. Calculate the percentage of plants from your belt transect that constitute the most numerous plant type. Use the formula below:

$$\frac{(\text{number of most numerous plant type} + \text{total number of plants}) \times 100}{\text{percentage of the most numerous plant type}}$$

Example: $(300 \text{ Marram grass} + 500 \text{ plants}) \times 100 = 60\% \text{ Marram grass}$

8. Record your results in Table 4 of the data and observations section. Record your data on line one and add each of the other groups data to the other lines.
9. Describe the appearance of your sampled belt transect in Table 5 of the data and observations section.
10. Repeat procedures 1-8 by laying out and investigating two more belt transects in the designated areas provided by your teacher. The belt transect in the interdune should be 30 m long and 3 m wide (instead of one-foredune), whereas the backdune transect should measure 30 m long and 5 m wide. Record the results of the interdune data in Tables 1b, 2b, 3, 4b, and 5b and the results of the backdune data in Tables 1c, 2c, 3, 4c, and 5c of the data and observations section.

Data and Observations

Table 1. Foredune Intercept Intervals (1 m)

Spp.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total # of plants

Table 1a. Interdune Intercept Intervals (1 m)

Spp.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total # of plants

Table 1b. Backdune

Intercept Intervals (1 m)

Spp.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total # of plants

Table 2. Foredune

Species	Total number of plants	Measurements of plant heights	Average height

Table 2a. Interdune

Species	Total number of plants	Measurements of plant heights	Average height

Table 2b. Backdune

Species	Total number of plants	Measurements of plant heights	Average height

Table 3. Abiotic Factors

Belt Transect	Light Intensity	Wind Velocity	Air Temp.	Soil Temp.	Moisture Content	Water-Capacity
1. (A) Foredune						
2. (B) Interdune						
3. (C) Backdune						

pH	Organic Content	N	P	K

Table 4. Foredune

Group	Most numerous plant type (Foredune)	Number of most numerous plant type (Foredune)	Total number of plants	Percentage of most numerous plant type

Table 4a. Interdune

Group	Most numerous plant type (Interdune)	Number of most numerous plant type (Interdune)	Total number of plants	Percentage of most numerous plant type

Table 4b. Backdune

Group	Most numerous plant type (Backdune)	Number of most numerous plant type (Backdune)	Total number of plants	Percentage of most numerous plant type

Table 5. Foredune

Description	Observations
Most numerous plant type	
Tallest plants (average height)	
Percent of ground shaded or covered by vegetation	
Percent of ground lacking vegetation	
Distribution of plants (even/uneven)	

Table 5a. Interdune

Description	Observations
Most numerous plant type	
Tallest plants (average height)	
Percent of ground shaded or covered by vegetation	
Percent of ground lacking vegetation	
Distribution of plants (even/uneven)	

Table 5b. Backdune

Description	Observations
Most numerous plant type	
Tallest plants (average height)	
Percent of ground shaded or covered by vegetation	
Percent of ground lacking vegetation	
Distribution of plants (even/uneven)	

10

5. Make a sketch of each belt transect, using a key to represent plant types. Write the average height on one of each of the plant symbols.

Transect 1-

Transect 2-

Transect 3-

6. Plot line graphs of your data with "Number of Plants" on the vertical axis and "Intercept Intervals" on the horizontal axis for each transect.

Transect 1-

Transect 2-

Transect 3-

7. Did you observe a pattern of observed changes in abiotic patterns as you progress away from the lake? Explain.

8. What evidence shows that facilitation is an important process in primary succession of a sand dune?

9. How does the vegetation change with respect to each belt transect or successional stage (e.g. number of species, species composition, etc.)?

Conclusion

Appendix C9a

Mr. Woolcock

Introduction to Ecology Quiz

Name:

Hour:

Matching: Write the correct letter in the blank before each numbered term.

