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TO AT-RISK HIGH SCHOOL STUDENTS
THROUGH THE USE OF
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TEACHING THE DYNAMICS OF EXOTIC SPECIES TO AT-RISK HIGH SCHOOL STUDENTS THROUGH THE USE OF LABORATORY INVESTIGATIONS

By

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ABSTRACT

TEACHING THE DYNAMICS OF EXOTIC SPECIES TO AT-RISK HIGH SCHOOL STUDENTS THROUGH THE USE OF LABORATORY INVESTIGATIONS

By

Stella Ann McCartney-Peters

The purpose of this study was for students to explore the dynamics of exotic species in the environment and further develop their ecological literacy. The unit demonstrates the ecological principles of intraspecific and interspecific competition, exponential growth, and predator-prey relationships. Hands-on laboratory investigations were tailored for students with poor attendance, low academic achievement, and a school with limited laboratory resources and equipment. Included in this unit were nine laboratory investigations, four audio/visual presentations, magazine/newspaper articles, and resource Internet web sites.

The unit's outcomes provides students with exotic species information while exploring their impact on native species within the environment. The unit assists students with identifying preventative strategies for invasive organisms. Students will encounter exotic species in their daily lives therefore a science topic worth investigating. This unit has lessons to be learned for any age group.

This thesis is dedicated to my mother
who passed away on June 25, 1999, during the first week of my research.
Her support of my continued education gave me strength to complete my study.

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My thanks and appreciation to Dr. Merle Heidemann for her understanding and support during my research. Thank you to my students who were cooperative and eager to learn about "exotic species". A special thank you to my husband, Russ, for his patience and understanding during the Masters' program.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

STATEMENT OF PROBLEM AND RATIONALE FOR STUDY

The purpose of this study was for students to explore the dynamics of exotic species in the environment and further develop their ecological literacy. Exotic species are known by many aliases. Whether they are called invasive, nonnative, alien, introduced, or nonindigenous, exotic species are organisms originating elsewhere that have been accidentally or purposefully relocated. Some exotic species are reproducing and invading habitats worldwide at alarming rates and causing economic and ecological disasters. In a sense, exotics are causing a form of "biological pollution."

Most high school students have an understanding of what air and water pollution is, but when given the term "biological pollution" they may be stumped. According to the New Webster's Dictionary (1976), the term "pollution" refers to making something unclean, foul, or tainted. So how is it possible that plants and animals could contribute to this? Some people may argue that the invasion of exotic species is not "biological pollution" but rather the "loss of biodiversity" in an environment. Nevertheless, both concepts reflect devastating consequences.

My teaching focus has always been to create lessons that incorporate "real life" concepts. I teach at an alternative education high school and my students are considered "at-risk." They are quick to challenge any science topic with the question "Why do I need to know this"? In fact, some students are quick to challenge why they have to learn anything because education has not been given any importance in their families. As a teacher, I strive to identify science issues they need to explore and learn. Exotic species are organisms students and adults have the most contact with on a daily basis but know the least about. An excerpt from a book written by Robert S. Devine (1998) illustrates this:

> The alien invasion is the least known of the world's major environmental issues. Some of our ignorance regarding these intruders stems from the fact that often they come wrapped in pretty packages. Our hearts quicken when we see a band of wild horses galloping along a distant ridge, and we savor the showy blooms of purple loosestrife waltzing with the breeze. Most of us don't realize that wild horses degrade native grasslands and purple loosestrife destroys wetlands.

In nature, the presence of exotic species is not always what it seems to be. Education is the key to overcoming such ignorance.

Most of my students will not go on to college but their knowledge of exotic species and their actions in the environment and community can make a difference. One situation my students or just about anyone could be in: nearly everywhere, driving down the roads, people can observe long, beautiful, purple stands of flowers. They are found in the ditches amongst the cattails and look beautiful when they are in full bloom during the summer. People might ask themselves, "What harm could it do to take a bunch of flowers home to put in a vase with the cattails?" Due to their lack of knowledge, they have just engaged in transporting and spreading an invasive exotic species known as "Purple Loosestrife." Depending on what time of the year the flowers were transported, they may have released seeds into uninfected areas. The transmission of the seeds may result from physically moving the flowers or by transporting the seeds attached to their clothing and depositing them elsewhere. Another scenario could include sport fishing. A day of fun in the sun and fishing could lead to a disastrous outcome. If someone went fishing at one lake and found that the fish were not biting they might choose to try another lake. At the first lake they might have had a bucket of minnows. During the course of fishing at the first lake it would be necessary to replenish the bucket with some fresh water from the lake. After a long period of time they decide to pack it up and try another lake. They would probably replenish their minnow bucket one more time for the journey. At the second lake they might have some luck. Nevertheless, before leaving they dump their minnows and water into the lake. Little did they know they have just infected the second lake with small zebra mussel veligers from the first lake, which will quickly develop into adults. Presently there are at least 119 inland lakes infected with these exotic species (Michigan Seagrant, 1999). That number is bound to rise unless the information gets out not to exchange water from one lake to the next. Another way veligers are spread is by moving boats and boat trailers from one lake to the next without proper cleaning. Zebra mussels have had a tremendous negative impact on the Great Lakes Basin ecosystem by out-competing other native mussels and small fish for food. Possessing the knowledge of exotic species and how they impact an environment can make the difference between spreading a deadly killer or containing it.

Another example of how quickly an exotic species can adapt and spread in an environment was a case study in a textbook by Miller (1994):

> The fast-growing water hyacinth is native to Central and South America. In 1884 a woman took one from a New Orleans exhibition and planted it in her back yard in Florida. Within 10 years the plant, which can double its population in two weeks, had become a public menace. Unchecked by natural enemies and thriving in Florida's nutrient rich waters, water hyacinths rapidly displaced native plants, clogging many ponds, streams, canals, and rivers, first in Florida and later in the southeastern United States.

From one simple seemingly harmless act, a nuisance was born. Another species, the "kudzu" vine, was imported from Japan in the 1930's to help control soil erosion. Little did anyone suspect that its prolific nature would engulf and displace many native species. It is estimated that if global warming continues, the kudzu could reach as far north as the Great Lakes by the year 2040.

Students and adults may be unaware of the dynamics that exotic species are creating in our native habitats. In fact, many teachers instructing our students may not even be aware of the importance of teaching about exotic species. I say this because in March (2000), another teacher and I presented ideas from this unit at the Michigan Science Teachers Association conference. The title in the program was "Exotics Invading Our Classrooms." I thought it was a rather "catchy" title and really expected an overwhelming turnout -- standing room only. The room was only half full and I was rather disappointed with the turnout. I began to think of some reasons for the low teacher attendance. These include: 1) our session was offered at 3 o'clock in the afternoon and many teachers had possibly gone home, 2) we did not have any exploding experiments, 3) teaching about exotic species is not specifically identified as a concept in the

Michigan Essential Goals and Objectives for Science Education (MEGOSE), or 4) teachers may not be concerned or interested in exotic species. As teachers, we can approach the exotic species problem from a pro-active rather than re-active standpoint. Who else should we educate regarding exotic species than a new generation of leaders and citizens?

One of the outcomes from this study were educational posters representing different exotic species created by the students. The posters would be displayed at a local Outdoor Education Center. When the posters were delivered, the assistant director stated that he really liked the posters and that they should have a program there pertaining to exotic species. From an educational perspective, teaching sound ecological habits begins in the classroom and certainly at outdoor education centers.

The dynamics exotic species play in an environment are best understood when considering the region it invades. The State of Michigan is greatly influenced by what goes on in the Great Lakes Basin because approximately 99% of both the upper and lower peninsula is part of it. The other 1%, located in the upper peninsula, is actually part of the Mississippi River watershed. The rest of the Great Lakes Basin is made up of the following states and provinces: Wisconsin, Minnesota, Illinois, Ohio, Indiana, Pennsylvania, New York, Ontario and Quebec. These states and provinces contribute only partial land mass and waterways to the basin. Since the State of Michigan is almost entirely contained within the Great Lakes Basin it also has the most to lose from the invasion of exotic species. The Great Lakes provides a tremendous source of economics and recreation to Michigan. Tourism itself brings in approximately $10 billion dollars a year. As the baby boom generation enters their peak earning years and retirement phase of their lives, the Great Lakes Basin will be attractive for vacations, second homes and retirement homes (Fridgen, 1998). Economically, the Great Lakes sport and commercial fishing industry is valued at almost $4.5 billion dollars annually (Great Lakes Panel, 1998). As the beauty of the Great Lakes draws people to it, the invasion of exotic species can destroy the very essence of its natural landscape, waterways, and native species.

The seriousness of the exotic species problem is also recognized at the federal level. On February 3, 1999, President Clinton signed Executive Order 13112 "to prevent the introduction of invasive species and provide their control and to minimize the economic, ecological, and human health impacts that invasive species cause…" (Clinton, 1999). This order creates a task force of federal agencies to investigate the problem of exotic species in the United States. Included in the task force are the Invasive Species Council and the Department of the Interior. These agencies are to produce an Invasive Species Management Plan within 18 months of the Executive Order, which should be ready for review by August 2000. The Great Lakes Basin is not the only area plagued with exotic species. Many other areas of the United States are battling either the same or different exotic species.

An invasive species has escaped its "natural boundaries", therefore the level of concern also becomes an international problem. A 1909 Boundary Waters Treaty between the United States and Canada established the International Joint Commission (IJC) to deal with various environmental issues relating to the Great Lakes Basin. The IJC has continually investigated water and air pollution. Now it also focuses on biological pollution.

The Great Lakes Basin is a mecca of international shipping commerce. For this reason it is also vulnerable to the ballast water of freighters. Through the release of ballast water, many exotic species have been deposited into the basin. How the ballast water is eliminated from freighters remains a heated, on-going debate and yet to be resolved. This issue also involves the International Maritime Organization (IMO) of the United Nations (UN). One of the responsibilities of the IMO is to prevent and control marine pollution from ships. The Marine Environment Protection Committee (MEPC) of the IMO investigates and submits recommendations or guidelines to the United Nations assembly for approval. There is also a wealth of international organizations dedicated to global biological and ecological monitoring. Such organizations include: Special Committee on Problems of the Environment (SCOPE), Global Environmental Monitoring System (GEMS), United Nations Environment Programme (UNEP), and many others (Spellerberg, 1991). The role of these organizations is to monitor changes in land use, study the effects of habitat loss, and promote the conservation of species, natural communities and landscapes. All of these international organizations must work together to find solutions to the continuous, global invasion of exotic species.

The sheer magnitude of the exotic species invasion makes one think "What can I do about it?" A beginning solution would be to attack the problem from an "act local, think global" perspective. This conviction has led me to become professionally and personally interested in exotic species. Teaching science in my school has given me the opportunity to pursue my interests as well as instructing students in an area of environmental biology that is least recognized.

A look into the history of man's existence and nomadic tendencies gives a clear understanding of his influence on the planet. Before 1500 AD, man's activities included forest clearing, primeval agriculture, long-range wars and invasions, migration, building large empires, and shipping trade to the Far East.

> A historical turning point occurred around 1500 AD with the exploration, discovery and colonization of new territories. It also marked the beginning of the globalization of exchanges, while still keeping a very strong European focus (Drake, 1989).

These movements included the discovery of the New World, migration to northern and central Asia, and Pacific islands. With each of those movements, man also transported the plants and animals he was accustomed to or needed for food production. The biogeographical movement of man has accelerated in the last century. The invention of the airplane, improvements in maritime transportation, and railroads has allowed human migrations to take place at an even greater rate. Each migration lends an opportunity to transport exotic species, ultimately leading to the accidental or intentional release of them. An Office of Technology Assessment (OTA, 1993) report to Congress illustrates how many exotic species are transported without detection:

> Many live organisms now are available through catalogue sales, including insects and other animals for biological control, as well as a wide variety of plants and seeds. Catalogue sales do not present the same inspection and regulatory opportunities that are available in the case of ordinary retail outlets. Nurseries and aquatic plant dealers sell several federally listed noxious weeds through the mail, such as the rooted water hyacinth, which can clog waterways and cause a navigation hazard. This opens the possibility that commercial distribution may provide a pathway for spread of potentially harmful non-indigenous species (NIS), including pathogens and parasites.

As technology continues to increase, so does the opportunity for man to spread his influence to every corner of the globe. The Internet also serves as a vehicle of transporting exotic species. People can log on, shop, and purchase any type of exotic species. Many of these purchases are probably delivered without inspections.

EXOTIC SPECIES TRANSPORT MECHANISMS OR ROUTES

What are the mechanisms of transport for exotic species?

> Most new NIS arrive in association with human activity, transport, or habitat modification that provides new opportunities for species' establishment. Numerous harmful species arrived as unintended byproducts of cultivation, commerce, tourism, or travel. For example, they arrived as contaminants of bulk commodities, packing materials, shipping containers, or ships' ballast. Weeds continue to enter the country as contaminants in seed shipments; both plant and fish pathogens have arrived with diseased stocks. Some NIS stow away on cars and other conveyances, including military equipment. Other harmful NIS were intentionally imported as crops, ornamental plants, livestock, pets, or aquaculture species-later escaped (OTA, 1993).

The type of exotic organism it is dictates the pathway in which it immigrates. Some exotic fish have been intentionally transplanted in order to enhance sport fisheries. Other exotic fish may have been illegally released by aquarium dealers and individual aquarium owners, while others are escapees from aquaculture facilities. Vertebrates are mostly intentional introductions while invertebrates are usually accidental. Insects, aquatic and terrestrial mollusks are common hitchhikers on plants, commercial shipments, ships' ballast water, aquarium/aquaculture shipments, household goods, and travel baggage. Plants have either been imported for horticulture or agriculture purposes, while others may be stowaways. The problem with the mechanism of exotic species' transport is that accidental introductions have actually caused more harmful effects than any intentional releases. For this simple reason, it is essential to promote ecological literacy among students and adults. Many plants and animals have been disposed of or planted by individuals without any thought about their impact or ecological consequences.

Another form of unintentional NIS introductions has been through the release of a ships' ballast water. "Ballast" is referred to as the weight an empty vessel must carry in order to maintain stability while navigating across an ocean or large lake. Water is used by all ships and freighters because it is accessible and convenient. Many aquatic exotic species have hitchhiked into the Great Lakes via ballast water.

> Since the mid 1980s, ballast water has likely been responsible for bringing zebra mussels, gobies, Eurasian ruffe, spiny water flea, and most recently, the fishhook flea into the Great Lakes. Battle lines have been drawn in the fight to prevent nonindigenous species from entering the Great Lakes in the ballast water of ocean-going ships. Michigan State Senator Ken Sikkema (R-Grandville) introduced legislation in February that would regulate ballast water discharge in Michigan's Great Lakes waters. The legislation would require that ballast water be sterilized before ships enter Michigan's Great Lakes waters

> and prohibit ships from discharging ballast water in the state's Great Lakes waters without a permit from the Michigan Department of Environmental Quality (Upwellings, 2000).

While the disagreement on how to handle ballast water lingers, so does the ability of NIS invasions. There are also a large number of vessels that enter the Great Lakes system claiming to be "NOBOB", or "no ballast on board." Even though these vessels may not contain ballast water, they carry contaminated slop and sediments in their tanks. While these ships cross the lakes they dump their unwanted sludge into them. Most of this slop and sediment can also harbor exotic species. Therefore, the legislative issue does not end with ballast on board (BOB), but also must take into consideration NOBOB's. Before water was used as ballast, ships would load dirt or rocks on board for stability and dump the unwanted contents on land or in the lakes. The dirt and rocks were also a transport mechanism for many exotic plants and invertebrates. Maritime transportation has led to dumping one thing or another onto the soil or in the water.

According to the OTA (1993), at least 4,500 species of foreign origin have established free-living populations in this country. Where does a teacher begin to instruct her/his students about exotic species? One way to determine the answer is to look at which exotic species are subjected to human influences. While teaching this unit I chose to focus on human activities leading to the introduction of several exotic species in the Great Lakes Basin.

THE EXOTIC SPECIES STUDIED

One exotic species the students seemed the most interested in was the **sea lamprey**. They were mystified by its attachment to large native fish and how it basically sucked the life out of its prey. The sea lamprey is native to the Atlantic Ocean and was observed in Lake Ontario in the 1830's. Niagara Falls was a natural barrier between Lake Ontario and the four other Great Lakes. A passageway was sought for trade ships to navigate the Great Lakes, St. Lawrence Seaway, and out to the Atlantic Ocean. The Welland Canal was constructed enabling ships to circumnavigate the falls. This manmade marvel also opened a Pandora's box. The exotic organisms that were held back by the Falls' physical barrier now had a gateway to new territory. The invasion of the sea lamprey began. The Great Lakes Fishery Commission (GLFC, 2000) states that sea lampreys were first observed in Lake Erie in 1921. After spreading into Lake Erie, sea lampreys moved rapidly to the other Great Lakes, appearing in Lake St. Clair in 1934, Lake Michigan in 1936, Lake Huron in 1937, and Lake Superior in 1938. According to the GLFC (2000), by the late 1940's sea lamprey populations had exploded in all of the upper Great Lakes causing severe damage to lake trout and other critical fish species. The sea lamprey is a primitive jawless eel-like fish. Its' mouth is a large sucking disk with sharp teeth and file-like tongue. The teeth and tongue are used to scrape away fish scales, allowing attachment to the skin so that it can suck the life juices from its' victim. During its parasitic adult life, one sea lamprey can consume 40 or more pounds of fish. By the time biologists and fisherman had discovered the extent of the sea lamprey's spread it had already caused a severe decline in lake trout, whitefish, and chub populations. As a result, commercial and sport fishing were in a state of collapse. During the time of highest sea lamprey abundance, up to 85% of fish somehow not killed by sea lampreys exhibited sea lamprey wounds (GLFC, 2000). With no natural predators in the Great Lakes, a method to control the spiraling sea lamprey population was imperative. Even though stopping the sea lamprey seemed impossible, its complex life cycle provides some hope to the problem. During the spring and early summer, adult sea lampreys move into gravel areas of tributary streams. Here the male and female build their nest and lay eggs before dying. When the eggs hatch, the larvae travel downstream to burrow into sand and silt. During this non-parasitic larval stage which can last from 4-6 years, the sea lamprey is most vulnerable. After the larval stage, an amazing transformation occurs in which these non-parasitic creatures develop into the eel-like parasitic fish. Now adults, the sea lampreys migrate to open waters to spend the next 12-20 months feeding on fish. Although the average life cycle is about 6 years, it can be as long as 20 years.

