Dear Compass Reader,

As I re-read the almost-finished version of the 2014 Compass, I was struck by how many and how deep are the connections between the Department of Forestry and Natural Resources at Purdue and the world outside Indiana. The number and importance of these connections is a natural consequence of being part of a world-class university. Students and faculty who designed and performed the research described in these pages came to FNR from around the United States and around the globe. So they naturally have a broad perspective. Indiana's globalized economy introduces a large number of new species into our State every year, often by accident, so a better understanding of how species become invasive is critical to maintaining healthy resources in Indiana. Climate change is a global challenge that has enormous implications for the health and well-being of the wild animals, plants, crops and people of our State. Finally, how we manage resources touches many outside of Indiana; fish, migratory birds and other wildlife, wood products, water and air all move freely across borders, so what we do here affects many far beyond our local streams and forests. The most important way FNR contributes to a better and greener world is by training future leaders in natural resources. The articles in this year's Compass reflect the enormous diversity and talent of the students in FNR. When they leave, they will be ready to serve the world.

Dr. Keith Woeste 
Compass Faculty Advisor
The coloration of animals such as fish and ducks is produced by carotenoids. (Fish photo by Farhana Islam, Shed aquarium, Chicago, IL... Duck photo by Farhana Islam, Colombian park, West Lafayette, IN)

(at the cellular level) the trade-off between survival now and reproduction later.

Global climate change induces OS in plants, raising the possibility that synthesis of carotenoids at the base of the food chain will be altered. Coloration and disease resistance in animals may be altered by consuming these plants, leading to long-term fitness consequences throughout the food chain. By studying the link between fertility and the molecular signals of oxidative stress, we hope to shed light on one way that climate change can affect the interactions of organisms with each other and their environment. The goal of our research, then, is to explain and measure how climate-related OS might ripple outward from plants to animals, affecting their reproduction and fitness. By clarifying this process, better models of the consequences of climate change can be developed.

As an initial step in this new line of research, I am developing a chemical assay to quantify both major groups of carotenoids in algae and identifying experimental methods to induce OS in algae using increased temperatures. Future experiments will focus on gene expression patterns influenced by environmental stressors and the flow of critical antioxidant signals in aquatic and terrestrial food webs.

The coloration of animals such as fish and ducks is produced by carotenoids. (Fish photo by Farhana Islam, Shed aquarium, Chicago, IL... Duck photo by Farhana Islam, Colombian park, West Lafayette, IN)
The Response of Small Coastal Fish to Oil, Water, and Low Oxygen Levels in the Gulf of Mexico

By Christopher Klinkhamer

The explosion of the Deepwater Horizon oil rig off the coast of Louisiana on April 22nd 2010 led to the release of an estimated 210 million gallons of crude oil into the northern Gulf of Mexico. For 87 days, oil flowed from the ruptured wellhead under tremendous pressure. By June of the same year, oil was found along the coastlines of Louisiana, Mississippi, Alabama, and Florida. In addition to the oil visible on the surface, researchers raised concerns about the amount of oil still underwater in giant plumes of dissolved oil, and its effects on dissolved oxygen levels in the area. After the well was finally capped, scientists estimated that 50% of the total volume of released oil remained underwater, and as much as 1/3 of the released oil may have become mixed with ocean sediments. This massive and devastating spill has resulted in ongoing consequences to the economy, the health of local residents and response workers, US policy regarding offshore drilling, and the environment.

Among the thousands of species affected by the spill, scientists in Purdue’s Department of Forestry and Natural Resources (FNR) and their collaborators became interested in one in particular, the Gulf killifish (Fundulus grandis). Gulf killifish live in partially enclosed coastal areas of brackish water called estuaries, and are common along the Gulf of Mexico and the Atlantic Ocean. Studies have shown that up to 30% of estuaries in the northern Gulf of Mexico are affected by low levels of dissolved oxygen, a condition known as hypoxia. During warmer months, hypoxic conditions may develop and dissipate on a daily basis in shallow estuaries. Given the extent of the Deepwater Horizon oil spill and the amount of oil released, it is likely that killifish living in the area at the time of the spill were simultaneously exposed to hypoxic conditions and high levels of dispersed oil. Hypoxic conditions have been shown to reduce the spawning success of Gulf killifish. The connection between oil and poor health in fish is reinforced by the observation that the cellular pathway fish use to defend against hypoxic conditions is similar to the pathway used to defend against exposure to hydrocarbons found in crude oil. My study examines the stress caused by hypoxia and the stress caused by exposure to oil, both individually and in combination. As a result of these experiments, I will determine whether hypoxia and/or the presence of oil in the environment lower killifish’s survival and reproduction.