- | | |
|----------------------------|--|
| _____ 1. community | a. where an organism lives |
| _____ 2. generalist | b. phenomenon that insulates Earth from the freezing temperature of space |
| _____ 3. ecology | c. members of a single species living in one place at a time |
| _____ 4. resources | d. organisms interacting in a specific area |
| _____ 5. habitat | e. increase in average global temperature due to trapped excess greenhouse gases |
| _____ 6. population | f. a species with a broad niche |
| _____ 7. greenhouse effect | g. study of the interactions between organisms and their environment |
| _____ 8. global warming | h. energy and materials needed by a species |

True-False: If a statement is true, write T in the blank. If a statement is false, write F in the blank, and then in the space provided, explain why the statement is false.

- _____ 9. The world's population tripled from 2 billion to 6 billion people in just 66 years.
- _____ 10. The greenhouse effect is a phenomenon caused by excess fossil fuels being burned.
- _____ 11. A tolerance curve shows the range of a certain environmental factor that a species can tolerate and the optimal range for that factor.

- _____ 12. Regulators change their internal conditions as their environmental changes.
- _____ 13. The realized niche of a species is the range of resources it actually uses.

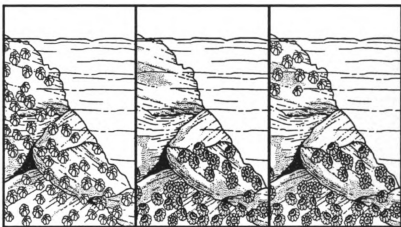
Multiple Choice: Write the letter of the most correct answer in the blank.



- _____ 14. Which of the figures above depicts a conformer?
- a. A
 - b. B
 - c. C
 - d. D
- _____ 15. The small percentage of ultraviolet radiation that strikes the Earth from the sun is the cause of
- a. climate changes.
 - b. sunburns and skin cancer.
 - c. global warming.
 - d. the greenhouse effect.
- _____ 16. The broadest, most inclusive level of organization in ecology is
- a. an ecosystem.
 - b. a community.
 - c. a population.
 - d. the biosphere.

- _____ 17. When organisms affect and are affected by other organisms in their surroundings and with the non-living parts of their environment, it is called
- a. ecology.
 - b. disturbances of the ecosystem.
 - c. interdependence.
 - d. modeling.
- _____ 18. An example of an abiotic factor is
- a. tree.
 - b. sunlight.
 - c. bird.
 - d. grass.
- _____ 19. Some organisms adjust their tolerance to abiotic factors through
- a. adaptation.
 - b. acclimation.
 - c. application.
 - d. resources.
- _____ 20. Conformers are organisms that
- a. use energy to control internal conditions.
 - b. change over many generations.
 - c. do not regulate internal conditions.
 - d. none of the above
- _____ 21. A long term strategy to avoid unfavorable conditions by moving to another, more favorable habitat is called
- a. dormancy.
 - b. migration.
 - c. hibernation.
 - d. all of the above
- _____ 22. A species' fundamental niche is
- a. the range of resources it can potentially use.
 - b. the range of conditions it can potentially tolerate.
 - c. where it probably competes for resources.
 - d. all of the above
- _____ 23. The range of resources a species actually uses is called
- a. an abiotic factor.
 - b. resource tolerance.
 - c. a realized niche.
 - d. a regulator.

- _____ 24. Temperatures may increase on Earth because
- a. decomposers essential to recycling matter are being destroyed.
 - b. too much oxygen is now given off by plants.
 - c. increasing carbon dioxide would trap more heat.
 - d. the Earth tilts toward the sun in the summer.
- _____ 25. Rising coastal sea levels are expected to result from
- a. increased ocean floor volcanic activity.
 - b. global warming.
 - c. ozone layer depletion.
 - d. acid rain.
- _____ 26. An ecosystem consists of
- a. a community of organisms.
 - b. energy.
 - c. the soil, water, and weather.
 - d. all of the above
- _____ 27. The physical location of an ecosystem in which a given species lives is called
- a. habitat.
 - b. tropical level.
 - c. community.
 - d. food zone.
- _____ 28. An organism's niche includes
- a. what it eats.
 - b. where it eats.
 - c. when it eats.
 - d. all of the above
- _____ 29. If the niches of two organisms overlap,
- a. the organisms may have to compete directly.
 - b. the two organisms will always form a symbiotic relationship.
 - c. both organisms will disappear from the habitat.
 - d. one organism usually migrates to a new habitat.
- _____ 30. Ecology is the study of interaction of living organisms
- a. with each other and their habitat.
 - b. and their communities.
 - c. with each other and their physical environment.
 - d. and the food they eat.