What is the solution to the sea lamprey dilemma? In 1958, scientists discovered a chemical, TFM (3-trifluoromethyl-4-nitropenol), to be effective in killing larval sea lampreys while in the tributary streams. Every year United States Fish and Wildlife biologists treat streams with this chemical that seems to have a minimal effect on other fish and aquatic organisms. However, just treating tributary streams is not a cure-all for the problem. Additional control methods are also being utilized. Areas of the St. Marys River are still considered prolific breeding grounds for the sea lamprey which are treated with Granular Bayluscide as a chemical control treatment. This particular chemical also affects the larval stage of the lamprey. Global positioning satellites determine "hot spots" of the larvae and helicopters deposit the chemical into the water much like crop dusting for weeds. Another method of control is trapping the adults as they make their way to spawning grounds. From the trappings, adult males are removed and used for the final method of control: sterile-male-release technique. Once the adult sea lamprey males are sterilized they are released back into the water. One might ask, "Why throw the males back into water once you have already caught them?" The explanation makes perfect sense. The sterilized males act as aggressively as the fertile ones thus competing for a chance to mate with a female. If the female chooses a sterile male to spawn with, the eggs will be unfertilized. If none of the sterile males were released all of the eggs would be fertilized by normal males. At a recent conference Professor Michael Jones, MSU, (2000), stated that although the multi-control methods seem to be effective, 54 percent of the lake trout population in Lake Huron are still being killed by sea lamprey. So the battle continues to reduce the sea lamprey population and return the Great Lakes to its native aquatic inhabitants.

While students cannot directly control or prevent the spread of the sea lamprey, it was a great species to use as an anticipatory set to the unit. Students were horrified to think that such a hideous looking creature inhabited the Great Lakes. After viewing a couple of videos about sea lampreys from the GLFC, students said they were afraid to go swimming in the lakes because they might come out with sea lampreys attached to their bodies. I reassured them that humans were not the kind of prey in which the sea lamprey was interested. The sea lamprey certainly peaked their interest in exotic species and they wanted to learn more about other ones.

The construction of the Welland Canal let the door open not only to the sea lamprey but other exotic species as well.

> Following the sea lamprey was another ocean fish that wreaked its own special form of havoc in the Great Lakes ecosystem - the **alewife**. Thanks to the sea lamprey, this small, sardine-like fish found a Great Lakes devoid of large predators, and in a short time alewives exploded in number in each of the upper four lakes except Superior, which is apparently too cold for it. First reported in Lake Michigan in 1949, for example, the alewife was already being harvested commercially in 1956. As the numbers of valuable fish in the lake continued to decline, some fisherman could at least market the plentiful alewives for use in fishmeal, fertilizer, and pet food. By the 1960's, the alewife made up more than 80 percent of the lake's total number of fish and half of the total biomass (The Fisheries Of The Great Lakes, 1984-86).

The tremendous numbers of alewives caused severe competition for food and habitat between other Great Lakes native fish. Declines in lake herring population were the results of competition and commercial over-fishing. Students can still experience the results of the alewife population explosion. From time to time, alewives die-off in massive numbers and wash up on the Great Lakes shoreline. The alewife die-off is due to its inability to totally adapt to the Great Lakes' harsh winters, cold spring water temperatures, and spawning stressors. The stench from the dead alewives is enough to take anyone's breath away and ruin a perfectly nice day at the beach.

The **white perch** is also an immigrant of the Great Lakes through the Welland Canal. Its native habitat is the salty waters of the Atlantic coast. This species is a member of the bass family and is not a true perch. Presently the white perch is found in the lower Great Lakes. Is it a matter of time before it inhabits all of the Great Lakes? No one knows for sure. One thing is certain; it is a serious competitor of the treasured yellow perch that inhabits all of the Great Lakes. If the white perch continues to colonize other parts of the Great Lakes, food and habitat competition will increase among other fish, especially the yellow perch.

Besides the influence of man-made canals, the issue of ships' water ballast has contributed to many NIS transports. Several exotics such as the **zebra mussel**, **round goby**, **tubenose goby**, **river ruffe**, and **spiny water flea** have been linked to ballast water exchange. The zebra mussel has caused the most economic and recreational destruction of the ballast water transport species. Intense research is being done to hinder its spread. The United States Fish and Wildlife Service has estimated that the cost of industrial, utility, and municipal-water-use reductions due to biofouling, plus the impact zebra mussel on navigation, boating, and sport fishing, could reach $5 billion by the year 2000 in the Great Lakes alone (Ludyanskiy, et al, 1993). As consumers, that means we are all paying the price for the zebra mussel clean-up in some way, shape, or form. The mussel is native to southern Russia and was unintentionally introduced by way of ships' ballast water. Since its first appearance in Lake St. Clair in 1985-86, it quickly spread to all of the Great Lakes and connecting tributaries within six years. The zebra mussel's ability to breed prolifically has made it a successful invader.

Zebra mussels are a freshwater bivalve mollusk ranging in size between 0.5 to 3.5 cm long. Most have striped shells similar to that of a zebra. Some have been found to be solid black or brown. The life span of the zebra mussel is typically 3-5 years. Zebra mussels are generally sexually mature in their second year of life.

> A fully mature female mussel may produce up to one million eggs per season. Eggs are fertilized outside the mussel's body and within a few days develop into free-swimming larvae called veligers. Veligers swim by using their hair-like cilia for 3 to 4 weeks, drifting with the currents. If they don't settle onto firm objects in that time, they die; and the vast majority actually suffer this fate. It is estimated that only 1 to 3 percent survive to adulthood. Those that find a hard surface quickly attach and transform into the typical, double-shelled mussel shape; they are then considered juveniles (Ohio Sea Grant College Program, 1994).

Zebra mussels attach themselves to any type of hard surface with strong fibers called byssal threads. Besides rocks, pipes, and boats, zebra mussels have been found attached to another animal's shell (living or dead). One of the largest concerns of the zebra mussel invasion is the disruption of the food web. An adult mussel is capable of filtering one or more liters of water per day and consuming whatever phytoplankton or zooplankton it happens to ingest with the water. By removing significant amounts of phytoplankton from the water, zebra mussels remove the food source for microscopic zooplankton, which in turn are food for larval and juvenile fishes and other plankton-feeding forage fish (Ohio Sea Grant College Program, 1994). The competition for phytoplankton at the base of a lake's food web could generate a negative cascading effect among all trophic levels of a lake. The impacts of food and habitat competition remain to be seen.

In the meantime there are ways students and adults can control and prevent the spread of zebra mussels to their community lakes. The prevention is quite simple: 1) Clean boats, engines, bait buckets, and fishing gear before moving to another lake; 2) Make sure all mud and plant debris is removed from the boat, trailer, propeller, live well, canoes, and anchors; 3) Use caution when transferring baitfish from one lake to another; 4) Never transport water from one lake to another; and 5) Always keep in mind that what you can not see, can hurt!! If students and adults follow these guidelines they can feel reasonably certain they haven't transported a nuisance.

Another newly acquired NIS may assist in controlling the zebra mussel population. The **round goby** is a native of the same area as the zebra mussel and also thought to have been transported in ballast water. Its cousin, the **tubenose goby** has also been transported in the same manner. The gobies were first sighted in the St. Clair River in 1990. The gobies are deep water dwellers and could be a fierce competitor of the native sculpin, darters, and logperch. The goby's appearance resembles that of a dogfish. The tubenose goby has two distinct tubelike projections from its head, while the round goby has a black spot on its dorsal fin. The tubenose goby grows to a length of about 4-5 inches whereas the round gobies can reach lengths up to a foot long. The tubenose goby is an endangered species in its native land.

> Perhaps the best news about the round goby, our most recent invader is that it has quite an appetite for zebra mussels. But the ability of round gobies to impact or reduce the zebra mussel populations that have exploded here is still questionable. It is their appetite for zebra mussels in particular which has singled them out as not just another troublesome invader; but perhaps, a partial solution

> to a serious ecological problem. One thing is certain. It may be years before we know whether the round goby will be an asset or a liability (Johnson, Lashbrook, 1993).

Studies have shown that one round goby may consume from 1 to 78 zebra mussels per day. Besides ducks and other fish, the round goby may provide a way to bring the zebra mussel population under control. Water recreationalists are informed that if they spot or catch a round or tubenose goby they are to kill it, freeze it, and call the Michigan Sea Grant Program, U.S. Fish and Wildlife Service, or the Michigan Department of Environmental Quality for species confirmation. Regardless of their possible assistance in the zebra mussel dilemma, the round and tubenose gobies are exotic species capable of displacing and out-competing native species.

The **river ruffe** (rhymes with tough) is a small, aggressive fish measuring 4-6 inches long. The ruffe resembles a yellow perch but has walleye markings. Distinct characteristics of the ruffe are a very large dorsal fin with 11-16 spines in front, a downturned mouth, and no scales on its head. This particular species is a member of the perch family and capable of living in varied environments. Transport of the ruffe is thought to have been by ships' ballast. Presently the river ruffe has colonized the Duluth harbor area located in Lake Superior. Biologists are concerned the transport of the ruffe will most likely occur through intra-basin boat movement. The ruffe has a high reproductive rate and is able to eat a large variety of foods. Its ability to consume many types of food will contribute to increased competition among native species. The ruffe's sharp, spiny, dorsal fins limit the type of predators that will eat it as prey. If predators are unable to feast on the ruffe as a food source, predator populations could dwindle.

Anglers, boaters, and bait dealers can assist in controlling the spread of the ruffe. Special precautions should be taken not to transport the ruffe. If a ruffe is caught, individuals should contact their local Department of Natural Resources. Ruffe should never be thrown back into the water alive.

The only crustacean studied in this unit was the **spiny water flea**, *(Bythotrephes cederstroemi)*. It is also referred to as B.C., short for its genus/species name. This creature is native to Europe and was discovered in the Great Lakes around the 1980's. A unique body structure gives B.C. a competitive advantage over other small crustaceans. A spiny tail makes up nearly 70 percent of the total body length. The spiny tail also makes B.C. less desirable to predators allowing it to continue eating and reproducing. The spiny water flea consumes zooplankton and is in competition with other native zooplankton for food and habitat. An unusual reproductive cycle also gives B.C. an advantage. The spiny water flea is able to reproduce asexually when environmental conditions favor increased population size. When environmental conditions decline, females will produce more males that can fertilize the eggs. This type of reproductive cycle makes the spiny water flea an extremely successful invader. Like any other exotic species the spiny water flea is here to stay, but individuals can assist in reducing its spread. Not transferring water between other lakes is one preventative measure. Anglers can check their tackle, downriggers, and fishing lines for any signs of B.C. or eggs (very small and orange colored) and clean equipment with hot water. The impacts of the spiny water flea are unknown.

Exotic plants have also been intentionally or accidentally introduced into areas as a direct result of man's activities. Many of these introductions are connected with agricultural or horticultural enterprises. Exotic agricultural plants have been used for erosion control and livestock feed. The kudzu is an example of an exotic species planted for erosion control. Now it is one of the most noxious weeds in the United States. Other exotic plants have been imported for horticulture and landscaping use. Some aquatic exotic plants are being sold by aquarium dealers. The problem with many of these introductions is that the landscape is transformed with new territorial plants. In this new landscape native plant or animal species must compete successfully, adapt, or perish.

> Plants form the foundation of a biological community; they are the center from which the food web fans out, and they profoundly influence the soil, the water, the air, and the very shape a community takes. When exotic plants replace native plants, the habitat changes. Recent surveys indicate that at least 6,000 non-native plants have become established in the United States. Most are benign or of minor consequence, but hundreds cause serious trouble. These are known as exotic invasive weeds-a weed simply being any plant that humans deem to be in the wrong place (Devine, 1998).

There are many plants placed on the United States' noxious weeds list. But according to OTA (1993), state agriculture and natural resource officials, Federal land managers, members of conservation organizations, and scientists have expressed their concern that existing Federal weed laws are flawed, their implementation incomplete, and too few resources have been directed toward weed problems. Lack of funding to enforce laws and continue noxious plant research creates problematic situations when trying to get these weeds under control.

In this unit one exotic terrestrial plant was studied. The **purple loosestrife** was the exotic chosen due to the fact students probably encounter this plant on a daily basis. Whether growing on the side of the road, around lake boundaries, or in wetland areas, it is not hard to notice this beautiful purple plant. Disguised in its beauty, though, was a "purple plague." It was originally imported from Europe as an ornamental landscaping plant. This exotic species grows from 4-7 feet tall and has long spikes covered in purple flowers. One adult loosestrife can produce up to two million seeds per year. These seeds can be dispersed by wind, water, animals, or humans. The problem with purple loosestrife is that it is a fierce competitor of the native cattails. Loosestrife has no ecological value whereas cattails provide wildlife food and habitat. There are some preventative measures students and adults can do to help minimize the spread of purple loosestrife. Any new sightings of loosestrife should be reported to the Department of Natural Resources (DNR). If the patch is small, it is recommended that individuals pull out the plant and its entire root system. There are aquatic herbicides (labeled for aquatic use) that can be used to clear an infested area. The DNR should be contacted if using a herbicide in wetland areas as permits are required.

There is another control method to the purple loosestrife problem unfolding in many school classrooms around the State of Michigan. The "Purple Loosestrife Project" is being initiated by Michigan State University (MSU) and the Michigan Sea Grant College Program. This project is designed to get school-age students involved in a real ecological problem. Classrooms are equipped with purple loosestrife plants and exotic imported beetles (*Galerucella calmariensis*, *Galerucella pusilla*, *or* *Hylobius transversovittatus*).

The beetles are reared by students in netted receptacles containing Purple Loosestrife until there are sufficient numbers of them to release into the environment. Students then physically monitor the release area for three or more years to measure any impact. These beetles have been extensively researched as being Purple Loosestrife species-specific; therefore it is of minimal risk to other plants in the area. Using an unresearched biological control method could create more problems than the original invasion itself.

The last plant species studied in this unit was an aquatic plant called the **Eurasian Water Milfoil**. This exotic plant was imported from Europe and Asia giving it the name "Eurasian." It was most likely introduced as a result of aquarium dealers or individual aquarium owners dumping the plant into some pond, lake, or river. The plant has long, flexible feather-like leaves attached in whorls of four. Milfoil is spread by transferring fragmented weeds attached to boat motors or trailers, fishing equipment, or exchanging water from one lake to the next. Once transported to another lake it quickly reproduces and forms dense surface mats. This thick vegetation crowds out native plants and interferes with water recreation. A special reproductive feature of Milfoil is that it can break up by itself by "autofragmentation." Once broken up, plant fragments can be carried away by wind, wave action, and pleasure craft activities. This reproductive method allows for Milfoil to have a competitive advantage over other plants. There are some preventative measures individuals can practice to prevent the spread of Water Milfoil. Boating and fishing equipment should be cleared of all vegetation before transporting to another lake. Lake water containing vegetation should not be transported and dumped into other lakes. If individuals notice any strange aquatic vegetation in a lake they should contact the DNR. The DNR has designed several programs to control the spread of Water Milfoil. Public awareness is stressed as being the most important aspect.

An important issue to point out while teaching this unit is that not all immigrant exotic species have been nuisances. Immigrants have molded the United States into what it is today. Those immigrants include plant and animal species, especially *Homo sapiens*. Of course there are harmful exotic species that continually create havoc across the country, but that number is much smaller compared to the beneficial exotics that live here. Many of those imported beneficial exotic species have enhanced man's economic and social existence. According to OTA (1993), approximately 15 percent of the NIS in the United States cause harm. Eighty-five percent of the remaining exotic species have beneficial impacts. In regards to any exotic species introduction, man has acted before thinking of any negative consequences relating to their transplant. In the future, there is hope that lessons from the past can help prevent future noxious invasions.

There were a couple of beneficial exotic fish species presented in this unit. Many of these fish species were transplanted by government agencies to strengthen sport and commercial fishing businesses that had declined dramatically with the sea lamprey invasion. Students learned that the Coho and Chinook salmon were introduced as predatory fish into the Great Lakes to assist in reducing alewife populations. Both of these salmon have also proved to be excellent sporting fish.

In summary, the exotic species studied in this unit have been linked to human activities. The construction of the Welland Canal made it possible for the Sea Lamprey, Alewife, and White Perch, to invade the Great Lakes. The Welland Canal expanded international shipping into the Great Lakes allowing the Zebra Mussel, Round Goby, Tubenose Goby, River Ruffe, and Spiny Water Flea to invade the Great Lakes. Purple Loosestrife was intentionally imported for ornamental use and Eurasian Water Milfoil for aquariums but unintentionally released. Finally, the Chinook Salmon and Coho Salmon were purposely transplanted by the DNR to increase a declining commercial and sport fishing industry. These exotic organisms represent only a few species that have been introduced through human activities.

ECOLOGICAL PRINCIPLES STUDIED

Ecological principles are necessary for students to investigate if they are truly going to understand the dynamics exotic species play in an environment. Competition is one of the most notable interactions that takes place between native and exotic species.

> By definition, competition occurs when interaction between two or more individuals or populations adversely affects growth, survival, fitness and/or populations size of each, typically when a common resource is in short supply. The interactions can be direct through interference, territoriality etc., or indirect through exploitation, involving joint use of some limited resource. Competition can occur between individuals of the same (intraspecific) or different (interspecific) species, and both types of interaction have important consequences in the community. Competition has adverse effects on all species utilizing a similar and limited resource at the same time and place (potentially leading to competitive exclusion of some species (Giller, 1984).

Species populations will compete for food or habitats. These competitions can occur within a particular species or across species boundaries. The competitive exclusion principle states that no two species of similar requirements can occupy the same niche (coexistence); therefore one species wins while the other looses. The intensity in which competition occurs is important when considering food chains and webs. Competition has always been associated with "survival of the fittest" or "may the best man win". In nature so many other factors come in to play. Sometimes survival it is just a matter of luck. Maybe it is being in the right place at the right time or the wrong place at the wrong time.

Another scientific concept studied in this unit was exponential growth. In many cases exotic species are able to reproduce quicker than native species giving them a competitive advantage.

> Population growth results when births and immigration exceed deaths and emigration. The difference between the two at any specified instant is the rate of increase for the population. Another way to express the rate of increase is to use the population's doubling time (how long it takes to double in size). What starts out as a gradual increase suddenly accelerates, and there is a burgeoning of number; this is the pattern of exponential growth (Starr, 1984).

This type of population growth is very deceiving at first. The numbers start out slowly and after a few doublings the population size increases to astronomically large numbers. The zebra mussel has a capacity to grow exponentially supporting its rapid invasion of the Great Lakes Basin. Other species such as the purple loosestrife produce enormous amount of seeds. This principle could also be applied to human growth populations.

Predator-prey relationships were also discussed. A predator is described as a organism that feeds on parts or all of a prey species. The predator, however, does not live on or in the prey. Predator-prey relationships can include: carnivore-prey, omnivore-prey, herbivore-prey, and parasite-host. In the Great Lakes Basin, predator-prey relationships are most important due to the fact that many exotic species have no known predators in a new territory. The lack of predators in an environment dramatically affects an ecosystem's food chain/web. The explosive invasion of purple loosestrife and sea lamprey are prime examples of what happens when population controls are not in place in nature.

EDUCATIONAL SETTING AND DEMOGRAPHICS

I have been teaching at an alternative education high school in southwest Michigan for six years. What is the definition of an alternative education high school? It is similar to any regular high school except the enrollment is much smaller. Depending on the program size, some alternative schools house between 50-200 students. Alternative schools have low teacher-student ratios which allows more one-on-one with students. Students attending an alternative school have left, dropped out, or been removed for various reasons from the regular high school setting. Most students are considered "at-risk". Graduates from alternative high schools receive a regular diploma with earned Michigan High School Proficiency Test endorsements.