While hypoxic conditions are common in the northern Gulf of Mexico, they are difficult to maintain in an experimental setting. The amount of air dissolved in water (what fish breathe, the dissolved oxygen content) increases if the surface of the water is disturbed by handling the sample or taking measurements. Accurate experiments on fish and other aquatic species require that the level of dissolved oxygen be accurately measured and maintained. For my experiments with the Gulf killifish, I need to maintain dissolved oxygen levels below 2.0 mg/L for 16 days, the average length of time it takes a Gulf killifish egg to hatch. My research is focused on the health of natural ecosystems and the role of antioxidants in regulating the metabolism of cells, an area that has received comparatively little research effort. As described above, environmental stresses like heat and ultraviolet (UV) light cause oxidative stress (OS) in plants and algae. Scientific studies show that stress also changes the amount of carotenoids in plants and algae. Because plants are at the base of many food chains, any changes in the carotenoids in plants or in algae move up the food chain to higher-level consumers. For example, when algae is exposed to heat or UV light, its carotenoid content decreases. The algae may be consumed by fish, and the fish consumed by humans or other animals, etc. In this way, a small change in the carotenoid content of a primary producer (a plant such as algae) may affect the whole ecosystem. Flows of antioxidants through the food chain remain poorly understood, however.

As mentioned above, there are many types of carotenoid pigments, and the wide range in their chemical structure makes them challenging to analyze. We intend to meet this challenge using a new approach that involves complex instrumentation. Modern biochemical analysis involves the use of devices that can separate solutions into their components (liquid chromatography or LC) and others that can identify the chemical constituents of mixtures (mass spectrometers or MS). These instruments can be combined in a single analysis that can monitor multiple chemical reactions at the same time, a process known as MRM. We have developed a method called LC-MS/MS-MRM that can differentiate the two chemical classes of carotenoids with a high degree of specificity and accuracy: This new LC-MS/MS-MRM approach will permit us to study the response of cells to oxidative stress in a wide array of experimental and natural settings, and we will be able to do so in more complete detail than was possible before.

Research into oxidative stress (OS) is expected to influence our understanding of evolution and life-history trade-offs. For example, it has been theorized that oxidative stress affects the ability of males to reproduce; both sexual coloration (carotenoids found in the feathers of colorful male birds) and sperm quality are linked and related to antioxidant status of males. Colleagues have argued that when organisms experience OS they must choose between spending the energy to repair the damage or not. If an organism decides not to increase its antioxidants (pay repair costs) more rapid damage from OS could be expected, leading to an acceleration of senescence and disease. If an organism decides to increase its antioxidants and/or repair costs, then the organism must reduce its investment in reproduction or immunity, a decision that can result in poor outcomes as well. In this way, how an organism copes with OS influences its ecological function by affecting
Carotenoids; Beautiful Plant Pigments that Control Injury from Stress and Disease

By MD Noman Siddiqui

Carotenoid pigments are a group of phytochemicals (chemicals produced naturally by plants) that are responsible for the stunning colors seen in plants and animals. Carotenoids include a wide variety of compounds, over 600 identified to date, that fall into two major categories, xanthophylls and carotenes. Although we appreciate them for their spectacular color, carotenoids have a function related to maintaining the health of cells. When cells are stressed by factors like intense light, heat, or UV rays, they use carotenoids to help reverse the resulting injury.

Metabolic activities inside the cells continuously produce toxic substances like reactive oxygen species (ROS). Carotenoid pigments have antioxidant properties that protect living cells from the toxic effects of ROS. Only plants and other animals associated with disease and decline. Carotenoids fight against these threatening conditions and delay diseases formation and aging. Thus, carotenoids appear to have a role in improving human and animals health. In those populations consuming high concentrations of carotenoids, prevalence of cancer, diabetes, macular degeneration, aging, bone fracture, and cardiovascular disease are reduced. These are all conditions where OS has a role in the initiation of to hatch once it is fertilized. These levels can be achieved experimentally by bubbling nitrogen into the water, but maintaining such low levels of dissolved oxygen requires that the test chamber be completely sealed to outside air. The constraints we faced in our experimental design required us to be creative when designing our research apparatus.