A. The barnacle *Chthamalus stellatus* can live in both shallow and deep water on a rocky coast.

B. The barnacle *Balanus balanoides* prefers to live in deep water.

C. When the two live together, *Chthamalus* is restricted to shallow water.

The following questions refer to the diagrams above illustrating experiments performed with two species of barnacles that live in the same area.

- _____ 31. Diagram "A" indicates that the barnacle *Chthamalus stellatus* can live in both shallow and deep water on a rocky coast. This is the barnacle's
- competitive niche.
 - realized niche.
 - fundamental niche.
 - exclusive niche.
- _____ 32. Diagram "B" indicates that the barnacle *Balanus balanoides* prefers to live in deep water. Deep water is the barnacle's
- competitive niche.
 - realized niche.
 - fundamental niche.
 - exclusive niche.
- _____ 33. Diagram "C" indicates that when the two barnacles live together, *Chthamalus* is restricted to shallow water. Shallow water is the barnacle's
- competitive niche.
 - realized niche.
 - fundamental niche.
 - exclusive niche.

Appendix C9b

Mr. Woolcock

**Geology/Glaciation of the
Great Lakes Region Quiz**

Name:
Hour:

Matching: Write the correct letter in the blank before each numbered term.

- | | |
|-----------------------------|--|
| _____ 1. stabilized dune | a. the upper portion of an open lake |
| _____ 2. inland dune | b. a structure that is formed when a longshore current carries sediment out of a bay |
| _____ 3. coastal dunes | c. currents that pass along the shoreline of Lake Michigan |
| _____ 4. foredune | d. ridges that are low dunes (30 to 50 ft.), closer to the water's edge |
| _____ 5. longshore currents | e. a reactivated dune, parabolic shape, caused by the absence of vegetation |
| _____ 6. fetch | f. generally the oldest dunes in the state |
| _____ 7. spit | g. a dune covered with vegetation |
| _____ 8. lower beach | h. younger than the inland dunes |
| _____ 9. upper beach | i. part of the beach closest to the water |
| _____ 10. interdune | j. part of the beach distinguished by the presence of marram grass |
| _____ 11. blowout | k. a low trough in the dunes between a foredune and a stabilized dune |

True-False: If a statement is true, write T in the blank. If a statement is false, write F in the blank, and then in the space provided, explain why the statement is false.

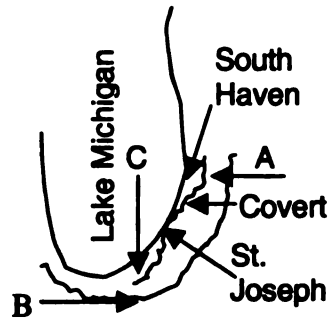
- _____ 12. Glaciers covered the entire Great Lakes region approximately 10,000-12,000 years ago.

- _____ 13. During the Nipissing Epic the lake now known as Lake Michigan was at its highest level in geological history.
- _____ 14. There were three major epics that evoked dune formation in the vicinity of Lake Michigan.
- _____ 15. Debris deposited at the receding edge of a glacier will not form an end moraine.
- _____ 16. The lake border moraine prevents the formation of coastal dunes when it lies adjacent to Lake Michigan.

Extended Response: Write a descriptive and thorough answer to the following question.

17. Draw and label the different portions of a sand dune extending away from the shoreline (label: interdune, foredune, lower beach, middle beach, upper beach, stabilized dune, blowout). Place the appropriate drawings of vegetation or objects found in each area.