The description of an "at-risk" student gives insight to the dynamics of an alternative education classroom. Most students attending alternative high schools have their own story as to why they are not in a regular high school. The characteristics of an "at-risk" student may include one or more of the following:

- Student history of alcohol and/or drug abuse
- Truancy
- Pregnant and/or teenage mother
- From bottom third in family income
- On probation or has been incarcerated
- Academic remediation
- Discipline problems
- Parents lack a high school diploma
- Poor self-esteem

According to a recent Michigan Alternative Education Study (1999), over 81 percent of Michigan alternative schools address academic remediation. The study also states that one of the most frequently cited problems is poor student attendance (38%) and secondly low student motivation (19%). With all these factors, it would seem almost impossible to run a classroom. An alternative education teacher must possess a desire to teach "at-risk" students, be organized, maintain high classroom expectations, and be a multi-social problem expert.

Approximately 170 students were enrolled throughout the school year (1999-2000). Twenty to twenty-five students are registered per classroom. School enrollment by gender is about 60 percent females and 40 percent males. Ethnicity is approximately 58 percent Caucasian, 37 percent African American, 3 percent Latin American, and 2 percent Native American. Twenty-five percent of the student population is represented in each of the 9-12 grade levels. The students come from primarily low income families.

Our high school has an academic and vocational focus allowing students to get hands-on experience in construction, marketing, technology, and communications.

PEDAGOGY

According to Larochelle, et al (1998), "A sociocultural perspective on teaching and learning rejects the overly simplistic appeal of a one-size-fits-all approach to enacting curriculum and cautions against technical adherence to rules about what does and does not work in promoting the learning of science." It is important to select teaching strategies that address the diverse learning needs of students. In order to meet those needs I incorporated hands-on laboratory and multi-sensory activities and administered several types of assessments.

One of the most important teaching strategies in any classroom is to incorporate multi-sensory activities to keep students engaged in the learning process. This is especially true in an alternative education classroom where students possess a lack of motivation for learning.

> Effective teachers use a variety of material and strategies to keep their interest. They structure the learning tasks in small sequential steps. By experiencing success, at-risk students can be motivated to learn. Classrooms that increase the likelihood of students' learning and retaining concepts are information processing as opposed to information receiving. That is, after teachers present the facts, students become involved in their learning with hands-on experiences. The more actively involved low achievers become in their learning, the greater the likelihood that it will have meaning, retention, and transfer (Lehr, 1988).

In this unit I incorporated visual, tactile, kinesthetic, and auditory activities (Reglin, 1993) for the students to perform. The activities included thought-provoking journal questions, lecture, discussion, lab investigations, magazine/newspaper articles, audio-visual presentations, games, and an art project.

The classroom instructional model used in this unit was the 5 E's (Bybee, 1997). The first E stands for "**Engagement**." The first objective is to engage students in the learning task. It is also dependent on assessing the students' prior knowledge. According to Olge (1986), "All of us carry around some vague and ill defined schemata; opportunities to talk about what we think we know, to put our bits of memory into order can really help us discover what we don't know." Olge is the creator of the **KWL** format I used for prior knowledge assessment. **KWL** stands for "what the students Know, what do the students Want to know, and what have the students Learned." This process helps set the stage for students, allowing them to focus on the topic of exotic species. At this point I also administered a pre-test (Appendix A, Section I) regarding exotic species. The students were upset with the pre-test because their prior knowledge was quite limited. I reassured them that the test would not affect their grade and would be used as an assessment tool. The second E stands for "**Exploration**." During this phase I used a myriad of hands-on activities. Since the hands-on activities were concrete and engaging, students were able to explore concepts or processes relating to exotic species. The teacher in this case acts as a facilitator or coach. The third E stands for "**Explanation**." Students communicate their explanations of the concepts or skills relative to the engagement and exploration activities. Next, the teacher further instructs students in scientific explanations or terminology. The fourth E stands for "**Elaborate**." This phase allows students to extend their conceptual understanding and skills. The use of thought-provoking journal questions can assist students in developing a broader understanding of the topic. Classroom discussions further enhance the learning process. The final E stands for "**Evaluation**." In this phase, the students can self-evaluate their own progress. The "**L**" in KWL assists the students in their self-evaluation and examination of whether their questions were answered relating to the topic. They can also pose new questions, encouraging further investigations. The teacher can assess whether educational outcomes were met in the form of traditional or alternative methods.

IMPLEMENTATION OF UNIT

The focus of this unit's goals and objectives were to incorporate the cognitive, affective, and psychomotor domains of human intelligence based on the research of Collette, et al (1984). These domains reflect the students' acquisition of knowledge (cognitive), arouses their emotions or feelings (affective), and requires them to use muscular activity associated with mental processes (psychomotor). The methods used provide various ways in which students can explore a topic.

The following goals were used as the focus of this unit. Students will:

1. Demonstrate knowledge of exotic species.
2. Demonstrate knowledge of humans influence on the introduction of exotic species.
3. Investigate the ecological principles of competition, exponential growth, and predator-prey relationships between exotic and native species.
4. Evaluate their own educational progress

The following instructional objectives of this unit were:

1. Identify and name five Great Lakes exotic species.
2. Explain the ways in which exotic species are introduced into the Great Lakes Basin.
3. Explain the impacts that exotic species have on the Great Lakes ecosystem.
4. Analyze the mechanisms or routes of exotic species invasions and assess possible solutions.

5. Simulate through laboratory experiments the impacts of competition between native/exotic species and predator-prey-exotic species relationships in an environment.
6. Construct data tables, graph the results of data, and analyze the results of graphing.
7. Calculate exponential growth to simulate a species population size
8. Measure yeast population densities using a Spectrophotometer 20.
9. Design and create exotic species educational posters.
10. Calculate species population size using a compound microscope.

The unit has also accounted for the following MEGOSE objectives:

1. Describe common patterns of relationships among populations.
2. Predict the effects of changes in one population in a food web on other populations.
3. Describe the ways in which humans alter the environment.
4. Describe the general factors regulating population size in ecosystems.
5. Explain the effects of agriculture and other human activities on selected ecosystems.

The topics taught during this unit included: competition, exponential growth, predator-prey relationships, identification of Great Lakes exotic species, mechanisms or routes of exotic species introductions, and preventative strategies of exotic species introductions for individuals. The outline on the next page shows a week by week synopsis of the topics covered and associated laboratory activities.

TOPICS	LABORATORY ACTIVITIES

WEEK 1:

Great Lakes Exotic Species	1) Lecture 2) Exotic Species in the Great Lakes Lab 3) "The Great Lakes Invader - Sea Lamprey video 4) "Great Lakes Invader: The Sea Lamprey Battle Continues" video

WEEK 2:

Mechanisms or Routes of Exotic Species Introductions	1) Mechanisms or Routes of Exotic Species Lab
Competition	1) Come On Now, Please Move Over Lab

WEEK 3:

Great Lakes Exotic Species	1) Lecture
Competition	1) Competition Study of Two Species of Paramecium Lab
Preventative Strategies, Mechanisms or Routes	1) "Great Lakes Invaders" Video 2) Journal questions

WEEK 4:

Competition	1) Here Today, Gone Tomorrow Lab 2) Journal Questions
Exponential Growth	1) Population Growth Lab

WEEK 5:

Predator-prey relationships	1) Sea Lam "PREY" Game 2) Lecture

WEEK 6:

Exponential Growth	1) Just Too Many of Those "Things" To Count Lab
Great Lakes Exotic Species, Preventative Strategies, Routes or Mechanisms	1) "The Great Lakes - Fragile Seas" Video 2) Journal Questions

WEEK 7:

Routes or Mechanisms, Preventative Strategies	1) "Aliens Invade America", "President Clinton Declares War on Exotics" magazine/newspaper article 2) Magazine/Newspaper Discussion Questions
Great Lakes Exotic Species, Preventative Strategies, Mechanisms or Routes	1) Michigan's Least Wanted Posters

The implementation of this unit incorporated five wet labs, three dry labs, four videos, and one art project. Dry labs used pen and paper activities while wet labs utilized laboratory equipment that required organisms, reagents, or various other materials. Incorporating wet lab investigations in my classroom was challenging since the classroom does not have running water or gas and lab equipment is limited.

I wanted to use "real" scientific equipment to collect and analyze data, incorporating the use of a Spectrometer 20 and compound microscope. I accomplished this by borrowing equipment from the local Math and Science Center. Students worked in groups and assisted others that were having difficulty with the equipment.

Teaching "at-risk" students requires using "bits and pieces" of many models to instruct the various abilities of my students. The 5 E's model incorporates many structural elements found in other instructional models. With this model I was able to utilize KWL. I used KWL (Appendix A, Section III) as a prior knowledge assessment tool that allowed me to find out what my students knew about exotic species and begin the learning process.

A pre-test (Appendix A, Section I) was used to assess the students prior knowledge of the dynamics of exotic species in an environment. Many of the students began the pre-test with a lot of anxiety because they did not know any of the terminology or even what an exotic species was. I reassured them they would probably be pleasingly surprised with their post-test (Appendix A, Section II) results as an indicator of what they had learned. Students also completed a KWL and discussed what they knew about exotic species. Most of the students agreed that an exotic species was something from another country. Based on their prior knowledge, I knew I had a lot of work ahead of me. I was up for the challenge though. I knew the activities I had modified and created would be fun and engaging for them.

A student survey (Appendix A, Section IV) was also administered to assess the unit. In the survey, students provided information regarding the effectiveness of the labs and accompanying activities. The survey provided an opportunity for students to comment on their attitudes relating to the unit's activities and exercises.

Exotic Species in the Great Lakes Lab (Appendix B, Section I)

The first lab was revised from the Great Lakes Instructional Materials for the Changing Earth System (Ohio State University, 1995) manual. The lab addressed recognizing some Great Lakes exotic species and identifying some of their impacts on the ecosystem. In this activity students were given exotic species picture cards and had to match other cards to them to determine transport mechanisms, ecosystem impacts, and the effects of global climate changes. Students found this activity challenging. This lab gave students insight as to the types of exotic species found in the Great Lakes and some of the dynamics of their presence.

Come On Now - Please Move Over (Appendix B, Section II)

The ecological principles of intraspecific or interspecific competition was introduced in this lab. Students planted various seed types and amounts into small containers and developed hypotheses about the outcome of limiting biotic and abiotic factors. The students were given the choice to manipulate some variables. Everyone's experiment turned out to be a little different. I liked giving my students choices but it was a little hectic. Some students only wanted to plant flowers while others wanted vegetables. Student absenteeism posed problems for data collection and plant maintenance.

Mechanism or Routes of Exotic Species (Appendix B, Section III)

A graphing exercise was used to determine the extent of mechanisms or routes in which exotic species are introduced. I created this lab based on my research relating to exotic species transport mechanisms. The students were given a data table in which they had to interpret, graph, and analyze the results. The results of graphing proved that shipping and unintentional releases were the most problematic mechanisms. A class discussion followed regarding current legislative efforts to control foreign ship ballast water from entering the Great Lakes. The mechanisms of unintentional releases were also discussed. Students brainstormed ways in which individuals could be responsible for some of those releases.

Competition Study of Two Species of Paramecium (Appendix B, Section IV)

This lab investigated competitive exclusion between two different types of paramecia. Students calculated the population sizes of *Paramecium (P.) multimicronucleatum* and *Paramecium (P.) aurelia*. Next they placed equal culture populations of *P. multimicronucleatum* and *P. aurelia* into two separate test tubes and one test tube of the two cultures mixed together. Students hypothesized which of the two would prevail as the competitive excluder -- the larger *P.multimicronucleatum* or the smaller *P.aurelia*. The results of the competition were graphed, and *P. multimicronucleatum* was found to be the competitive excluder. This was an excellent lab to demonstrate population counting methods and precise measurement techniques.

Here Today, Gone Tomorrow (Appendix B, Section V)

Based on the student survey, the next activity performed was one of the students' favorite. After the introduction of this activity things really got competitive. Students started pushing and scrambling to get food. As the rounds continued so did the competitiveness. Some students started positioning themselves where the food was more plentiful. At times some students tried to cheat by moving more food toward them before each round started. At the end of the lab investigation students graphed their results. It was clear that the exotic species introduction reduced the native species survival and reproductive rates.

Just Too Many Of Those Things (Appendix B, Section VI)

This lab assessed the impact exponential growth has on a species population size. Students calculated an exotic species growth potential over a five year period. They were surprised to find such an astronomically large number. In their conclusions, they determined that species population size could cause severe food and habitat competition. The previous food competition game provided insight for their analysis.

Population Growth (Appendix B, Section VII)

A yeast population lab was done to further investigate the concept of exponential growth. This lab illustrated that no species can grow exponentially indefinitely. Discussion of an ecosystem's carrying capacity and limiting factors took place before beginning the lab. The use of the Spectronic 20 (Spec 20) was used to measure yeast population densities at varying lengths of time. From their results, students concluded that as a system's carrying capacity and limiting factors were exhausted, the yeast cell population dramatically declined.

Sea Lam-"PREY" Game (Appendix B, Section VIII)

This was a board game that I designed while doing my research to simulate lake predator-prey relationships. The first six rounds were played with predator-prey fish. At the end of each round predator species could survive to the next round and produce offspring based on the amount of consumed prey. The prey species could survive to the next round and produce offspring based on the surviving number. At the beginning of the seventh round the sea lamprey was introduced into the game. It became apparent that the introduction of the sea lamprey, which has no predators, caused significant declines in the predator fish populations. The game illustrated what happens when control mechanisms are not in place in nature. In the game, the sea lamprey decimated populations of Northern Pike and Coho Salmon to the brink of extinction. Alewives were also introduced as a fish species. The declining numbers of predators resulted in an explosion of the alewife population. The board game simulated the real-life dynamics exotic species have inflicted upon the Great Lakes ecosystem. A sample of the species used in this activity is located in Appendix B, Section VIII.

Michigan's Least Wanted Posters (Appendix B, Section IX)

This last activity was an exotic species art project. Students were placed in cooperative groups to design and produce a Michigan's Least Wanted Poster. The posters and window display were exhibited at a local Outdoor Education Center. The groups were able to choose as their poster project a particular exotic species we had studied in class or research one we had not. A couple of groups decided they wanted to research gypsy moths and the Japanese beetle. Prior to designing the poster, students constructed a concept map to detail what information they wanted on their poster. It was difficult for the groups to decide what facts should be included. The target audience was primarily sixth grade groups so the information needed to brief. The students enjoyed working as a team on this activity. It also gave them an outlet to display their artistic talents. The project allowed students to increase public awareness and present preventative strategies.

Audio Visual Aids

There were four videos used throughout this unit. Three of the videos I was able to locate and order over the Internet. The first video, "The Great Lakes Invader - Sea Lamprey" was originally produced by The United States Department of the Interior and detailed the early detection of the sea lamprey in the Great Lakes. It also described the earliest control methods of electrical barriers in rivers and streams. It gave an excellent historical perspective to the sea lamprey invasion. The second video, "Great Lakes Invader: The Sea Lamprey Battle Continues", was produced by the Great Lakes Fisheries Commission in 1993. It detailed how the sea lamprey was introduced into the Great Lakes Basin and current control methods to reduce the sea lamprey populations. Control methods discussed were the use of sea lampricide, removal of larval sea lamprey, sea lamprey trappings, and sterile male release. Based on the student survey these two videos were their favorites.

Another video shown was called "Aquatic Invaders" produced by Information Television Network - The Cutting Edge Technology Report, Show # 1020. It contained information on various Great Lakes species and explored ship ballast water management. It also covered information regarding exotic invasions in the San Francisco Bay area.

The final video used was "The Great Lakes - Fragile Seas" by the National Geographic Society. The video discussed how man's activities and alterations have produced devastating effects on the Great Lakes environment. The video also documented the impacts of the zebra mussel, sea lamprey, and the spiny water flea on the Great Lakes Ecosystem.

Magazine/Newspaper Articles

Additional exercises the students engaged in included reading a magazine and a newspaper article pertaining to exotic species. The students read articles titled: "Aliens Invade America" by Newsweek, (1999) and a local newspaper article "Clinton Declares War On Exotic Species" (Battle Creek Enquirer, 1999). A recent survey illustrates the importance of incorporating science articles from everyday news sources:

> In preparation for the national forum, the American Association for the Advancement of Science (AAAS) conducted a survey in which samples of scientists, educators, teachers, and policy analysts were asked about the meaning of scientific literacy. The respondents rated the importance of fifteen attributes (that is, capabilities and attitudes) of scientific literacy for high school graduates. The highest ranked items were:
>
> - Read and understand science articles in the newspaper.
> - Read and interpret graphs displaying scientific information.
> - Engage in a scientifically informed discussion of a contemporary issue.
> - Apply scientific information in personal decision making.
> - Locate valid scientific information. (Bybee, 1997)

While reading news articles students should be able to gather important scientific information in which to make informed decisions. I had chosen the dynamics of exotic species in an environment as my thesis topic based on the fact that it personally interests me and it is also a contemporary issue. Students will encounter in their daily lives purple loosestrife, zebra mussels, alewives, gypsy moth, Japanese beetles, and the list could go on and on. This unit's instructional goals assisted students in exotic species identification, ecological impacts, and prevention strategies. In the end, students should view their own scientific and ecological literacy as a lifelong, continuous, learning process.

EVALUATION

The study group for this thesis consisted of twenty-eight students. Due to attendance problems, I was only able to evaluate fourteen students. The gender ratio of the evaluated group was eight females and six males. Ethnicity consisted of nine Caucasians and five African Americans. The academic level of the study group ranged from the 9th to 12th grades.

The evaluation of the exotic species unit was done in several ways:

1) Pre/Post test evaluation
2) KWL
3) Laboratory investigation reports
4) Video questions
5) Magazine/newspaper article questions
6) Journal questions
7) Student survey - Effectiveness of Exotic Species Unit

Discussion of Pre/Post Test Results

The pre/post test (Appendix A, Sections I and II) evaluations were solely used as tools to assess the effectiveness of the unit. The pre/post test had 65 possible points and were basically the same tests except for additional scaffolding of some discussion questions on the post test. The students' grades did not reflect their performance on either of the tests. On the pre/post tests I instructed the students not to guess on the matching or multiple choice questions. If they did not know any of the short answer or discussion question answers they were to respond with an "I do not know". I felt it was necessary for students to respond in some way rather than me thinking they just skipped over the questions. The average test score of the pre-test was 20%. It was evident that the test groups' prior knowledge of scientific terms and principles relating to the topic was very limited. The post-test was administered at the finish of the unit's activities. The students were not informed when the post-test was to be given. I wanted to be sure that the knowledge demonstrated on the post-test results was indicative of what they had retained as opposed to what they could cram for. The average post-test was 45%. Figure 1, on the next page, shows the pre and post-test scores for each student. The difference between the pre and post-test student scores averaged 32.5%. The average post-test score did not reflect a passing grade. However, it should be taken into consideration that the average attendance of the test group was only 60%. Also, since the pre and post-tests were not used as actual grades, some students may have shrugged it off. Based on my personal observations students worked very diligently on the post-test. It was as if they wanted to prove to themselves that they really had learned something. The results of these test scores represents the importance of using many different assessment tools as a means of measuring student learning. Did the test scores really assess what the students had learned throughout the whole eight week unit? Based on these results, students had acquired knowledge. In order for assessments to be relevant the teacher must look at the "Big Picture". There are just some students and adults that do not do very well on written tests.