Standard methods of measuring dissolved oxygen include colorimetric, trimetric, and potoraphic tests. In colorimetric tests, a sample of the test water is sucked into an easily breakable glass vial with reagents stored in the tip. When the tip is broken, the reagents react with oxygen present in the water sample to produce a visible color change in the tube. The color of the tube can then be compared to that of tubes of known dissolved oxygen content. Trimetric tests involve sealing sample water in specially designed “dissolved oxygen bottles.” Reagents added to the dissolved oxygen bottle react with oxygen in the water to form a product. Another chemical called the titrant is then added to neutralize the reaction. The amount of titrant required to neutralize the reaction can be related to the total amount of dissolved oxygen in the sample. Finally, polarographic tests involve submerging an electrode into the sample to quickly quantify the dissolved oxygen content. Although these methods are all currently in use and are capable of producing accurate results, they also all require some disturbance of our samples while the experiment is running.

In order to minimize disturbance of the samples during the experiment, I used a new kind of sensor made by dissolving a fluorescent dye into plastic. The dyed plastic can then be painted on the inside of the test chamber, in direct contact with the sample water. When the dye comes in contact with oxygen it gives off a small amount of light, and the amount of light given off is directly proportional to the amount of oxygen in the sample. The light produced by the dye is invisible to the naked eye, but easily measured with a specialized instrument called an optrode. Measurements can be taken by pointing the optrode at the sensor through any clear glass or plastic test chamber. This technology allows me to measure the dissolved oxygen in my samples while minimizing disturbance of the sample and reducing the risk of inadvertently raising the dissolved oxygen content during the experiment.

With a method in place to maintain and monitor low levels of dissolved oxygen for extended lengths of time, experiments began in coordination with researchers at Purdue, the University of Connecticut, and Southern Mississippi State University. Initial experiments will be concerned with the early life stages of Gulf killifish and their potential impacts to the ecosystem as a whole.
The Role of Disease in Controlling Asian Carp

By Kensey Thurner

Aquatic invasive species threaten the balance of local ecosystems by competing with native species and disrupting native habitats. Silver carp (Hypophthalmichthys molitrix) and bighead carp (Hypophthalmichthys nobilis), also known as Asian carp, were introduced to the United States in the 1970s and have become prolific invasive pests in large Midwestern rivers. Both carp species are large-bodied, and they consume huge quantities of plankton, small organisms that are important food resources for gizzard shad (Dorosoma cepedianum) and other native fish. Silver carp are well-known for jumping out of the water and accidentally striking people in nearby boats. There is also concern that silver carp will spread into the Great Lakes and cause declines in valuable commercial and sport fisheries. Already, bighead carp have been spotted in Lake Erie and DNA from silver and bighead carp has been detected in the Great Lakes (eDNA, see story by Honsey on page 14). For all these reasons, it is important to understand how silver carp and bighead carp are able to thrive in their current range, including their susceptibility to native and invasive pathogens.

To help understand the role of disease in controlling Asian carp population size, I am identifying, with the help of several undergraduate students, viruses and bacteria that affect silver carp, bighead carp, and native fish in the Wabash River, including the prevalence of these pathogens in each species. To this end, we collected 138 fish total, including silver carp, bighead carp, and native fish from the Wabash River, the Tippecanoe River, and the White River, including the evidence to determine which diseases affect silver carp and bighead carp and how common those diseases are in these species. We hope to gain insight into whether diseases common to native fish and other aquatic species will affect the number and spread of invasive carp.

RNA was then purified to remove chemical contaminants left over from the extraction process. The next step will be to examine the DNA/RNA through powerful technologies known as next-generation sequencing. DNA can be sequenced because it is made up of a series of connected units called nucleotides that are something like beads on a string. Next-generation sequencers rapidly read the sequence of nucleotides in each piece of DNA or RNA in order. Since the order of the nucleotides is unique to each organism (in this case bacteria and viruses), we can use a computer program to look at the results and match the nucleotide sequences with the bacteria and viruses they come from. We also will examine the gut contents of each fish to determine if they carry any parasites, such as tapeworms.

“Aquatic invasive species threaten the balance of local ecosystems by competing with native species and disrupting native habitats.”

At the end of the project, we will examine all of the evidence to determine which diseases affect silver carp and bighead carp and how common those diseases are in each species. We hope to gain insight into whether diseases common to native fish and other aquatic species will affect the number and spread of invasive carp.