Multiple Choice: Write the letter of the most correct answer in the blank.



- _____ 18. In the figure above, letter "A" represents the
a. the Covert ridge (lake border moraine).
b. Valparaiso moraine.
c. Kalamazoo moraine.
d. Saugatuck moraine.
- _____ 19. In the figure above, letter "B" represents the
a. lake border moraine.
b. Valparaiso moraine.
c. Kalamazoo moraine.
d. Covert moraine.
- _____ 20. In the figure above, letter "C" represents
a. an area where dunes can form.
b. an area where dunes cannot form.
c. Covert ridge, another name given to the lake border moraine.
d. Lake Michigan.
- _____ 21. The three necessities for coastal dune formation include
a. sand, wind/water, and the absence of a lake border moraine.
b. sand, plants, and Lake Michigan.
c. sand, wind/water, and the presence of large trees.
d. wind/water, lake currents, and a lake border moraine.
- _____ 22. Glacial moraines are composed of
a. large chunks of ice.
b. accumulated till and debris.
c. lake sand and silt.
d. petrified wood.
- _____ 23. Winds that blow across Lake Michigan flow predominately from the
a. east.
b. west.
c. southwest.
d. northwest.

True-False: Write T in the blank if the statement is true, and F in the blank if the statement is false.

- _____ 24. Lake Algonquin was succeeded by smaller lakes due to isostatic rebound.
- _____ 25. Glaciers caused the lake levels to fluctuate over an approximate 5,000-10,000 year period.
- _____ 26. During glaciation, inland dunes were formed when lake levels were high.
- _____ 27. Lake levels fluctuated through three epics of geological history in the Great Lakes region.
- _____ 28. During the Algoma Epic, the lake drained through the Kalamazoo River Valley.

Appendix C9c

Mr. Woolcock

Populations Quiz

Name:
Hour:

Matching: Write the correct letter in the blank before each numbered term.

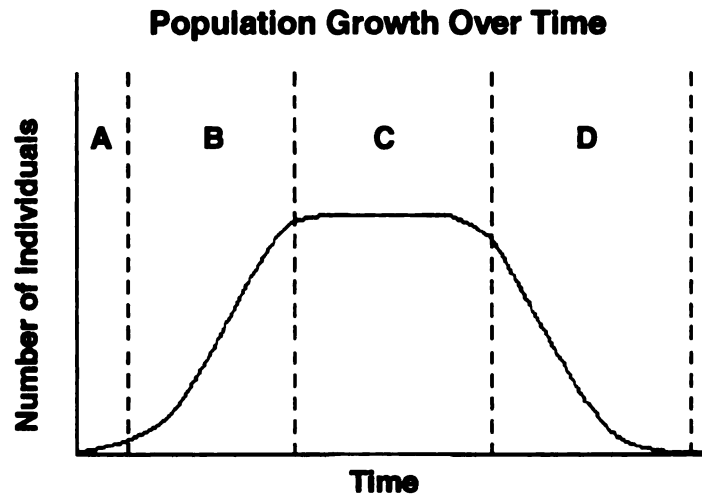
- | | |
|-------------------------------------|--|
| _____ 1. limiting factor | a. number of individuals per unit area |
| _____ 2. carrying capacity | b. population size the environment can support for a long time |
| _____ 3. density-dependent factor | c. a population is at its carrying capacity, the birth rate equals the death rate and growth stops |
| _____ 4. density-independent factor | d. food shortages and living space |
| _____ 5. exponential growth | e. a variable that affects population size regardless of population density |
| _____ 6. logistic growth | f. restrains growth of a population |
| _____ 7. population density | g. the amount by which a population's size changes in a given time |
| _____ 8. growth rate | h. the larger a population gets, the faster it grows |

True-False: If a statement is true, write T in the blank. If a statement is false, write F in the blank, and then in the space provided, explain why the statement is false.