Discussion of KWL

The use of KWL as an assessment strategy is subjective. The format for the KWL is found in Appendix A, Section III. The purpose of utilizing this strategy was to allow

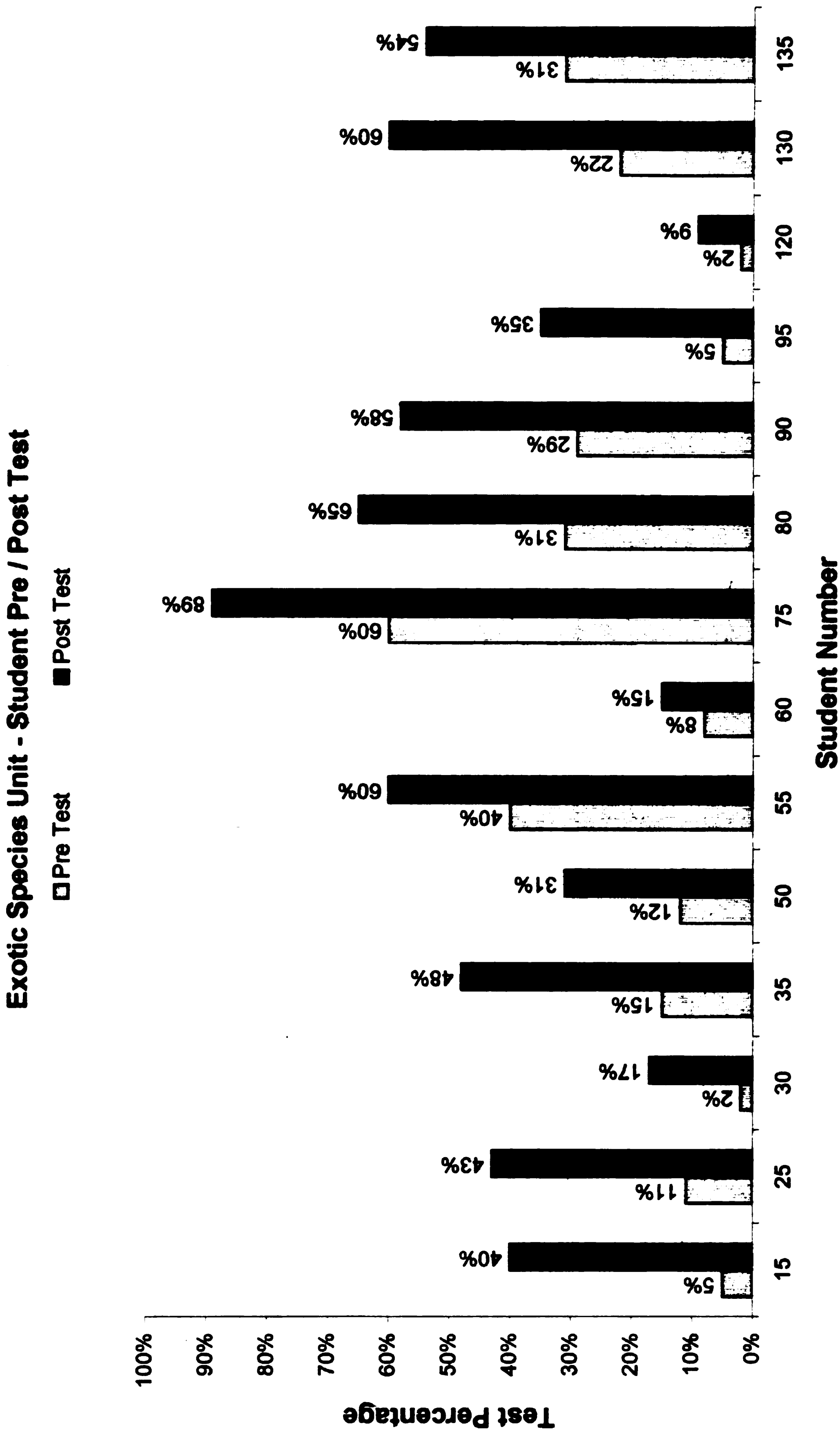

Exotic Species Unit - Student Pre / Post Test
Pre Test
Post Test
Test Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Student Number
15
25
30
35
50
55
60
75
80
90
95
120
130
135
5%
40%
11%
43%
2%
17%
15%
48%
12%
31%
40%
60%
8%
15%
60%
89%
31%
65%
29%
58%
5%
35%
2%
9%
22%
60%
31%
54%

Figure 1

students to self-evaluate and help process what they had learned. In the "L" category, six of the students identified that they had learned about a ships' ballast water and how it transports exotic species. In the classroom discussions on ballast water they did not even know what the term meant. Ten students were able to identify at least five exotic species. In the prior assessment, only one student could name a couple. Five students identified man-made canals, ships' ballast, and intentional releases as human activities leading to exotic species invasions. The analysis of KWL indicated that students had in fact learned some important principles and exotic species identification from the unit.

Laboratory Investigation Reports

The criteria for the graphing exercises were posted on the blackboard as follows:

1) Data table set-up/completeness
2) Correct graph set-up and title
3) Neatness/presentation
4) Following directions
5) Accuracy of graphed data
6) Analysis and conclusions

Each laboratory exercise was assigned a number from 1 - 9 as follows:

Lab #	**Laboratory name**
1	Exotic Species in the Great Lakes Lab
2	Come On Now, Please Move Over
3	Mechanisms or Routes of Exotic Species
4	Competition Study of Two Paramecium Species
5	Here Today, Gone Tomorrow
6	Just Too Many of Those Things to Count
7	Population Growth Lab
8	Sea Lam-Prey Game
9	Michigan's Least Wanted Posters

Figure 2 shows the class averages on each of the laboratory investigations. The class averages for all nine laboratory reports was 83%. Despite the students' low attendance, they were able to finish the labs. I selected high attendance days based on past attendance records to accommodate most of the students in the laboratory investigations.

Michigan's Least Wanted Posters

The students were especially proud of their "Michigan's Least Wanted Posters". I have included some copies of the students' exotic species posters (Figures 3-7). I laminated them so that when they are done being displayed at the Outdoor Education Center I can use them again in the classroom.

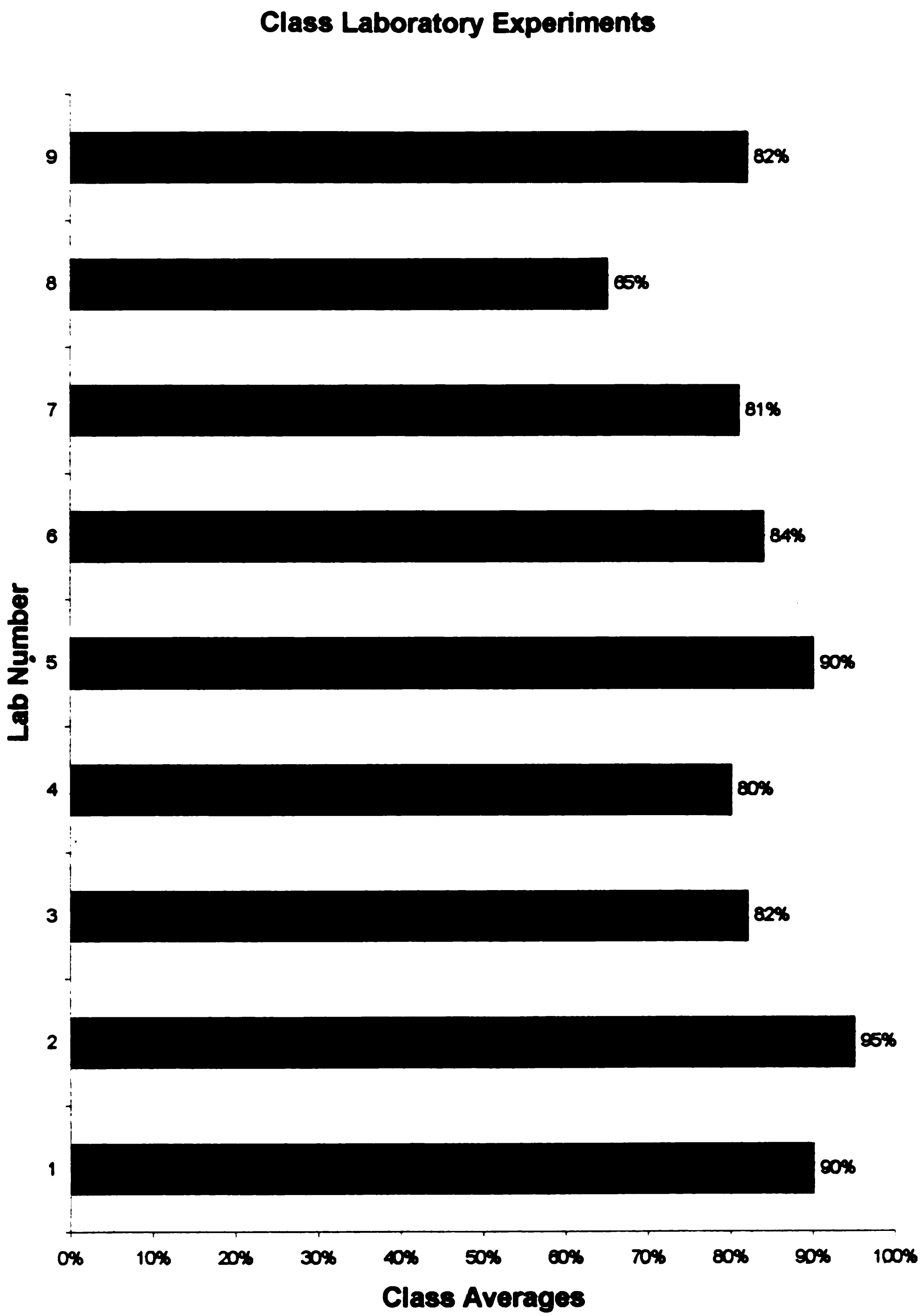

Class Laboratory Experiments
Lab Number
9
82%
8
65%
7
81%
6
84%
5
90%
4
80%
3
82%
2
95%
1
90%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Class Averages

Figure 2

Michigan's Least Wanted Posters

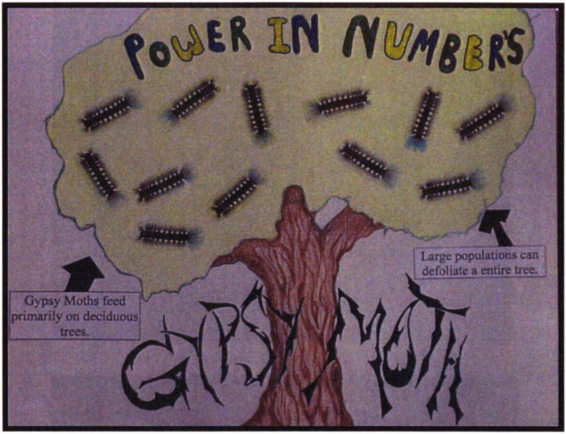


Figure 3 - Student Poster and 3-Dimensional Window Display

Michigan's Least Wanted Posters

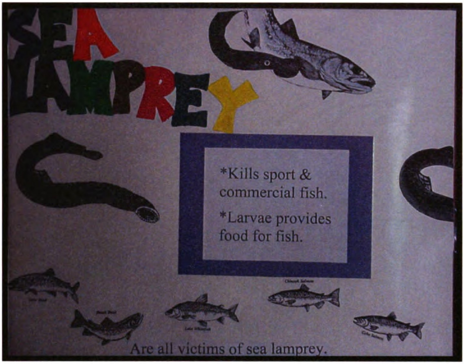


Figure 4 - Student Posters

Michigan's Least Wanted Posters

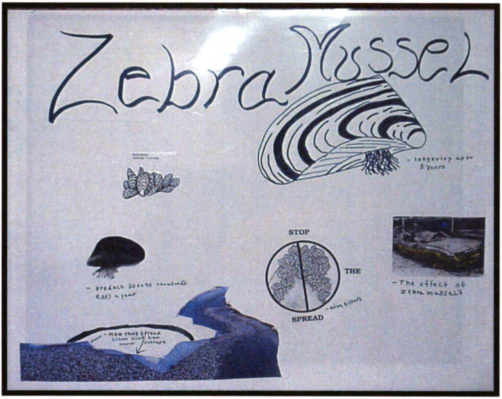


Figure 5 - Student Posters

Michigan's Least Wanted Posters

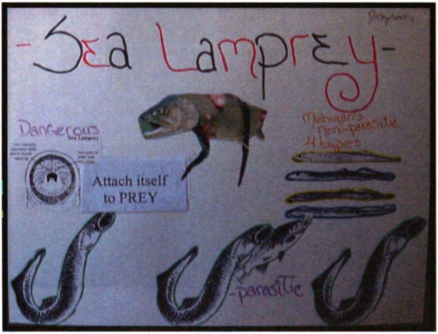


Figure 6 - Student Posters

Michigan's Least Wanted Posters

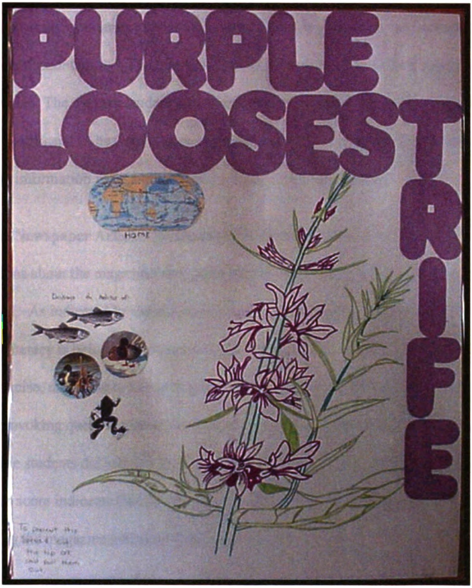


Figure 7 - Student Poster

Video Questions (APPENDIX A, Sections V and VI)

Questions used for "Aquatic Invaders" and "The Great Lakes - Fragile Seas" are located in Appendix A, Sections V and VI. Discussion questions were assigned to two of the videos shown and the other required a summary. Students do not like to answer questions or write summaries related to a video. The video questions and summaries are assigned for accountability. The questions also generate class discussions during and after the video. The average student scores from the video questions were: "Aquatic Invaders" - 65% and "The Great Lakes - Fragile Seas" - 72%. These scores indicate that processing information from audio/visual presentations is still needed.

Magazine/Newspaper Article Questions (APPENDIX A, Section VII)

Questions about the magazine/newspaper articles are located in Appendix A, Section VII. As indicated by the survey conducted by the AAAS, an attribute of scientific literacy is being able to read and understand science articles in the newspaper. In this exercise, the students had to comprehend and interpret information. A couple of thought-provoking questions made the students look beyond the printed pages of the article. The students did not do very well on these questions with an average score of 58%. This score indicates that the students struggled with comprehending and interpreting the magazine and newspaper articles.

Journal Questions

Journal questions (sample: Appendix C, Section I) help to identify student misconceptions and also provide an indication as to how the students are progressing. Based on journal responses, the teacher can facilitate a class discussion to attempt to "correct" any misinformation. Answers to journal questions were not graded formally. I asked a journal question in the beginning of the unit and was not happy with their responses. I re-taught these concepts. After reviewing responses to a few other journal questions I went back to the same question and received improved responses. As I review their journal responses I am looking for particular ideas and grade them with a credit/no credit.

Student Survey - Effectiveness of Exotic Species Unit

The survey (Appendix A, Section IV) assessed the students' attitudes about the effectiveness of the science lessons presented. The students did not have to put their names on the survey, so they were quite honest in their evaluation. It also gave them an opportunity to grade the unit. Table 1 represents the percentages of responses to the student survey questions. The first question, "Before this unit, I really did not know exotic species even existed", 55% responded with an "Agree" to "Strongly Agree". The response indicates that it was a worthwhile topic to investigate.

Students were asked to finish the sentence on a couple of questions. The following responses were based on videos shown in class.

<u>Sea Lamprey/Sea Lamprey Battle Continues</u>

1) This video really gave me a clear view of this particular species and a good insight as to how they live.
2) The sea lamprey video was exciting to me because I like seeing them suck on other fish and they look like a little monster.
3) I didn't even know about the sea lamprey and I learned how dangerous they are to other fish.

TABLE 1 - Student Survey: Percentages
Effectiveness of Exotic Species Unit

The following statements concern the effectiveness of the labs and accompanying activities relating to the Exotic Species Unit. Circle the appropriate number following each statement based on the scale below.

1 Strongly agree
2 Agree
3 Neutral
4 Disagree
5 Strongly disagree

	1	2	3	4	5
1. Before this unit, I really didn't know exotic species even existed.	32%	23%	27%	18%	0%
2. The labs performed helped me understand the impact exotic species have on native species.	23%	36%	32%	5%	5%
3. The labs demonstrated the concept of competitive advantage or exclusion.	20%	30%	35%	15%	0%
4. The labs were interesting and fun.	20%	15%	35%	20%	10%
5. The labs were well organized.	10%	33%	43%	5%	10%
6. The labs were easy to understand.	10%	40%	25%	20%	5%
7. The lab analysis/conclusion questions made me think.	24%	38%	29%	0%	10%
8. Prior to this unit, I wasn't very good at making graphs.	9%	18%	50%	14%	9%
9. The use of graphs in the labs helped me understand how to create and interpret them.	5%	48%	29%	10%	10%
10. After completing a data table and graph activity, I feel it isn't necessary to analyze it.	0%	19%	57%	14%	0%
11. The labs were easy to read.	9%	35%	39%	13%	4%

	1	2	3	4	5
12. The objectives at the beginning of the lab helped me focus on what the outcome would be.	5%	30%	45%	20%	0%
13. The introduction was helpful in knowing some background information about the lab organisms or concepts covered in the lab.	10%	35%	30%	20%	5%
14. As a consumer, it is necessary to learn about exotic species in order to further prevent the spread of them.	20%	40%	30%	5%	5%
15. The videos used in the unit were helpful in learning about exotic species.	15%	55%	15%	10%	5%

The best video was:

Sea Lamprey/Sea Lamprey Battle Continues - 47%
Aquatic Invaders - 29%
Great Lakes - Fragile Seas - 24%

The best lab performed was:

A. "Come On Now - Please Move Over" - 5%
B. "Exotic Species in the Great Lakes Lab" - 10%
C. "Here Today, Gone Tomorrow" - 47%
D. "Competition Study of Two Paramecium" - 0%
E. "Just Too Many of Those Things to Count" - 5%
F. "Michigan's Least Wanted" posters - 32%
G. "Sea Lam-"Prey" predator - prey game - 0%

In your opinion, the overall exotic species unit could be graded as:

A. 20%
B. 40%
C. 30%
D. 10%
F. 0%

The Great Lakes - Fragile Seas

1) It showed all kinds of different species and showed how they have fun on the ice.
2) I liked that one because they showed you how the exotic species came into the Great Lakes. The Great Lakes were okay until they put up that canal and let the sea lamprey and alewives in.

Students had to choose the best lab done and explain why they thought so. The following are samplings of their responses:

Come On Now, Please Move Over

1) Because I liked that we were growing our own plants and it was fun to see whose plant was growing the fastest.

Exotic Species In the Great Lakes Lab

1) Because the cards gave you information you need to know and made you familiar with the species.