- _____ 9. Population growth is determined by total births, deaths, immigration and emigration.
- _____ 10. Two major properties of populations include their inability to change in number and evolve over time.
- _____ 11. Overlapping generations are present when parents and offspring are in different populations as reproductive adults.

- _____ 12. Discrete generations occur when one generation lives and dies before the next generations lives and dies.
- _____ 13. Exponential growth occurs in populations with overlapping generations and continuous reproduction.

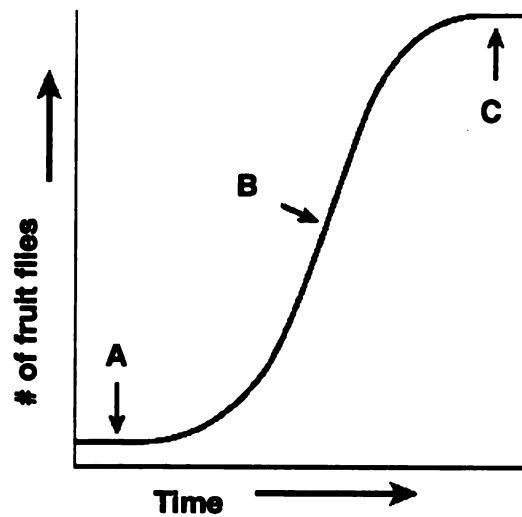
Multiple Choice: Write the letter of the most correct answer in the blank.



- _____ 14. Refer to the illustration above. During which time period are the birth rate and death rate equal?
- period "A"
 - period "B"
 - period "C"
 - period "D"
- _____ 15. Refer to the illustration above. The rate of growth of a population is represented by r . During which time period will $r=0$?
- period "A"
 - period "B"
 - period "C"
 - period "D"
- _____ 16. Refer to the illustration above. The time period during which r would have a negative value is
- period "A"
 - period "B"
 - period "C"
 - period "D"

- _____ 17. As a population reaches its carrying capacity, there is an increase in competition for
- a. food.
 - b. shelter.
 - c. mates.
 - d. all of the above.
- _____ 18. Which of the following is a density-independent regulatory factor?
- a. food
 - b. water
 - c. temperature
 - d. number of nesting sites
- _____ 19. Which population might be least likely to be devastated by a disease outbreak?
- a. a small population who are all offspring of healthy, related parents
 - b. a large, genetically-diverse population
 - c. a small, genetically-uniform population
 - d. a few strong, healthy individuals
- _____ 20. A population of organisms grows
- a. with no natural restrictions except the availability of food.
 - b. when the birth rate exceeds the death rate.
 - c. only in the absence of predators or natural diseases.
 - d. all of the above
- _____ 21. When the birth rate and the death rate of a population are equal,
- a. the population is growing in size.
 - b. the population is remaining constant in size.
 - c. the population is decreasing in size.
 - d. the life expectancy of individuals in the population is very great.
- _____ 22. In the exponential model of population growth, the birth rate
- a. increases while the death rate remains constant.
 - b. remains constant while the death rate increases.
 - c. and the death rate remain constant.
 - d. and the death rate increase.
- _____ 23. During exponential growth,
- a. populations grow very slowly.
 - b. an increasing number of individuals in the population will lead to decreased growth.
 - c. a population always grows at a maximal rate unaffected by density-independent factors.
 - d. a population always grows at a maximal rate unaffected by density-dependent factors.