Here Today, Gone Tomorrow

1) Because everyone enjoyed the lab, we all laughed, played, got into the game at the end we all had a decision.
2) This lab, I think was the one that showed the competitive advantage of exotic species the best.
3) This lab was really helpful explaining and displaying how food scarcity, overcrowding and what a pre/predator imbalance can do to an ecosystem.

Michigan's Least Wanted Posters

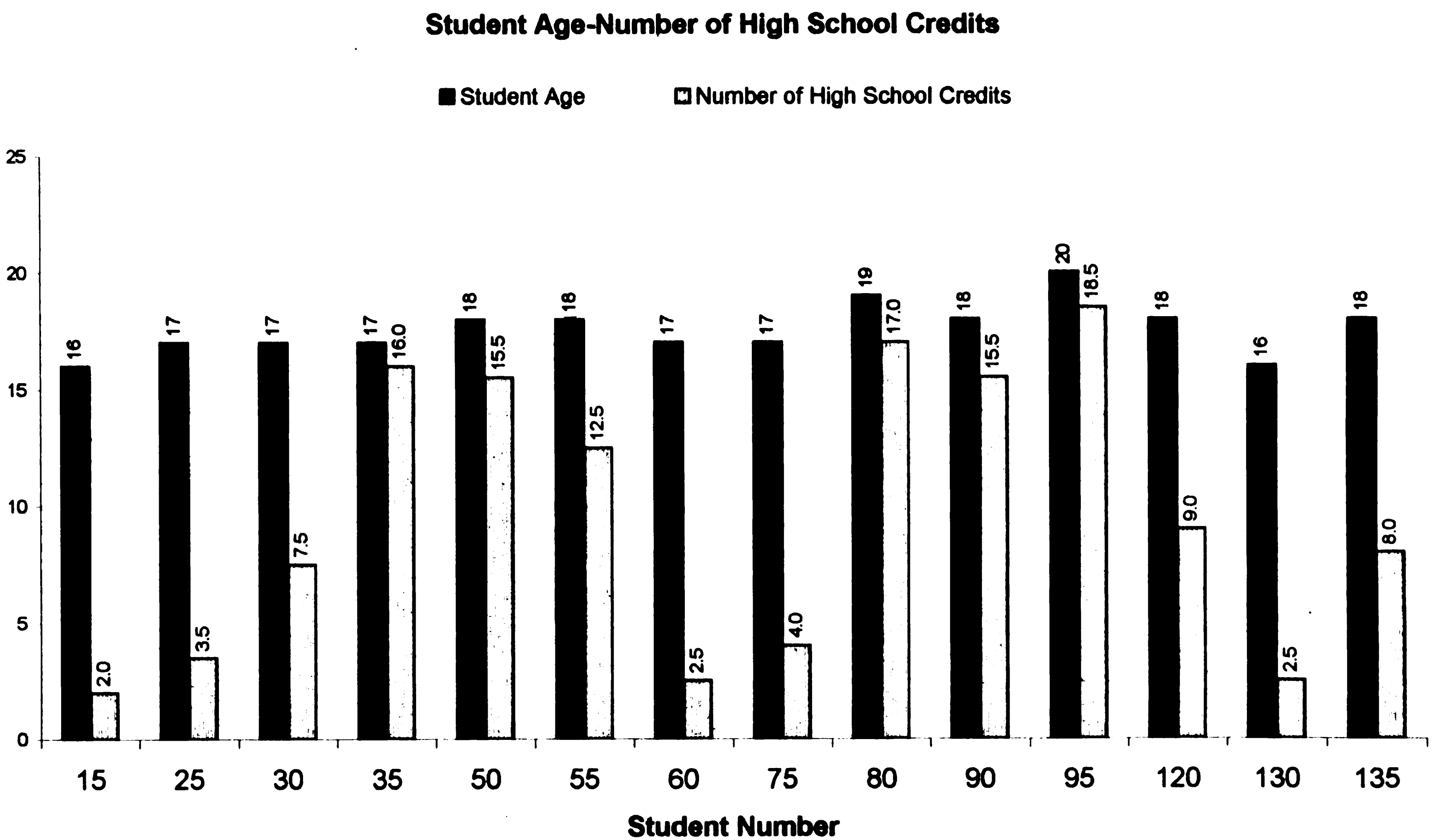
1) It was the best one because we used a lot of team work and it wasn't as hard as the others.
2) I liked this lab because it taught you how to work in a team and be organized. The posters were looking good and were hard work.
3) You can get out to people and tell them what's going on and the more that they know the better because we all could help.

The last series of anecdotes indicate how students felt about the exotic species unit. Their responses were as follows:

1) People need to know about this in order to help prevent it.
2) I think it deserves an "A" because it was a fun unit and I really learned a lot. It made me think more about exotic species because I never really thought about it before.
3) First of all it is a part of something we need to know and it's close to our home town.
4) I feel that the unit can only get better with time. After going through this stuff a few times and making correction it will be excellent.
5) It taught us about the damage they do to our lakes and rivers, also the native species

The student responses indicate that they enjoyed the exotic species unit. Some of the laboratory investigations have "some more bugs" to be worked out.

A final analysis of the exotic species unit addressed the academic level of the study group. According to Figure 8, the average age of the study group was 17.5 years old. The average number of earned high school credits of the test group was 9.5. Typically a graduating high school senior would be about 18 years old and have anywhere from 20-25 credits. The figure shows that many of my students enter my classroom with academic disadvantages.



Student Age-Number of High School Credits
Student Age
Number of High School Credits
25
20
15
10
5
0
16
2.0
17
3.5
17
7.5
17
16.0
18
15.5
18
12.5
17
2.5
17
4.0
19
17.0
18
15.5
20
18.5
18
9.0
16
2.5
18
8.0
15
25
30
35
50
55
60
75
80
90
95
120
130
135
Student Number

Figure 8

DISCUSSION AND CONCLUSIONS

From the very first day of entering the Division of Science and Math Education Masters' program I knew that I wanted to do my research on exotic species. I wanted to develop classroom experiments that demonstrated the impact exotic species have in an environment. In order to portray the relationships that exist between native and exotic species I would need to illustrate competition. When I began my research I realized how difficult it would be to simulate competition in a classroom setting. After researching many laboratory manuals and not finding many competition labs I almost gave up on it. I am glad I did not. I found some lab investigations that served the purpose, although simulating competition studies using living protozoa is difficult. The creatures are sensitive to changes and sometimes die. An important concept to keep in mind is that teachers as well as students learn the most from experiments that do not work as opposed to the ones that do. My students learned that science experimentation is not always perfect. To problem solve and learn from those mistakes is the most important thing.

I learned some valuable lessons about experiments along the way. The most important one I learned is that when you work with living organisms just about anything can and will happen. When I do the plant competition lab the next time I will use radishes or beans. Some of the seeds the students used took up to 14 days just to germinate. It seemed that the interest level of students faded while waiting for their plants to grow. They sometimes forgot to water them. The plant competition lab is a significant student experience that I will continue to perfect. The paramecium competition lab also posed problems. The growth medium containing the paramecium started to stink after awhile. Because the paramecium were thriving in that "stinky stuff" the students had to work with them anyway. The Sea Lam-Prey game also needs some revising. When I tested the game during my summer research with teacher colleagues, it seemed to work just fine. However, when I gave students the game, something entirely different happened. Students had problems counting the number of surviving fish, adding new offspring, and keeping track of population numbers using the data table. The next time, I will have students roll dice to determine how many and which species live, die, or reproduce. I will continue to use the laminated fish pieces along with the dice. The fish pieces were instrumental in helping the students identify the different types of fish in the Great Lakes. The game chart needs to be revised as students seemed overwhelmed with so many boxes. I enjoyed working with these new lab activities and looking for ways to make them better.

The exotic species unit was challenging in many ways. I knew the lack of student attendance would present problems. I originally started out with twenty-eight students in the study but ended up with fourteen. Some of the girls left on maternity leave while the others just stopped coming to school. The pre-test scores and KWL indicated the students' prior knowledge of ecological principles and exotic species was quite limited. Some of the students do not have a sound science background on which they can build new knowledge. The seven weeks it took to get through the lessons and laboratory experiments allowed additional time to re-teach concepts and juggle task completion's due to student absenteeism.

Students entering our program have many educational shortcomings. Some are returning drop-outs while others clearly demonstrate special educational needs. As an alternative education teacher, it is my job to find ways to help students fill the academic void or assist others with low academic/achievement disadvantages. It is necessary to expose <u>all</u> students to various tasks and skills in which they can find success or discover their potential. One thing we must all keep in mind is that Albert Einstein was also identified as a low-achieving individual until he found his niche. Sometimes a teacher does not know the special skills a student possesses until they give them the keys to unlock it. This exotic species unit allowed students to explore different skills while using "real" scientific equipment and completing a variety of tasks in which they could find success.

There were some positive and humorous things that happened during this unit. Students enjoyed the unit and seemed interested in the topic. My passion for the subject matter rubbed off on the students. A couple of months later I still heard students referring to the exotic species, especially from one student that I did not think was paying attention. During the food competition game, I was especially humored by the students behavior. Talk about "survival of the fittest" - they were all trying different strategies to survive even if it meant cheating.

There are some things I would include or change the next time I teach this unit. There were numerous Internet web sites directed at exotic species (Appendix C, Section VI) that I would have liked the students to explore. Our building was in the process of being networked and I was unable to access the computers for the students. There was an excellent Internet slide show on the Environmental Protection Agency web site regarding exotic species that would have been ideal for the students.

I had contemplated doing the "Purple Loosestrife Project" through MSU and Michigan Sea Grant College Program during this study. I wanted to see how this unit worked before making a three year commitment to track the progress of the beetles. The project would be a great way for students to gain hands-on field experience. I have not ruled out becoming involved in the project.

I would highly recommend teaching students about exotic species to any science teacher. The key to preventing further exotic species invasions is education. The loss of native plant and animal species will change our planet into a "monodiversity" instead of a "biodiversity". The loss of "native species" and "biodiversity" would truly be devastating. This unit has lessons to be learned for any age group.

Appendix A

Evaluation

NAME:____SCORE:__________

PRE-TEST: DYNAMICS OF EXOTIC SPECIES ON AN ENVIRONMENT

MATCHING: On the blank line, write the letter of the definition in the second column which defines the vocabulary word in the first column.

1.______ ballast water	A. to enter as an enemy or intruder
2.______ intraspecific competition	B. not native to a region
3.______ carrying capacity	C. rivalry between the same species
4.______ noxious	D. producing an abundant amount of offspring
5.______ interspecific competition	E. native to a particular region
6.______ nonindigenous species	F. a bivalve clam
7.______ limiting factors	G. carried by ships and freighters to increase navigating stability
8.______ competitive advantage	H. number of organisms supported by an ecosystems resources
9.______ indigenous species	I. eel-like animal with suctorial mouth that preys upon fish
10._____ proliferating	J. ecological condition controlling population size
11._____ invasive	K. relationship with other species that gives one species an edge over the other
12._____ biodiversity	L. wide mouth of river where tide meets currents
13._____ mussel	M. harmful or nuisance
14._____ lamprey	N. number of different species found in an area or genetic variations in a species
15._____ estuary	O. rivalry between opposite species

MULTIPLE-CHOICE: On the blank line, write the letter preceding the word or expression that best completes or answers the question.

1.________ Which group represents examples of exotic species in Michigan:

A) sea lamprey, round goby, catfish
B) sea lamprey, round goby, yellow perch
C) sea lamprey, round goby, white perch
D) sea lamprey, round goby, northern pike

2.________ Mechanisms or routes by which exotic species may be introduced to an environment include all of the following except:

A) shipping ballast water
B) unintentional releases
C) genetic mutations among species
D) intentional releases

3.________ Exotic species are

A) animals brought in from Africa
B) noxious plants
C) animals from pet stores
D) non-native plants and animals in an environment

4.________ The **largest** negative impact of exotic species in an environment is:

A) more food for predators
B) lack of food for native species
C) increase of diseases among species
D) more biodiversity, so there isn't a negative impact

5.________ The intentional introduction of exotic species have been related to:

A) sport fishing
B) the creation of shipping canals
C) releasing of shipping ballast water
D) anglers moving their boats from one lake to another

6.________ The **largest** advantage an exotic species has in an environment is:

A) camouflage
B) tolerance to environmental stressors
C) "lack of" or "no known" predators
D) defense mechanisms

7.________ These "exotic species" have been known to eat zebra mussels:

A) round goby
B) sea lamprey
C) rainbow smelt
D) carp

8.________ This exotic organism is responsible for improving water quality leading to plant overgrowth:

A) spiny water flea
B) round goby
C) zebra mussel
D) sea lamprey

SHORT ANSWER: Respond to the following questions in the space provided. Use complete sentences when necessary.

1. What is an exotic species?

2. List 5 (five) noxious aquatic species in Michigan.

    1.

    2.

    3.

    4.

    5.

3. What are 5 (five) negative impacts noxious aquatic species have on an environment.

    1.

    2.

    3.

    4.

    5.

DISCUSSION QUESTIONS: Respond to the following questions in narrative form. Use complete sentences.

1. Compare and Contrast the rational behind the introductions of exotic species to an environment.

2. What human practices have led to the invasion of exotic species in an environment?

3. Describe the various relationships exotic species maintain with native species in a habitat. Discussion of these relationships may have a beneficial or harmful impact.

4. For Christmas you received an aquarium with some fish from the pet store. At first you really liked having the aquarium but after awhile it became a nuisance. After much thought you decide to take the fish to the Battle Creek River and let them go in the spring. What predictions can you make regarding the release of your fish into the river? **Relate other possible situations to this scenario?**

NAME:______________________________________SCORE:__________

POST-TEST: DYNAMICS OF EXOTIC SPECIES ON AN ENVIRONMENT

MATCHING: On the blank line, write the letter of the definition in the second column which defines the vocabulary word in the first column.

1.______ ballast water	A. to enter as an enemy or intruder
2.______ intraspecific competition	B. not native to a region
3.______ carrying capacity	C. rivalry between the same species
4.______ noxious	D. producing an abundant amount of offspring
5.______ interspecific competition	E. native to a particular region
6.______ nonindigenous species	F. a bivalve clam
7.______ limiting factors	G. carried by ships and freighters to increase navigating stability
8.______ competitive advantage	H. number of organisms supported by an ecosystems resources
9.______ indigenous species	I. eel-like animal with suctorial mouth that preys upon fish
10._____ prolific	J. ecological condition controlling population size
11._____ invasive	K. relationship with other species that gives one species an edge over the other
12._____ biodiversity	L. wide mouth of river where tide meets currents
13._____ mussel	M. harmful or nuisance
14._____ lamprey	N. number of different species found in an area or genetic variations in a species
15._____ estuary	O. rivalry between opposite species

MULTIPLE-CHOICE: On the blank line, write the letter preceding the word or expression that best completes or answers the question.

1.________ Which group represents examples of exotic species in Michigan:

A) sea lamprey, round goby, catfish
B) sea lamprey, round goby, yellow perch
C) sea lamprey, round goby, white perch
D) sea lamprey, round goby, northern pike

2.________ Mechanisms or routes by which exotic species may be introduced to an environment include all of the following except:

A) shipping ballast water
B) unintentional releases
C) genetic mutations among species
D) intentional releases

3.________ Exotic species are:

A) only animals brought in from Africa
B) native plants and animals
C) indigenous species
D) non-native plants and animals in an environment

4.________ The **largest** negative impact of exotic species in an environment is:

A) more food for predators
B) lack of food for native species
C) increase of diseases among species
D) more biodiversity, so there isn't a negative impact

5.________ The **intentional** introduction of exotic species have been related to:

A) sport fishing
B) the creation of shipping canals
C) releasing shipping ballast water
D) anglers moving their boats from one lake to another

6.________ The **largest** advantage an exotic species has in an environment is:

A) camouflage
B) tolerance to environmental stressors
C) "lack of" or "no known" predators
D) defense mechanisms

7.________ These "exotic species" have been known to eat zebra mussels:

A) round goby
B) sea lamprey
C) rainbow smelt
D) carp

8.________ This exotic organism is responsible for improving water quality leading to plant overgrowth:

A) spiny water flea
B) round goby
C) zebra mussel
D) sea lamprey

SHORT ANSWER: Respond to the following questions in the space provided. Use complete sentences when necessary.

1. What is an exotic species?

2. List 5 (five) exotic species in Michigan.

    1.

    2.

    3.

    4.

    5.

3. What are 5 (five) negative impacts exotic species have on an environment?

    1.

    2.

    3.

    4.

    5.

DISCUSSION QUESTIONS: Respond to the following questions in narrative form. Use complete sentences.

1. Discuss the different ways exotic species have been introduced into an environment.

2. Man's activities and alterations of the environment sometimes produce devastating effects to an ecosystem. In what different ways has man enhanced the invasion of exotic species through these practices?

3. Describe the various relationships exotic species maintain with native species in a habitat. Discussion of these relationships may have a beneficial or harmful impact on the environment.

4. For Christmas you received an aquarium with some fish and water plants from the pet store. At first you really liked having the aquarium but after awhile it became a nuisance. After much thought you decide to release the fish and plants into the Battle Creek River. What predictions can you make regarding the release of your fish and plants into the river?

5. How could the above scenario be connected to the unit we have just finished on exotic species?

If you agree that it is connected, justify your reasoning with the concepts you've learned to support your stance.

If you disagree that it isn't connected, justify your reasoning with concepts you've learned to support your stance.

NAME: PRE-ASSESSMENT DATE: POST-ASSESSMENT DATE:

K (What you **KNOW** about exotic species)	**W** (What do you **WANT** to learn about exotic species)	**L** (What have you **LEARNED** about exotic species – any further questions about exotic species)

Student Survey - Effectiveness of Exotic Species Unit

The following statements concern the effectiveness of the labs and accompanying activities relating to the Exotic Species Unit. Circle the appropriate number following each statement based on the scale below.

1 Strongly agree
2 Agree
3 Neutral
4 Disagree
5 Strongly disagree

Circle only one number for each statement. Example:

Sea lampreys are disgusting looking creatures	1	2	3	4	5

By circling number one, you believe that sea lampreys are disgusting, ugly looking creatures. If you circled number five, you believe that sea lampreys are cute, harmless looking creatures.

1. Before this unit, I really didn't know exotic species even existed.	1	2	3	4	5
2. The labs performed helped me understand the impact exotic species have on native species.	1	2	3	4	5
3. The labs demonstrated the concept of competitive advantage or exclusion.	1	2	3	4	5
4. The labs were interesting and fun.	1	2	3	4	5
5. The labs were well organized.	1	2	3	4	5
6. The labs were easy to understand.	1	2	3	4	5
7. The lab analysis/conclusion questions made me think.	1	2	3	4	5
8. Prior to this unit, I wasn't very good at making graphs.	1	2	3	4	5
9. The use of graphs in the labs helped me understand how to create and interpret them.	1	2	3	4	5

10. After completing a data table and graph for a lab activity, I feel it isn't necessary to analyze it.	1	2	3	4	5
11. The labs were easy to read.	1	2	3	4	5
12. The objectives at the beginning of the lab helped me focus on what the outcome would be.	1	2	3	4	5
13. The introduction was helpful in knowing some background information about the lab organisms or concepts covered in the lab.	1	2	3	4	5
14. As a consumer, it is necessary to learn about exotic species in order to further prevent the spread of them.	1	2	3	4	5
15. The videos used in the unit were helpful in learning about exotic species.	1	2	3	4	5

16. The best exotic species video was:
(circle only one)

A. Sea Lamprey / Sea Lamprey Battle Continues
B. Aquatic Invaders
C. Great Lakes - Fragile Seas

17. The above video was the best one because.......

____

____

____

____

____

____

____

18. The best lab performed was:
(circle only one)

A. "Come On Now - Please Move Over" plant lab
B. "Exotic Species in the Great Lakes" exotic species card matching
C. "Here Today, Gone Tomorrow" food competition using beans, macaroni, etc.
D. "Competition Study of Two Paramecium"
E. "Just Too Many of Those "Things" to Count", round goby population scenario
F. "Michigan's Least Wanted" posters

19. The above lab was the best one performed because……

____

____

____

____

____

20. When using the following grading scale use (A) as the best, (F) being the worst. (Circle one only) In your opinion, the overall exotic species unit could be graded as:

A B C D F

21. I feel the exotic species unit deserved the above grade because…….

____

____

____

____

____

____

"Aquatic Invaders" video

Name:____ Score:_________/ 36__

1. List the aquatic invaders from the Great Lakes documented in this video. (6 pts)

    1.
    2.
    3.
    4.
    5.
    6.

2. Describe how many of these aquatic invaders get into the Great Lakes ecosystem? (5 pts)

3. What aquatic invader is a predator of the zebra mussel? Why is this invader of such concern when the zebra mussel is a nuisance species? (5 pts)

4. What are some solutions to limiting the spread of aquatic invaders? (10 pts)

5. What is meant by ballast water management? Why is this type of management considered an extremely difficult task? What is being done to correct this difficulty? (10 pts)

<u>"The Fragile Seas"</u>
by: National Geographic

Respond to the following questions after viewing the video. Use complete sentences and include as much information as necessary to answer the discussion questions.

1. Man's activities and alterations of the environment sometimes produce devastating effects to an ecosystem. In what different ways has man enhanced the invasion of exotic species in the Great Lakes? There are several different ways man's activities and alterations have allowed this.

2. In the video, <u>**THREE**</u> exotic species have been documented. What are the <u>**NAMES**</u> of these species?

3. How has <u>**EACH**</u> of these <u>**THREE**</u> species impacted the Great Lakes ecosystem? You may use the back of this paper to finish responding to this question.

ALIENS INVADE AMERICA!

Newsweek August 10, 1998

After reading the article, whether outloud in class or silently, respond to the following questions in complete sentences. Use your own words when responding rather than copying right from the article. Use a separate sheet of paper for your answers.

1. In the article, the green crab has been identified as being "absolutely omnivorous". Explain what is meant by this statement?
2. How many exotic species (plant and animal) now make their homes in the United States?
3. Why do you believe some exotic species have been invited here by mankind? What purposes do these exotics serve?
4. Why is Hawaii's habitat more devastated by alien invasions?
5. In a new environment, exotic species can take over, control and edge out native species. What enables them to do that?
6. In what ways could alien invasions be slowed down?
7. Aliens mating with native species have been compared to having a mule instead of a horse. Explain what the author means by this?
8. The United States is considered a melting pot of immigrants. Why should we be concerned with a few more plants and animals?

CLINTON DECLARES WAR ON EXOTIC SPECIES

Battle Creek Enquirer - February 4, 1999

1. What was the outcome of President Clinton's war on exotic species?
2. In what ways has man contributed to the invasion of exotic species?
3. Where has the most dramatic and noticeable exotic invasions taken place? What is happening there and by whom?
4. Between the two articles, what are your personal thoughts regarding these exotic invasions?

Appendix B

Student Laboratory Investigations

APPENDIX B - Section I
Exotic species in the Great Lakes Lab

Objectives:

- Students will visually recognize drawings of Great Lakes exotic species and identify their names.
- Explain the ways in which exotic species are introduced into the Great Lakes Basin.
- Explain the impacts that exotic species have on the Great Lakes ecosystem.
- Based on the mechanism or route of exotic species invasions and impacts, students will analyze the impact of these species in relation to global climate change.

Introduction:

Since the early 1800's, at least 139 exotic species have been introduced into the Great Lakes ecosystem from Europe, Asia, and other foreign countries. Likewise, some of our North American species have invaded their countries also. These species have included aquatic plant, fish, mollusks, microorganisms, and many others. These organisms are introduced to our ecosystem with devastating effects. Many of these exotic species find themselves in an ecosystem void of predators or able to compete in such a way that they force out the native species. Many of these exotic species have been introduced accidentally, intentionally, or just "hitched a ride" in the ballast water of commercial foreign vessels. As ships and freighters become faster and shipping times decrease, the threat of introducing more exotic species becomes greater.

Presently, the International Joint Commission requires ships entering the Great Lakes Basin to release their ballast water in the ocean and replace it with salt water to reduce the introduction of new exotic species.

The exotic species explored in this activity are: Zebra Mussel, Sea Lamprey, Spiny Water Flea, River Ruffe, Alewife, White Perch, Purple Loosestrife, and Eurasian Water Milfoil.

Materials:

Four color groups containing 8 different information cards per color group
Construction paper
Glue sticks

Procedure:

1. Obtain one complete 4 color set of 32 information cards. The card categories include: invader picture, introduction, ecosystem impact, and global climate change.

2. In groups of two or individually, match the invader picture with its introduction, ecosystem impact, and effects of global climate change.

3. Once you have determined which invader belongs to the other categories, glue them on one side of the construction paper.

Conclusion Questions:

1. Why should people be concerned with the introduction of exotic species to the Great Lakes?

2. Global warming may have a positive or negative impact to any of the exotic species in this activity. Discuss which species may benefit from global warming?

3. What possible jobs may be created through the introduction of exotic species?

4. Identify Great Lakes jobs affected by the introduction of these species? Justify why you've chosen these jobs. Remember, some of these jobs may be impacted either positively or negatively.

Extensions to this Activity:

1. Students could construct a poster on an invader, develop a fact sheet or brochure to pass out to the community or school.

2. Research methods that have been utilized to control these introduced exotic species. Report on the successes or failures of these methods.

3. Create a funny cartoon showing the effects that exotics have on the native species.

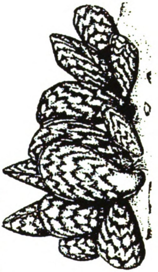
References:

Ohio Sea Grant Education Program with support from NOAA National Sea Grant College Program, 1995. *Great Lakes Instructional Material for the Changing Earth System (GLIMCES),* Mercury Marine, a Brunswick Marine Company.

Exotic Species In The Great Lakes Lab

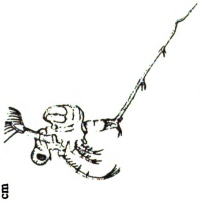
Great Lakes Instructional Material for the Changing Earth System (GLIMCS)
Biodiversity: Nonindigenous Species

INVADER #1
Zebra Mussel (*Dreissena polymorpha*)
Adult size: 1-4 cm long

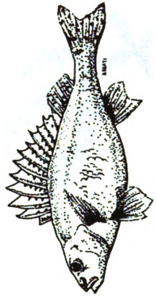


INVADER #2
Sea Lamprey (*Petromyzon marinus*)
Adult size: 3 feet (91 cm)

INVADER #3
Spindy Water Flea (*Bythotrephes cedarstromi*)
Adult size: 1 cm

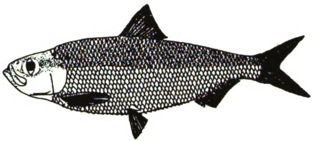


INVADER #4
River Ruffe (*Gymncephalus cernuus*)
Adult Size: usually less then 15 cm long



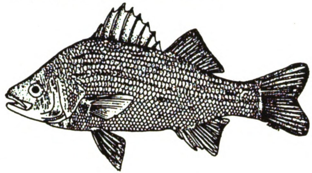
INVADER #5

Alewife (*Alosa pseudoharengus*)
Adult size: 3 cm



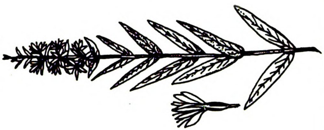
INVADER #6

White Perch (*Monrone americana*)
Adult size: 30 cm (20 cm is more common)



INVADER #7

Purple Loosestrife (*Lythrum salicaria*)
Adult height: .5 to 2 meters tall



INVADER #8

Eurasian Water Milfoil (*Myriophyllum spicatum*)
Leaflet is actual size

Introduction

Originally it came from the Caspian Sea region of Poland, Bulgaria, and Russia. Canals built during the early 1800s allowed it to spread throughout Europe. By 1830 it had invaded Britain. First introduction into the Great Lakes was about 1985, when one or more transoceanic ships discharged ballast water into Lake St. Clair. Freshwater ballast from a European port likely contained larvae and possible yearlings. Being a temperate, freshwater species, it found the plankton–rich Lake St. Clair to its liking.

Introduction

Arriving from the freshwater and brackish water in northern Europe, this invader was discovered in Lake Superior in 1986. It is assumed that it "hitchhiked" in ballast waters from Europe and Asia. In 5 years, its population reached 1.8 million adults, making it the most abundant fish in the Duluth harbor. This bottom feeder can reproduce in its first year and the females may lay 13,000 to 200,000 eggs per season.

Introduction:

Originally, it came from the Atlantic Ocean, the St. Lawrence, and Hudson Rivers, and their tributaries for spawning, and possibly Lake Ontario. It swam from Lake Ontario into Lake Erie through the Erie and Welland Canals, gaining entry into the upper Great Lakes by attaching to hulls of boats.

Introduction

A native of northern Europe, it made its way into Lake Huron in 1984 and was present in all Great Lakes by 1987. It is believed to have been brought over in fresh water or mud in ballast water of European freighters from Eastern Baltic Ports, as studies show that the Great Lakes species closely resembles the species in the ports of Finland and St. Petersburg (the former Leningrad).

INTRODUCTION

This species was intentionally imported from Northern Europe over 100 years ago, because its hardiness and beautiful flowers were popular with landscapers, florists, and gardeners.

INTRODUCTION

It came from Europe, Asia and North Africa and was introduced into North America as an aquarium plant. It has since spread to 37 states and 3 Canadian provinces.

INTRODUCTION

Coming from the salty Atlantic Coast, this invader migrated through water routes, including canals in New York State and the St. Lawrence River. It swam into the upper Great Lakes through the Welland and/or Erie barge canal before 1931.

INTRODUCTION

From saltwater areas of the Atlantic Coast, this invader moved up the Hudson River and via various canal systems into Lake Ontario and Lake Erie.

Ecosystem Impact

This is a large plankton form that eats the smaller plankton, thereby competing with small fish for their food source and affecting their survival and growth rates. Its spiny tail prevents young fish from swallowing it, thus removing it from the food chain. It is an invader species so new that it may take years to determine its total impact.

Ecosystem Impact

It is called "the beautiful killer," because its dense roots choke waterways as it competes with other vegetation. It spreads quickly, crowding out valuable plants that provide food for migrating waterfowl, and destroys habitat for almost all other forms of wetland life.

Ecosystem Impact

Only about 8 inches long, this perch-like fish has no value as a sport or food fish. It is less temperature-dependent than perch and tolerates more polluted areas. It also can find hidden prey in soft sediments more efficiently than its competitors. This fish is not preferred by predators because of its spiny fins. It displaces sport and food fish, especially yellow perch and walleye, yet is not readily consumed in the food web. This invader made up 90 percent of the fish population in the Scottish lake, Lock Lomond, only 9 years after it was introduced.

Ecosystem Impact

Forms thick mats that choke out native aquatic vegetation. It disrupts all forms of water recreation—boating, swimming, and fishing.

Ecosystem Impact

It destroys valuable fish, especially lake trout, by attaching with its sucker-like mouth to suck out the blood and body tissues. It upsets the ecological balance by removing top predators, allowing for explosion of the populations of smaller fish such as alewives. It had great economic impact on the commercial fishing industry of the Great Lakes during the 1950s.

Ecosystem Impact

Suspected to be partially responsible for the decline of Lake Erie's yellow perch because of competition.

Ecosystem Impact

It filters the plankton from the water, binding what it doesn't use into pellets that cannot be used by other plankton-feeding organisms. It accumulates on objects such as boat hulls and underwater pipes, clogging valves of both industrial and municipal water intake sources.

Ecosystem Impact

Large numbers die off in spring and summer because of electrolyte imbalance from living in fresh water. These die-offs clog municipal and industrial intake pipes and foul beaches. In 1967 bulldozers had to remove 50,000 tons of the rotting fish. The sea lamprey enabled this invader to thrive in Lake Erie by killing lake trout and other fish at the top of the aquatic food chain. After the sea lamprey arrived, this invader proliferated. Between 1960 and 1966, for example, they went from representing 8 percent to 80 percent of Lake Michigan's fish by weight. Presently this invader is food for larger game fish.

Effects of Global Climate Change

Warmer stream temperatures create a more favorable environment for this parasitic organism, enabling it to spawn successfully at more locations throughout the Great Lakes Basin. This could result in an increase in population, that may further upset the ecological balance of the Great Lakes.

Effects of Global Climate Change

This plant thrives as waters warm each summer, increasing in volume in relation to the increased water temperature. If this is any indication of its temperature requirement, as waters in the Great Lakes region warm, this invader will thrive in the new climate, spreading rapidly to become an even bigger problem.

Effects of Global Climate Change

It is very likely that this bivalve will be a permanent part of the Great Lakes environment. It is limited to waters with a temperature between 12-27°C. As global warming increases the temperature of the Great Lakes, it will spread faster north into warmer waters. As the water level in the Great Lakes recedes, it will be able to colonize new areas that at one time were too deep for its survival.

Effects of Global Climate Change

This invertebrate is sensitive to water temperature increases above 25°C, as is noted in the Western Basin of Lake Erie. As water temperatures increase, they will move into colder, deeper parts of the Great Lakes, where temperature conditions are more hospitable.

Effects of Global Climate Change

The effects of global climate change on this invading fish are unknown at this time. It is an aggressive competitor that extends well north of the Arctic Circle and tends to dominate any ecosystem it enters. It is predicted to spread throughout North America. This invader is so new that temperature effects are as yet unknown.

Effects of Global Climate Change

As waters warm, walleye and yellow perch may seek cooler waters in the deeper areas of the Great Lakes, leaving the shallower areas to this competing fish. Without competition of the other species, this invader will be able to reproduce into an even larger population, competing with still more species.

Effects of Global Climate Change

These herring-like fish need deep water with moderate temperature to overwinter. A rise in water temperature would probably result in fewer die-offs and would enable the fish to be more abundant in Lake Superior, where they currently are scarce. This would certainly alter local fisheries, but the specific impacts are not yet clear.

Effects of Global Climate Change

As water levels decrease, this invader will find new wetlands in which to spread, choking out more and more vegetation as it follows the receding waterline.

APPENDIX B - Section II
Come On Now - Please Move Over - Student Lab

Introduction:

Plants and animals compete for many of the same resources. Whether it's water, food, shelter, or possible mates to produce offspring, some organisms are better suited for survival than others. It could be examples of genetic advantage or just being in the right place at the right time.

The purpose of this laboratory investigation is to explore what happens to plants when they are squeezed for space and nutrients. Do plants squeezed for space and competing for the same nutrients grow as well as those with room to spare? In this activity you will explore variables set by your teacher or variables you have chosen. Based on your experimental set-up, you may observe the effect population size, nutrient competition, or biotic/abiotic factors have on individual plants.

Methods/Materials:

Vegetable or flower seeds
Small potting containers
Scissors
Potting soil
Measuring cups
Masking tape for container labeling
Pen to label containers
Water

Procedure:

1. Collect 4 potting containers and seeds.

2. If the containers are milk cartons, cut the tops off and label them accordingly:
   Sample #1, Sample #2, Sample #3, Sample #4

3. Fill the containers with the same amount of potting soil using the measuring cup, unless soil amount is being used as a variable.

4. Place in Sample #1 (5 seeds), Sample #2 (10 seeds), Sample #3 (20 seeds), and Sample #4 (40 seeds).

5. Place containers in a sunny window or under a grow lamp.

6. Water containers with the same amount of water each time, unless water is being used as a variable.

7. In your journal, write two hypotheses for the outcome of your experiment.

8. When the sprouts are 2 cm high, record the number of sprouts in each container. Record the number of surviving sprouts every other day for 10 - 15 days after sprouting. Sprouts that have died (not standing) should not be counted after this initial recording.

9. Once all the data has been collected, graph the (number of surviving sprouts VS number of days).

10. Compare results with your classmates. Inquiry into the similarities and differences should be explored and written in student journals.

11. Explore what abiotic and biotic factors produced the results.

Laboratory Discussion Questions:

1. Discuss what abiotic factors may have contributed to your results. For each abiotic factor, explain why you thought it might have contributed.

2. Discuss what biotic factors may have contributed to your results. For each biotic factor, explain why you thought it might have contributed.

3. Which days did you see the most noticeable change in your experiment? IE: More deaths than usual. What possible explanation can you give for this?

4. What do you think happens to a population when its size exceeds the resource capacity? How might one change the outcome of a population exceeding the resource capacity? Hint: Think about what happens in a garden or in farming practices.

5. How does this model reflect the need for space and food in human populations? For example, countries such as Kenya or China?

References:

Watkins, Patricia A. Life Science: Laboratory Manual/Study Guide. Orlando, San Diego, Chicago, Dallas. Harcourt Brace Jovanovich, Publishers, 1989.

Mechanisms or Routes of "Exotic Species"

Graphing Exercise

Introduction:

The transfer of exotic species occurs globally and effects aquatic and terrestrial ecosystems alike. The effect of exotic species is the least ecological disaster recognized by man. Many native species may be driven away or wiped out, new predator-prey relationships created, or the new species population goes unchecked and grows out of control, collapsing the ecological balance and natural food web. Not all exotic invasions are successful due to their inability to compete for biotic and abiotic factors. Meanwhile, man's intervention has become crucial in "successful invasions". The role of man is two-fold. The first crucial component is man's extensive travel and commerce. Sometimes these organisms are intentionally transported or the exotic species just "hitches a ride" in the packaging. Secondly, human-altered environments often reduces competition among native organisms allowing the new species to take root.

Objective:

The objective of this assignment is to manipulate the following data into a bar graph and analyze the results.

Procedure:

1) Title your graph: Mechanisms or Routes of Exotic Species
   Number of species VS Mechanisms/Routes

2) Prepare your graph using a ruler. Left hand margin should be approximately 1 inch and hole punched. An (Y) axis and (X) axis line drawn.

3) The (Y) axis should be numbered to represent a total of 50 units. The (X) axis should contain (5) five separate categories.

4) The (Y) axis should be labeled "Number of Species", (X) axis labeled "Mechanism/Route".

5) The (X) axis categories should be labeled to match the categories in the data table.

5) The data should be graphed on the table.