- _____ 24. The letter "K" on a logistic growth curve symbolizes the
- a. death rate.
 - b. carrying capacity.
 - c. birth rate.
 - d. vital capacity.
- _____ 25. Which of the following is a density-dependent regulatory factor?
- a. food shortages
 - b. decreased nesting sites
 - c. decreased territories
 - d. all of the above
- _____ 26. Logistic growth is evident in a population when
- a. the population increases until it reaches its carrying capacity.
 - b. the population increases forever.
 - c. the population increases, then decreases dramatically.
 - d. all of the above
- _____ 27. Populations are mostly regulated by
- a. density-dependent factors.
 - b. the amount of food resources.
 - c. the amount of space.
 - d. all of the above
- _____ 28. Predation occurs when
- a. a predator captures and wounds its prey.
 - b. a predator captures, kills, and consumes its prey.
 - c. a predator lets its prey escape.
 - d. all of the above
- _____ 29. Parasitism is a form of predation where
- a. one individual is harmed and the other is killed.
 - b. one individual is not harmed and the other benefits.
 - c. one individual is harmed and the other benefits.
 - d. one individual is harmed and benefits from it.
- _____ 30. Populations may be regulated by density-dependent factors like
- a. competition.
 - b. disease.
 - c. dispersal.
 - d. all of the above



The following questions refer to the graph shown above.

- _____ 31. Point "A" indicates
- a. fast growth.
 - b. a population crash.
 - c. steady growth.
 - d. the carrying capacity (K).
- _____ 32. Point "B" indicates
- a. fast growth.
 - b. a population crash.
 - c. steady growth.
 - d. the carrying capacity (K).
- _____ 33. Point "C" indicates
- a. fast growth.
 - b. a population crash.
 - c. steady growth.
 - d. the carrying capacity (K).

Appendix C9d

Mr. Woolcock

Community-Interactions Quiz

Name:

Hour:

Matching: Write the correct letter in the blank before each numbered term.

- | | |
|---------------------------------|---|
| _____ 1. commensalism | a. number of individuals per unit area |
| _____ 2. symbiosis | b. species interaction where one organism is harmed while the other benefits |
| _____ 3. character displacement | c. a harmless species resembles a poisonous or distasteful species |
| _____ 4. mimicry | d. evolution of anatomical differences that reduce competition between species |
| _____ 5. parasitism | e. each species uses only part of the available resources |
| _____ 6. competitive exclusion | f. cooperative relationship in which both species benefit |
| _____ 7. mutualism | g. interaction in which one species benefits and the other is unaffected |
| _____ 8. resource partitioning | h. one species is eliminated from the community due to competition for scarce resources |

True-False: If a statement is true, write T in the blank. If a statement is false, write F in the blank, and then in the space provided, explain why the statement is false.

- _____ 9. Predation is an example of a symbiotic relationship.
- _____ 10. Mimicry results in confusion on the part of a predator, resulting in the predator eating both harmless and poisonous species.
- _____ 11. When two species compete for limited resources, competitive exclusion is sure to take place.

_____ 12. Mutualism is a symbiotic relationship in which only one party benefits.

_____ 13. When two dissimilar species live together in a close association, they are part of a symbiotic relationship.

Multiple Choice: Write the letter of the most correct answer in the blank.

_____ 14. A tick feeding on a human is an example of

- a. parasitism.
- b. mutualism.
- c. competition.
- d. predation.

_____ 15. Which of the following is an example of mimicry?

- a. a poisonous species that resembles a harmless species.
- b. coloration that causes an animal to blend in with its habitat.
- c. a harmless species that resembles a poisonous species.
- d. similarly colored body parts on two poisonous species.

_____ 16. Characteristics that enable plants to protect themselves from herbivores include

- a. thorns and prickles.
- b. sticky hairs and tough leaves.
- c. chemical defenses.
- d. All of the above

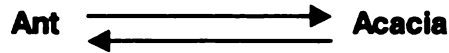
_____ 17. Which of the following usually results when members of the same species require the same food and space?

- a. primary succession
- b. competition
- c. secondary succession
- d. interspecific competition

_____ 18. Competitive exclusion occurs when

- a. a species is eliminated from a community because of competition.
- b. new species enter an ecosystem.
- c. species reproduce.
- d. a species occupies a fundamental niche.

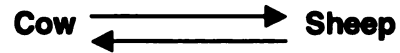
The ant keeps predators away from the acacia tree.



The acacia provides shelter and food for the ant.