Data:

Mechanism/Route	Number of introduced species
1) shipping	41 exotic species
2) unintentional releases	40 new species
3) ship or barge canals, railroads, deliberate releases	17 species
4) unknown entry vectors	14 species
5) multiple entry mechanisms	27 species

Grading:

1) Students follows directions as detailed in procedure	15 pts
2) Data is graphed correctly	10 pts
3) Student used a ruler	5 pts
4) Is apparent student has taken time working on graph	5 pts
5) Graph neatly presented	5 pts
6) Conclusions questions	10 pts
Total	**50 pts**

Conclusions:

Some ideas to think about as you write your conclusions:

What are the significant mechanisms or routes of exotic species into the Great Lakes basin? What could account for this significance? If you were reporting this data to the local Department of Natural Resources what suggestions could you make to limit the introductions of exotic species?

References:

Edsall, Thomas A. et al. Exotic Species in the Great Lakes[Online] Available http://biology.usgs.gov/s+t/frame/x185.htm

APPENDIX B - Section IV
Competition Study of Two Species of Paramecium Lab

Objectives:

- Identify what happens when two species populations are sustained by the same resource.
- Determine the consequences of competition for the two species being investigated.
- Conclude if there is any relationship between competition for a shared resource or an evolution by natural selection.
- Construct graphs to illustrate the process of competition between the two species over a specific time frame.

Introduction:

Paramecium is a single-celled, ciliated protozoan that feeds on bacteria. It can be raised in a test-tube containing a broth of bacteria which is its food supply. What would happen if two different species are raised in a medium together? These two ciliates are competing for a limiting resource, share the same niche, and competition determines that only one survives. This experiment challenges the principle of **competitive exclusion**: No two species of similar requirements can occupy for long the same niche (coexistence).

Competition occurs when two species require the same resource that is in short supply, so that the availability of the resource produces a negative affect on one of the species. Competition takes place when the members of one species uses up the resources making them unavailable to members of the second species. These resources might include nest sites, food, water, or minerals in the soil. This is called ***indirect competition***. This type of competition is most problematic for species with similar needs such as occupying the same trophic level with similar ecological roles or niches. ***Direct competition*** occurs when members of one species interferes or directly harms members of the second species. Examples of this would include fights over territory, release of chemicals by plants that inhibits the growth of another plant species (allelopathy).

Competition is a powerful force of nature affecting a species growth, distribution, or the abundance of different populations. Often one species is a superior competitor while another may be able to adapt to environmental changes.

Materials:

Two different cultures of paramecia: *P. Multimicronucleatum*, *P. aurelia*.
Three test tubes or containers
Growth medium for paramecia, boiled wheat grains
Pipettes to measure 1.0 ml
Graduated cylinder

Masking tape, marking pen, cotton
Microscope and microscope slides
Compound microscope

Hypothesis:

Write two hypotheses predicting the population sizes of each of the test tubes of paramecia.

Procedure:

Preparation of cultures:

1. Students are to obtain the above materials. 10.0 ml of the growth medium and 2 wheat grains measured out into each of the three test tubes.

2. The test tubes should be labeled to reflect the following:

   Test tube #1 - *P. multimicronucleatum* only
   Test tube #2 - *P. aurelia* only
   Test tube #3 - *P. multimicronucleatum* & *P. aurelia* mixed

3. In each of the three test tubes add 1.0 ml of stock species solution. **It is extremely important to use separate pipettes for each culture to prevent cross-contamination.**

4. Test tube #1 contains: 10.0 ml growth medium, 2 wheat grains, and 1.0 ml stock species solution.
   Test tube #2 contains: 10.0 ml growth medium, 2 wheat grains, and 1.0 ml stock species solution.
   Test tube #3 contains: 10.0 ml growth medium, 2 wheat grains, **and 1.0 ml of each stock species solution.**

5. Cotton should be place on the top of the test tubes to prevent contamination. The test tubes placed in a dark, cool place.

Counting populations:

1. Samples of each test tube should be counted and recorded in a data table. The data table should reflect the following: Population of test tube # 1 - *P. Multimicronucleatum*, Population of test tube #2 - *P. aurelia*, and Population of test tube #3 - *P. multimicronucleatum* & *P. aurelia* mixed together.

2. The sample should be pipetted out of the test tube and should equal 0.25 ml. Use the 1.0 ml pipette to do this.

3. The sample should be spotted out on microscope slides until all of the 0.25 sample is gone. This may take about 2-4 microscope slides and should resemble the following diagram. It is important to use more microscope slides with less spots to decrease the chances of picking up the slides with your fingers and destroying your sample spots. **<u>Be careful handling the slides so you do not spoil your sampling spots!!!</u>**

4. Diagram of spotting technique on microscope slide:

O	O	O	O
O	O	O	O

Each circle represents a small drop of sample.

5. In your journal record the number of species in each spot sample. For example: if you have 8 spots on your slide you should have 8 counts even if the count is zero.

   Slide #1 - Population sample - 2, 0, 1, 4, 4, 5, 2, 1 = 19 paramecia for slide #1.

   ⇒ **The number of paramecia should be multiplied by 4 to represent the number of paramecia found in 1.0 ml of sample. This is the amount you will record in your journal.**

   ⇒ **(Number of paramecia in 0.25 ml) x (4) =**
   (number of paramecia in 1.0 ml of sample solution)
   (19) x (4) = 76 paramecia in 1.0 ml

6. This count should be performed every 4 days over the next 3 weeks following the same procedure as above.

7. In the event that there are no living species found in your samples, the **<u>Preparation of cultures</u>** should be re-done. If this is the case make note of it in your journal.

Experiment Analysis:

1. Graphing of this activity will require two separate graphs. This first graph will be of the two species alone and the second graph will be of the two mixed together.

2. The graphs will have the following titles:

   Graph # 1
   Competition Study of Two Species of Paramecium Grown Alone
   Population Size per 1.0 ml VS Time in Days

   Graph #2
   Competition Study of Two Species of Paramecium Grown Together
   Population Size per 1.0 ml VS Time in Days

3. There are four basic relationships possible for the mixed culture:

   - one species or the other survives, depending on the initial numbers of the two species
   - coexistence
   - species 1 (only) survives
   - species 2 (only) survives

4. Compare and contrast the two graphs. What are the consequences of growing the two paramecia together as opposed to growing them alone?

5. Is there any relationship between competition for a shared resource or is it natural selection? Anotherwords, "survival of the fittest".

6. Draw conclusions from the data and graphs. Refer back to the introduction at the beginning of this experiment to help with your analysis.

7. Write your conclusions in your journal. In what ways do your conclusions coincide with your hypotheses?

References:

Cox, George W. Laboratory Manual of General Ecology. Dubuque, Iowa. Wm. C. Brown Company Publishers, 1976.

APPENDIX B - Section V
Here Today - Gone Tomorrow

Objectives:

- Students will simulate the effects of an introduced species to an environment.
- Students will create a line graph from the data collected during the simulation.
- Analyze the results of the graph.

Introduction:

"Alien, invasive, nonnative, exotic, non-indigenous, or introduced" species are those that have evolved elsewhere and have purposefully or accidentally been relocated to another area. While some of these species have invaded on their own (migrating wildlife, plants and animals floating on debris or during flooding), humans have dramatically increased their invasion through exploration, commerce and trade, importation of agricultural and forestry products, or land disturbance. With an increasing human population growth, expansion of land development has proved favorable for the spread of exotic species.

Non-indigenous species have been implicated in the decline of 42 % of the 958 United States species currently listed as threatened or endangered. For 18 % of those species, the presence of exotic species represent the major factor to their endangerment. Of the 40 North American freshwater fish that have become extinct in the last century, it has been documented that the "exotics" have contributed to 68 percent of those extinctions.

In an exotic species natural habitat they are held in check by nature through competition, predation, or diseases. Unleashed in a new territory, they are able to grow unchecked and create havoc on the indigenous species and their communities. These invasive species can impact native species by eating them, competing for habitat or food, mating with them, decreasing the genetic diversity, introducing diseases, and disrupting nutrients and habitats.

The purpose of this experiment is to look at an environment inhabited by three native species. During the experiment simulation, an exotic species will be introduced. Data will be collected in the form of food eaten and population sizes with and without the exotic species.

The Simulation:

Students participating in this activity will each represent a different type of bird. Some will be native species while others will be an introduced "exotic" species. The object of the game if to get enough food with your "beak" in order to survive. If you gather enough food your species will produce an offspring. Obtain less food, your species population can either remain the same or decrease in size.

Materials:

Native species A: paper clip with a hook shape
Native species B: plastic spoon
Native species C: pen or stick with magnet attached
Exotic species D: hand you don't write with - use only thumb/index finger

Feeding area will be prepared and marked by the teacher.

The food will be distributed in this area and will consist of: elbow macaroni, paper clips, and kidney beans.

Plastic cups to put food in
Graphing paper, data table, ruler, colored pencils

Rules of the Simulation:

Round One:

1. Native Animals:

   * Use on your "mouth part" to pick up food or die (be disqualified)!
   * You can pick up any type of food. Remember you want to get a lot of food.
   * Pick up only one piece of food at a time and put it in the cup. You can use your free hand to take off the food from your "mouth part" and put it in the cup.
   * If your cup fall over, you lose all that food.
   * Food falling off the table is lost to the ecosystem and cannot be recovered.
   * You will only be feeding for one minute (teacher is the timer).

2. Native Animals: Give your cup to the counter or you may do it yourself if there isn't an assigned counter

3. Counter (If available):

   * Count and record the number of food pieces for each animal species.
   * Give this data sheet to the recorder.

4. Recorder (If available, otherwise teacher can keep a tally on the board):

   * Record the number of food pieces eaten for each population.
   * Animals having food pieces of 16 or more will have an increase in one offspring.

* Animals having food pieces of 6 -15 will remain the same in population.
* Animals having food pieces of 5 or below starve and die and are removed from the population.

5. Teacher:

    * Remove the animal with food pieces of 5 or below from the population.
    * Add one animal to the population that ate 16 or more food pieces.

6. Recorder: Write the number of animals in the new population.

Round Two:

1. Repeat steps 1-6, one more time - only native animals feeding.

Rounds Three through Eight:

1. Introduced "exotic" species enter the feeding area.
2. Repeat steps 1-6 six or more times - native and exotic species feeding.

After the Simulation:

1. Copy the class data of the population during each of the rounds played (up to 8).
2. Use the data in the table to create a line graph of "**Population VS Round (Year)**". Put all 4 populations on the same graph using a different colored pencil for each species population.

Analysis and Conclusions:

In order to analyze the data and graph, the following questions should be considered. These questions are to assist you in drawing your conclusions and not intended to be answered individually.

1. What characteristics, or behavior made each bird species unique from each other?
2. How did the birds' characteristics or behaviors affect their eating habits? Were they able to eat any type of food? Why or why not?
3. What happened to the native populations after the arrival of the exotic species?
4. For these native populations, was the arrival of the exotic helpful or harmful? Justify your reasoning?
5. Relate this activity to the question: What are the Dynamics of an Exotic Species on a Native Species?

APPENDIX B - Section VI
"Just Too Many of Those "Things" To Count"

Objectives:

- Students will calculate a species' population size over a 5 year period.
- Students will assess the implications of an exotic species exponential growth potential on an environment or ecosystem.

Introduction:

To understand the impact that exotic species may have on an environment, the concept of "exponential growth" must be explored. An exotic species may enter an environment in which there are no predators and it may proliferate at alarming rates. The term **"proliferate or prolific"** refers to the ability of an organism to produce abundant numbers of offspring at any one time or could be a repeat spawner (producing eggs many times during a spawning season). Without predators or diseases to keep these exotic species in check, they can reproduce out of control.

A female **zebra mussel** is capable of releasing at least a million eggs per year. The **round goby** spawns over a prolonged period of time, capable of producing eggs every 18-20 days. The female **sea lamprey**, which is slightly larger than the male, can contain more than 64,000 eggs. The sea lamprey is a known survivor because it belongs to an ancient family of "jawless fishes" that first existed more than 250 million years ago-long before the dinosaurs. A mature **purple loosestrife** plant can produce up to 2.7 million seeds annually. Some seeds may lay dormant for several years before sprouting. The **spiny water flea** has an unusual reproductive cycle. The reproductive female carries offspring in a balloon-like pouch on her back. The pouch can be filled with either developing embryos or resting eggs. The female spiny water flea is able to reproduce through asexual reproduction. Through asexual reproduction the female can produce one to ten eggs that develop into new females without mating or fertilization. Since males are not needed for reproduction, they are rarely found when food is plentiful, or when environmental conditions favor rapid population growth. The resting eggs are also able to remain dormant for long periods of time until environmental conditions are right for their survival.

The purpose of this lab is to explore mathematically "exponential growth". The concept of exponential growth can also be applied to human populations.

Materials:

Calculator
2 sheets of paper (data table, lab analysis/conclusions)

Scenario:

The round goby spawns within the months of April - September. The amount of eggs per female ranges from 328 - 5,221. If a spawning pair (1 male, 1 female) produce 500 fish to adulthood within the first year, what will the round goby population size be after 5 years. Since the male dies after each spawning, assume there is another one to take his place.

Procedure:

1. Construct a data table consisting of (2) columns and (7) rows.

2. The 1st column labeled **YEAR** and number that column 0 - 5. The 2nd column labeled **NUMBER OF ROUND GOBIES**.

3. Record on the second row Year (0) and the number of round gobies (2) to represent the reproducing adults.

4. Record how many surviving offspring are produced after Year (1). Refer to the scenario above for the number of be placed there. Be sure to include the original reproducing adults in your number.

5. Calculate the number of surviving offspring for Years (2 - 5). Assume each surviving generation is half female and half male. Record your data for each year.

Drawing Conclusions: Consider these ideas only when analyzing your data!

- ⇒ Where you surprised with the final number of round gobies?
- ⇒ How might this species population size affect another species that does not reproduce as quickly? What things could these two species be in competition for?
- ⇒ What environmental or ecosystem conditions are affected through such a vast population size?
- ⇒ This year the human population has reached 6 billion worldwide. What connections or predictions can make between this lab and the round gobies totals? What predictions can you make about the increasing human populations and resources?

"Population Growth"
Student Lab

Objectives:

- Students will observe the growth and decline in a population of yeast cells.
- Apply the principles of population growth to changes in other species populations.
- Relate the concepts of carrying capacity and limiting factors to the impact that exotic species have on an environment.
- Students will measure yeast population densities using the Spectrophotometer 20 (Spec 20).
- Prepare a graph illustrating the growth of the yeast population.

Introduction:

A **population** is a group of individuals of the same species living in the same place at the same time. The properties of populations include size, density, and dispersion. Dispersion refers to the general pattern in which the members of a population exist in their habitat. "Clumping" is a common pattern of dispersion such as a herd of zebras or a particular stand of trees. The ability of a population to sustain itself and reproduce is directly related to the **carrying capacity** of the environment. The carrying capacity is defined as the maximum number of individuals the environment can support for an indefinite period of time. All environments have some common **limiting factors** that prevents a population from exceeding its' carrying capacity. Examples of those limiting factors include food, water, space, presence of predators, temperature, nutrients, and light. For this reason no population can grow exponentially indefinitely. Sooner or later the limiting factors change or are exhausted and the ecosystem collapses. Nature always has limits to population growth.

Materials:

Prepared yeast culture
Prepared glucose solution
1 ml pipette
2 test tubes
Sterile cotton
Parafilm
Marking pen to label test tube
Spec 20
Graph paper
Ruler

Procedure:

1. Students will label their test tubes as: # 1 - Standard (this will be used to calibrate the Spec 20), and # 2 - Yeast culture.

2. Pour the glucose solution into each test tube until it is about half full.

3. Into test tube # 2 place **ONE DROP OF YEAST CULTURE SOLUTION**. This drop will be equivalent to approximately 0.1 ml.

4. Cut a small piece of plastic film and gently mix the test tube.

5. Prepare a data table with two columns and six rows. The first column is labeled **TIME** and the second is labeled **ABSORBANCE.** Date your data table.

6. The following values will be recorded under the **TIME** column. (0, 24, 48, 72, 96).

7. Using the Spec 20, calibrate the instrument according to the instructions using the standard test tube # 1.

8. After calibration, place the yeast culture test tube (# 2) in the machine and record the absorbance in the data table.

9. Prepare your graph using the ruler. The graph will plot ABSORBANCE (Y axis) VS TIME (X axis).

10. Title the graph: Population Growth of Yeast Cells
Absorbance VS Time

11. Repeat steps 7 and 8 for the next four days. Each day plot out the absorbance on your graph.

Conclusions and Analysis - Consider these ideas only!

⇒ When was the most rapid growth? The slowest growth?
⇒ When the yeast population reach its' growth peak?
⇒ How did the yeast population change over time?
⇒ What limiting factors do you think affected the population?
⇒ If you kept counting for several more days, what do you think would happen to the yeast population?
⇒ How do you think this experiment relates to the interaction of native species and exotic species?
⇒ How might this experiment relate to human populations?

Appendix B - Section VIII
Sea Lam-"PREY" Game

Objectives:

- Students will simulate a lake predator/prey relationship, then introduce some exotic species.

Introduction:

In order for every species to survive they must eat/obtain nutrients and reproduce. Some organisms are able to eat at the expense of another species. In nature, there are organisms that like to go along for a "free ride" and are called parasites. The **Sea Lamprey**, since its entry into the Great Lakes Basin around the 1930's, has done just that. It attached itself to a fish with its sucker-like mouth and clings to large predator fish as it goes about its own business of surviving. The predator fish, unable to shake its unwanted clinging guest literally has the life sucked out of it or the Sea Lamprey lets go because it isn't hungry anymore. After the life of that predator fish is gone or injured, the hungry Sea Lamprey moves on to another predator fish victim. With many predator fish being wiped out by the Sea Lamprey, the food chain collapses and allows some other fish species populations to explode. An example of such a population explosion is the Alewife. The purpose of this lab is to simulate an exotic species that parasitizes the Great Lakes.

Materials:

Exotic species game pieces
18 X 24 Blue poster board (game board)
Data table

NOTE: Students need to be aware that the exotic species used in this game are not added according to their chronological entry into the Great Lakes. For simplicity purposes, one has been added at a different time but the outcome will be the same.

Exotic species entry into the Great Lakes:

Sea Lamprey: around the 1930's
Alewife: around the 1930's
Coho Salmon: introduced 1967
(intentional stocking by the Michigan Department of Natural Resources)

Procedure:

1. Be able to identify the following game pieces: Northern Pike, Yellow Perch, Coho Salmon, Alewife, and Sea Lamprey.

2. The blue poster board will represent the lake that the fish will inhabit. Any fish that fall outside the blue poster board have moved out of the territory and must be removed from the following generation.

3. The conditions for species survival and reproduction are as follows:

PREDATORS:

A. The Northern Pike - must catch **(3) Yellow Perch only** to survive to the next generation and will produce (1) offspring. If the Pike does not survive, assume another Pike will move into the area and no offspring is produced.

B. Coho Salmon - must catch **(3) Yellow Perch or Alewives** to survive to the next generation and will produce (1) offspring. If the Salmon does not survive assume another new Salmon will move into the area and no offspring is produced.

PREY:

A. Yellow Perch - for every pair (2) surviving fish, one offspring is produced.

B. Alewife - for every pair (2) surviving fish, two offspring are produced. (competitive reproductive advantage)

PARASITE:

A. Sea Lamprey - Parasite of Predator fish (Northern Pike and Coho Salmon). All fish it parasitizes die. The Same Sea Lamprey returns for the next generation and (1) offspring is added.

4. The game begins with throwing (within the blue poster board boundaries):

    a. **Six (6) Yellow Perch**
    b. **Twelve (12) Alewives**

    Next throw:

    a. **One (1) Northern Pike on top** (Do not aim to catch any particular fish - the throw must be random.

5. If the Northern Pike lands on any Yellow Perch it is considered prey and removed (it has died) from the lake. The Pike does not prey on Alewives, so they are not removed. If at the beginning of the game, the Pike does not survive, assume another Pike moves into the territory and no offspring produced.

6. Count the number of fish removed and record the number of fish caught according to instruction #3. Record the number of predator fish that have starved. Add the correct number of offspring to the surviving fish total (per game instructions) and record that total for the start of the new generation.

7. Continue playing the same up to the beginning of the 5th generation. **NOW THROW DOWN TWO (2) COHO SALMON AFTER THE NORTHERN PIKE.** The Michigan Department of Natural Resources introduces an exotic species (Coho Salmon) to assist in controlling any species population that may be reproducing out of control. The Coho Salmon preys on both **Yellow Perch and Alewives.**

8. If two or more predator fish land on top of each other they are not eliminated but the prey fish they land on are removed.

9. Continue playing the rounds until the beginning of the 7th generation. **NOW THROW TWO (2) SEA LAMPREY AFTER THROWING DOWN THE NORTHERN PIKE AND COHO SALMON.** The Sea Lamprey must be thrown down randomly. The Sea Lamprey attacks and kills both the Northern Pike and Coho Salmon. The lamprey isn't interested in the Yellow Perch or Alewife - they're not much of a meal for them. The Perch and Alewives must be removed if they have been the meal of a Northern Pike or Coho Salmon. Add additional Sea Lamprey to the next generation according to instruction #3.

10. Continue playing the game to the end of the 10th generation.

Conclusions/Analysis:

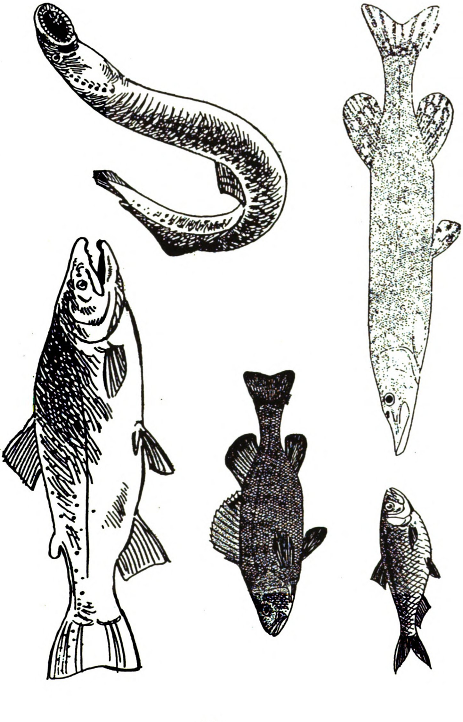
1. What population showed the biggest increase? Explain why?
2. What population showed the biggest decrease? Explain why?
3. What factors determined the size of the predator populations?
4. Describe the fluctuations of the prey population sizes.
5. Describe the fluctuations of the predator population sizes.
6. What do you think would happen if sport fishing eliminated all the Coho Salmon and Yellow Perch to extinction?
7. Why is the control of Sea Lamprey populations in the Great Lakes of such concern? Is it possible to eradicate the Sea Lamprey populations entirely? Explain why or why not.
8. This lab is just a dry lab simulation. How do you feel the lab compares or contrasts to what you know already happens in a lake infested with exotic species?
9. The Sea Lamprey is a real problem in the Great Lakes. What if you found a predator that could exterminate it? Would you use it? Explain why or why not. Justify your answer with supporting concepts or ideas.

Sea Lam-"PREY" Game

1) To be played on a 22 x 28 blue poster board.

2) Fish diagrams below are to be cut-out and used as game pieces.

EXOTIC SPECIES GAME PIECES



# Gen	# Start N.P.	# Start Alew	# Start Y. P	# Start Coho	# Start S.L.	# Starve N.P.	# Eaten Alew	# Eaten Y.P.	# Starve Coho	# Surv. N.P. + Offspr	# Surv. Alew + Offspr	# Surv.. Y.P. + Offspr	# Surv. Coho + Offspr	# Surv. S.L. + Offspr
1				XXX	XXX				XXX				XXX	XXX
2				XXX	XXX				XXX				XXX	XXX
3				XXX	XXX				XXX				XXX	XXX
4				XXX	XXX				XXX				XXX	XXX
5					XXX									XXX
6					XXX									XXX
7														
8														
9														
10														

"Michigan's Least Wanted" Posters
Student Lab

Objectives:

- Students will create and design exotic species "Least Wanted" posters to be hung up at the Battle Creek Public Schools Outdoor Education Center.
- Students will create a 3-dimensional window display of most and least wanted Great Lakes fish for the Outdoor Education Center.
- Students working in cooperative groups, will construct a concept map from which the group will decide what information about their exotic species is essential for other students and adults to know about.
- Students will further research their topic to provide adequate poster information.

Materials:

Poster board
Markers, crayons, paints
Sketching, tracing paper
Stencils, letter cut-outs

Procedure:

1. Students will be divided into groups of 2-4. Each group will be assigned an exotic species. As a group the students should create a concept map regarding their exotic species. The concept map must be presented and okayed by the teacher before the poster is designed.

PART 1: Concept Analysis:

Student questions to consider in your group:

1. What are the main concepts to be presented on the poster? These concepts should be understandable for 6th grade students and up.

2. What are the terms or ideas you feel are important to present to the viewer of the poster? If needed, further research your topic species to cover all important ideas.

3. Limit the number of words used on the poster to fewer than twenty.

Michigan's Least Wanted poster - Student Lab - page 2

PART 2: Poster Construction:

1. From the concepts and ideas the group has agreed upon, design a poster illustrating them.

2. Drawings and maximum amount of words used in the poster.

3. Color should be used to attract the viewer to the poster.

4. Attach the okayed concept map to the completed poster.

5. Slogans can be used on the posters. Example slogans: Keep Harmful Exotics Out!!, Don't Let them Spread, Save Our Lakes, Get Tough With The Ruffe.

PART 3: Project Assessment Rubric:

POSTER CRITERIA	**POINTS**
1. Accuracy of concepts or ideas	35
2. Creativity or expression	25
3. Neatness and eye appealing presentation	15
4. Completeness of project	10
5. Group effort	10
6. Completed on time	5
Total	**100**

Appendix C

Miscellaneous

"Here Today - Gone Tomorrow" Lab Assessment

NAME:____

Assessment Question: Think about this question and relate it to nature in terms of the impact "exotic species" have on a native species environment.

How did the lab "prove" or "disprove" the idea that exotic species have a competitive advantage or exclusion over the native species in an environment?

If the lab "proved" exotic species have a competitive advantage, explain your reasoning.

If the lab "disproved" that exotic species have a competitive advantage, explain your reasoning.

Did you feel the lab simulated the idea of competitive advantage? Explain your reasoning.

SPECTROPHOTOMETRY - Student Reading

Introduction:

A spectrophotometer is a machine that measures both the **absorbance** of monochromatic light as it passes through a colored solution and the **transmittance** of monochromatic light through that solution. A wavelength of monochromatic light is usually chosen that will be absorbed maximally by the substance being tested. The wavelength at which a single solution maximally absorbs light can be determined by subjecting the solution to the spectrum of visible light or known as its' absorption spectra. The most common spectrophotometer used is known as a Spectronic 20 or Spec 20.

The Spec 20 quantitatively analyzes the concentration of a solution when subjected to the monochromatic light. Quantitatively it measures the concentration amount of a solution (absorbance or optical density) or the fraction of light transmitted (transmittance) through a solution (what comes out the other side of the test tube).

The values of the solution being tested is measured against a standard solution or blank solution. The blank solution contains all the liquid being tested except for the chromophore being tested. The spectrophotometer is set with the blank solution so that the amount of light passing through it equals 100%. If the blank contains components that might change day to day, use pure water so the blank value can be determined more accurately.

The light absorbed at a fixed wavelength can give solution concentration information. If plotted on graph paper (absorbance VS time) it can illustrate the rates of reactions or rates of growth due to changes in optical density. Changes in optical density of the test solution compared to the blank solution are due to varying concentrations of the test substance. The higher the concentration of the test substance, the greater the optical density (absorbance), the lower the percent transmittance. Anotherwords, for our testing purposes, if the organisms placed in the test tube solution increase in population size at given time intervals, more light will be absorbed each time by the molecules and less light will be transmitted through the test tube.

Operating Instructions:

1. Turn the power switch on (pilot light will light up) and allow the instrument to warm-up for 5 minutes.

2. Select the wavelength as instructed in the laboratory instructions.

3. Adjust the zero control so that the needle reads). There should not be a test tube in the sample holder and the cover must be closed.

4. Standardization of instrument:

    a. Fill test tube half full of pure water or other reference liquid as instructed in the lab.

    b. Insert the test tube into the sample holder and close cover.

    c. Adjust the light control until meter reads 100% transmittance.

5. Sample measurement:

    a. Fill another test tube half-full with sample liquid.

    b. Remove the reference liquid or pure water test tube. Insert the sample liquid test tube. Close the cover and record the Percent Transmittance or Absorbance as instructed by the laboratory instructions.

IMPORTANT: Step 4 must be repeated each time the wavelength is changed. If the Spec 20 is used at a fixed wavelength for a long period of time or is sitting idle, re-check with standardized solution for meter drift. The meter should be at 100% transmittance.

APPENDIX C - Section III
Teacher Notes: "Come On Now - Please Move Over"

Introduction:

Plants and animals compete for many of the same resources. Whether it's water, food, shelter, or possible mates to produce offspring, some organisms are better suited for survival than others. It could be examples of genetic advantage or just being in the right place at the right time.

The purpose of this laboratory investigation is to allow students to explore what happens to plants when they are squeezed for space and nutrients. There are many variables students can investigate in this experiment. Students can vary the amount of seeds placed in the containers, water, fertilizer, sunlight, kind of seeds used, or the type of soil. It is up to the teacher to designate what variables they would like the students to experiment with. This lab would fit into lessons that explore competition, abiotic/biotic factors, or carrying capacity.

Methods/Materials:

Various vegetable or flower seeds (petunias are too small, preferred seeds: marigolds, morning glory, cosmos, mustards, brussel sprouts, tomato, cucumber, beans)
Any type of small containers: school or half-gallon milk cartons, or small plastic flower pots

Scissors	Masking tape for container labeling
Potting soil	Pen to label containers
Measuring cups	Water

Procedure:

1. Instruct students or allow them to decide what variables they are to investigate.

2. Students cut off the milk cartons tops and label them according to their laboratory instructions.

3. Students should fill the containers with the same amount of potting soil using the measuring cup, unless soil amount is being used as a variable.

4. Students will label their containers and plant their seeds according to the lab instructions.

5. Students should place them in a sunny window or under a grow lamp.

Teachers notes: "Come On Now - Please Mover Over" lab - page 2

6. Students should water their containers with the same amount of water each time, unless water is being used as a variable.

7. When the sprouts are 2-cm high, students should record the number of sprouts in each container. Have them record the number of sprouts every other day for 10 to 15 days after sprouting. Students should record the number of surviving sprouts. Sprouts that have died (not standing) should not be counted after this initial recording.

8. Once all the data has been collected, have students graph the (percentage or number of surviving sprouts VS number of days). Students could use a bar graph for their results.

9. Have students compare results with their classmates. Inquiry into differences should be explored and written in their student journals.

10. Students should explore what abiotic and biotic factors produced the results.

TEACHER NOTES: Be aware of seed packaging information. Some seeds may have been treated by the manufacturer to be drought resistant. It may be interesting to find out if drought resistant seeds have a better survival rate than non-resistant seeds of the same species. In my experimentation, I chose some morning glories that were drought resistant and their survival rate were approximately 30% higher than the others I chose.

Some students' plants may not grow. Problem solving can take place and connections about exotics can be made. The fact that some exotics are never able to establish themselves in a habitat can be the topic of discussion much like their plants that didn't grow either.

Lab Example:

Objective: Observe the effect population size has on individual plants.

Assessment: How does this model reflect the need for space and food in human population growth. Example: countries of Kenya VS China.

Procedure: Four containers of the same size were used. In each of the containers the following number of seeds were placed respectively: 5, 10, 20, and 40. This number was to model the doubling effect in population sizes. Sprout survival was recorded over a designated number of days. Sprout survival VS Number of days was plotted out.

Teacher Notes: "Here Today, Gone Tomorrow"

Time:

Approximately 2 class periods (2 - 2 ½ hours). Includes student activity, collecting data, and preparing data graph.

Background:

Based on a survey given to my students, they really enjoyed this lab. They were physically simulating food competition between native species and then with the introduction of the exotic species - things really got interesting. The students found that in the beginning food was plentiful and they were lax in their gathering. But once the exotics came into the picture they began pushing and gathering their food quickly. The "exotics" brought a whole new light on their food gathering habits not unlike what really happens in nature.

Observations:

This lab was designed for a class population of 15 - 20. Depending on the class roster, teachers may need to modify the number of food pieces consumed for survival by each species. At one point, the rise in exotic species population produced an interesting dilemma. Some students that died off from one population found themselves being an exotic species to cover the growth in that population. When teachers start running out of students to play a specific species the class can problem solve together as how to remedy the situation. The students seem to come up with some great plausible ideas. One of my classes suggested taking some food from the table to increase species competition. This idea worked and made sense because in nature there would be more food scavenging due to population increases. Another class suggested the exotics could eat only 1 or 2 types of food rather than all of them. This idea also worked because the exotic species may adapt to eating 1 or 2 types of food depending on what' available.

Nevertheless, the students had a lot of fun with this lab and learned about food competition. They were able to view the gain and loss in a species population once they graphed all 4 species on it. Some student suggestions were to extend the rounds to 15 - 20 rather than 8. They felt the sampling wasn't large enough to show food competition among the species. I would agree but this activity really gets the students going and I don't know how out-of-control the students would be after 15 - 20 rounds. I feel the objective was adequately met after 8 rounds.

Teacher Notes: "Michigan's Least Wanted" Posters

Background:

Many times students are able to express themselves in a creative way rather than taking a paper and pencil test. This activity allows students to express their knowledge by means of an unconventional method while encouraging creativity, analytical skills and cooperation within the group. Working in groups may be quite a learning experience for students as some students seem to take charge, while others may be along for a "free ride" and not contribute anything. In this case, you may want to assign students various jobs within the group to prevent this from happening. Another option would be to create mini posters. Students are able to pick one exotic species and create their own individual poster.

This activity also gives students a chance to participate in peer assessment. Students could assess another classes' posters. Points of assessment could include: concept or main ideas, creativity or expression, neatness, and eye appealing presentation.

If your school has a science fair these posters would be perfect to display in the hallways to promote public awareness of these exotic species. There are also small cards that can be obtained from the Michigan Sea Grant Program and could be passed out then.

Observations:

This activity really brings out the creativity in students. It's amazing what ideas they come up with. The down side to this activity: students sometimes don't work very well in cooperative groups. There always seems to be those students that do more work on the poster, while others just sit, watch, and contribute very little. Nevertheless, I believe working in groups is a good experience for students because they begin to realize how important it is to work together to get a job done. I assigned mini posters to students that may have missed a lot of class time during that week.

Time:

The class time required varies on the abilities of the students involved. 2-4 days of class time should be sufficient to complete this activity.

EXOTIC SPECIES WEB SITES

Amazing Environmental Organization Web Directory, Earth's Biggest Environment Search Engine
⇒ www.webdirectory.com/

Exotic Species Information Sources
⇒ www.lehigh.edu/~injrl/subindex/exotic_species.html

The Great Lakes Information Network, Exotic Species and the Effects on the Great Lakes
⇒ www.great-lakes.org/exotics.html

Nonindigenous Aquatic Species
⇒ http://nas.er.usgs.gov/

EPA - Environmental Education Resources
⇒ www.epa.gov/enviroed/resources.html

Our Great Lakes
⇒ www.cciw.ca/glimr/intro.html

Eisenhower National Clearinghouse - The best selection of K-12 mathematics and science curriculum resources on the Internet!
⇒ www.enc.org/

The Environmental Education Network
⇒ www.envirolink.org/enviroed/

Bureau of Land Management, US Department of Interior
⇒ www.blm.gov/nhp/index.htm

Great Lakes Fishery Commission
⇒ www.glfc.org

Great Lakes Info
⇒ www.eaglequest.com/%7Erlk/greatLake.htm

IGC: EcoNet
⇒ www.igc.org/igc/gt/EcoNet/

EXOTIC SPECIES WEB SITES - PAGE 2

Great Lakes Environment - USEPA
⇒ www.epa.gov/glnpo/

Biological Resources Division - USGS
⇒ http://biology.usgs.gov/

Michigan Department of Natural Resources
⇒ www.dnr.state.mi.us

Great Lakes Science Center - USGS
⇒ www.glsc.nbs.gov/

Great Lakes Commission
⇒ www.glc.org

International Joint Commission
⇒ www.ijc.org

Great Lakes Panel on Aquatic Nuisance Species
⇒ www.glc.org/ans/anspanel

K-12 Outreach Program
⇒ www.eecs.umich.edu/~coalitn/sciedoutreach/mainpage.html

Michigan Sea Grant Extension
⇒ www.msue.msu.edu/seagrant/

Minnesota Sea Grant Program
⇒ www.d.umn.edu/~seawww/

Ohio Sea Grant Program
⇒ www.sg.ohio-state.edu/osgrant/o-osgrant.html

Wisconsin Sea Grant
⇒ http://seagrant.wisc.edu/index.html

Great Lakes Sea Grant Network
⇒ http://seagrant.wisc.edu/greatlakes/glnetwork/index.html

New York Sea Grant
⇒ www.seagrant.sunysb.edu/

EXOTIC SPECIES WEB SITES - PAGE 3

Cornell Cooperative Extension
On-Line Catalog (Environment, Forests, Wildlife)
⇒ www.cce.cornell.edu/publications/natural-resources.html

Michigan United Conservation Club
⇒ www.mucc.org

National Wildlife Federation
⇒ http://nwf.org/

Great Lakes Sea Grant Coastwatch Home Page
⇒ www.coastwatch.msu.edu/index.html

NOAA Great Lakes Coastwatch
⇒ http://coastwatch.glerl.noaa.gov

A Field Guide to Aquatic Exotics Plants and Animals
⇒ www.ansc.purdue.edu/sgnis/publicat/mn-field.htm

Sea Grant Nonindigenous Species Site
⇒ New site address: www.sgnis.org/

Noxious Weeds, and Exotic and Invasive Plant Management Resources
⇒ http://refuges.fws.gov/NWRSFiles/InternetResources/Weeds.html

U.S. Fish and Wildlife Service Home Page
⇒ www.fws.gov/

Invasive Species Home Page
⇒ www.nbii.gov/invasive/index.html

List of 119 statewide lakes affected by Zebra Mussels
⇒ www.msue.msu.edu/seagrant/zmfiles/zmap&list.html

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