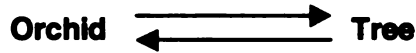
1

The cow eats grass.



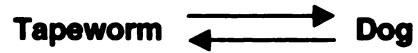
The sheep eats same grass.

2



The tree provides nutrients and a sunlit location for the orchid living on it.

3



The dog provides nutrients and shelter for the tapeworm living in its intestines.

4

- _____ 19. Refer to the illustration above. The relationship shown in diagram "4" above is
- commensalism.
 - competition.
 - mutualism.
 - parasitism.
- _____ 20. Refer to the illustration above. The relationship shown in diagram "2" above is
- commensalism.
 - competition.
 - mutualism.
 - parasitism.
- _____ 21. Refer to the illustration above. The relationship shown in diagram "1" above is
- commensalism.
 - competition.
 - mutualism.
 - parasitism.
- _____ 22. Refer to the illustration above. The relationship shown in diagram "3" above is
- commensalism.
 - competition.
 - mutualism.
 - parasitism.

Identification: Identify the common name of the plants shown on the computer display projector. (30 seconds per plant, repeats at the end)

23.

24.

25.

26.

27.

28.

29.

30.

31.

32.

33.

34.

Appendix C9e

Mr. Woolcock

Properties of Communities/ Succession Quiz

Name:
Hour:

Matching: Write the correct letter in the blank before each numbered term.

- | | |
|-------------------------------|--|
| _____ 1. species-area effect | a. stable end point of succession |
| _____ 2. species diversity | b. the sequential replacement of populations in a disrupted habitat |
| _____ 3. species richness | c. a pattern of species disruption in which larger areas contain more species than smaller areas |
| _____ 4. climax community | d. the predictable, sequential replacement of populations in an ecosystem |
| _____ 5. primary succession | e. the number of different species in a community |
| _____ 6. secondary succession | f. the first species to colonize a new habitat |
| _____ 7. succession | g. the sequential replacement of populations in an area that has not previously supported life |
| _____ 8. pioneer species | h. an index combining the number and relative abundance of different species in a community |

True-False: If a statement is true, write T in the blank. If a statement is false, write F in the blank, and then in the space provided, explain why the statement is false.

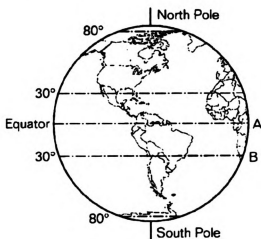
- _____ 9. A measure of the number of tree species in a community is a measure of the species diversity of trees in that community.
- _____ 10. Larger land areas usually include a greater diversity of climates than smaller land areas and can therefore support more species.

- _____ 11. Grasses are common pioneer species because they secrete acids that dissolve rock, releasing minerals for plant growth.
- _____ 12. Climate is not a factor in determining the ecosystem types found in the United States.
- _____ 13. Secondary succession typically proceeds from deciduous trees to shrubs and then finally grasses.

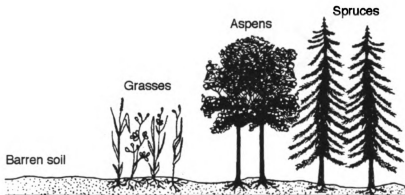
Multiple Choice: Write the letter of the most correct answer in the blank.

- _____ 14. Pioneer species
- a. disperse many seeds over a large area.
 - b. are usually small plants.
 - c. are usually fast-growing.
 - d. All of the above
- _____ 15. In the process of succession,
- a. an unchanging climax community is the final stage.
 - b. organisms change the environment so that it can support the growth of other species.
 - c. progress toward a climax community cannot be altered by further disturbances.
 - d. grasses are present in primary succession but absent in secondary succession.
- _____ 16. Which of the following is a characteristic of a stable community?
- a. good resistance to insect pests
 - b. the ability to recover rapidly from a drought
 - c. a high species richness
 - d. a low number of predators
- _____ 17. Which of the following types of succession would most likely occur following a forest fire?
- a. primary succession
 - b. old field succession
 - c. secondary succession
 - d. lake succession

- _____ 18. Which of the following is not a characteristic of pioneer species?
- a. They are small.
 - b. They grow quickly.
 - c. They reproduce slowly.
 - d. They disperse many seeds.



- _____ 19. Refer to the illustration above. An ecosystem located along latitude "A" would
- a. have a shorter growing season than an ecosystem on latitude "B."
 - b. probably contain fewer species than an ecosystem at lat. "B."
 - c. probably be more diverse than an ecosystem at lat. "B."
 - d. probably have less rainfall than an ecosystem at lat. "B."



- _____ 20. Refer to the illustration above. The process shown in the diagram is known as
- a. competitive exclusion.
 - b. succession.
 - c. symbiosis.
 - d. oligotrophy.

- _____ 21. The end stage of primary succession in a northern latitude would be characterized by the predominance of
- a. lichens.
 - b. needle-leaved evergreen trees.
 - c. small plants and shrubs.
 - d. grasses.
- _____ 22. Common types of plants found in areas in the early stages of secondary succession are
- a. shrubs.
 - b. lichens.
 - c. grasses.
 - d. trees.

Identification: Identify the common name of the plants shown on the computer display projector. (30 seconds per plant, repeats at the end)

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Observing Succession in Aged Tap Water

Problem: What changes occur in a microscopic water community over time?

Purpose: Examine the changes in the community structure (e.g. # of individuals, biodiversity, etc.) of aged tap water over a period of two weeks. Relate the changes in this small community to several larger communities (e.g. old-fields, sand dunes, etc.)

Materials (per group):

pen/pencil	coverslips
600 mL beaker	glass slides
1000 mL beaker	dropper pipettes
soil	microscope
grasses	reference books (e.g. A guide to the
dried leaves	Study of Fresh-water Biology, etc.)
white labels	

Procedure:

1. Fill a 600 mL beaker with tap water. Label the beaker with a white label with the names of the students in your group. Let the beakers sit undisturbed for 48 hours on the lab table near the mirror. This will allow gases harmful to microscopic organisms to evaporate. After 48 hours, this water is called aged water.
2. Put enough soil in the 1000 mL beaker to cover the bottom. Then fill the beaker with a combination of grasses, green leaves, and dried leaves. Pour the aged water over the leaves and soil.
3. Set the beaker aside on the lab table next to the mirror for 24 hours.
4. Examine the beaker for signs of life. Strong odors or cloudy water can signify bacterial growth, fuzzy growths or threads could indicate molds, and a greenish tint is algae.
5. Use a dropper pipette to remove some water from the beaker. Put a drop of the water on a glass slide and place a coverslip over it.
6. Examine the slide under low power. If no organisms are found, focus on some debris where microorganisms and bacteria are usually found. Then switch to high power to find any other microorganisms.

7. Use reference books to identify any microorganisms found in the slides. Note the number, size, and complexity of the organisms. Record your observations in Table 1 of the data and observations section.

8. Repeat steps 5-7 using water samples from several areas of the beaker.

9. Repeat steps 4-7 everyday for two weeks.

Data and Observations

Table 1.

Date	Observations

Analysis

1. Note any changes in the number and variety of organisms in the beaker over the two week period.

2. Describe any other changes that occurred in the community over the two weeks.

3. What types of organisms appeared in the community first? What type of organisms were found there after two weeks? Is there an explanation for these changes?

4. In ecology, what is the process of "change over time" called? Explain why a population such as that found in the aged water changes over time (hint: facilitation)?

5. Based on your findings, describe what would happen, over time, in a pond that once contained life that were killed off by toxins.

6. Imagine that you are sitting down to observe a barren sand dune for 200 years. Over the years, would you notice a change in the appearance of the dune? What do you think would happen? How is this process similar or different to the change in aged tap water?

7. Graph the population of each type of organism. Plot the dates on the x-axis and the number of organisms per field of view on the y-axis.

Conclusion

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