What PRICLE is telling us

So far, my colleges (Dr. Jeff Dukes and fellow Ph. D candidate, Nick Smith) and I have observed strong trends in response to more variable precipitation. Plant communities have shifted from containing relatively more grasses to containing markedly more wildflowers, primarily Canada goldenrod (Solidago canadensis). This is important because the ecology of grasses and wildflowers is different, and changes in species’ abundance can affect biogeochemical processes and the success of other plants and animals. For instance, we’ve observed that some invasive plants are being suppressed as goldenrod becomes more abundant. In general, these results indicate that prairies of the future might not look and function like the endless grasslands many of us associate with the Great Plains of the American Midwest.

PRICLE entered its second year in May 2013, and will continue through 2014. While our central hypotheses relate to which plants will increase and decrease in abundance, we are also studying nutrient cycling and plant-animal interactions. Some of these questions are addressed by undergraduate researchers that partner with PRICLE investigators through the Summer Undergraduate Research Fellowship (SURF) program. PRICLE has provided an opportunity to undergraduate researchers for the past two summers through the SURF program, but also provides research opportunities for many Purdue undergraduate students throughout the academic year.
Many of us have heard old-timers complain that "the fishing just isn’t what it used to be." In fact, some of us here in Purdue FNR might have the same opinion. Interestingly, there might be something to those complaints, and it could have to do with how people have over-harvested and otherwise disturbed freshwater fish populations during most of the last century. A number of important physical (i.e., phenotype) traits in fish and other organisms appear to be highly responsive to habitat degradation, species invasions, or harvest. Moreover, these changes in the behavior or appearance of fish may be occurring at surprisingly rapid rates. Examples of rapid evolution include the discovery that eelgrass swallows that live near highways have evolved shorter, more agile wings to better avoid traffic, and the body and horn size of bighorn sheep has been reduced by exposure to unrestricted trophy hunting. These types of evolutionary changes can influence individual behaviors and the size and age structure of populations, potentially altering species’ responses to future environmental change. The field of eco-evolution seeks to evaluate trait expression through the interaction of evolution (differences in traits based on genetic change and due to selection) and ecology (trait change without genetic change due to changes in the environment). Determining how evolutionary and ecological processes interact to define the expression of important traits can allow us to develop better conservation practices, improve our management of impacted species, and potentially predict their future responses to environmental change.

A Brief History of Fisheries-Induced Evolution

A primary example of eco-evolutionary processes at work is fisheries-induced evolution observed in overharvested fish stocks. The theory behind fisheries-induced evolution is that strong size-selective harvest (in other words, targeting and keeping the big fish) tends to select against fish that grow rapidly to large sizes and mature late in life, because those fish may never have a chance to reproduce before being caught. Thus, over time, fish in harvested populations tend to evolve to grow more slowly and mature at smaller sizes and younger ages. Researchers have found evidence for fisheries-induced evolution in many marine stocks like Atlantic cod (Gadus morhua), and in experiments with Trinidadian guppy (Poecilia reticulata) they have linked similar changes in appearance and behavior to changes in genes. While fishing is the most well-studied (and arguably strongest)

Evolution and Ecology in Great Lakes Fishes

By Zach Feiner

cause of these types of changes, any environmental stressor that changes the direction or strength of selection on a fish population, such as habitat loss, eutrophication, or invasive species, can potentially alter growth rates and maturation schedules of a fish species over time. This is problematic for several reasons: 1) people don’t like catching small fish, 2) it appears to be very difficult to stop or reverse evolution once it starts in an undesirable direction, taking 500 to 1,000 years in some modeling simulations, and 3) small, young, and sporty, larger mothers appear to produce fewer, smaller, and poorer quality offspring than larger, older mothers. These relationships between maternal size and offspring size, number, and survival are called maternal effects. Large mothers contribute disproportionately more offspring to the next generation, and thus play a bigger role in driving population growth and recruitment than smaller mothers. The interaction between fisheries-induced evolution (selecting for smaller, younger mothers by harvesting all the larger more mature ones) and maternal effects (smaller mothers making fewer, less fit offspring) may be playing a role in the poor recovery of species such as Atlantic cod, even though their commercial harvest has been severely restricted or completely closed for many years.

There are few better places to investigate the effects of human-caused stress on fish life history traits than the Great Lakes. Since the beginning of the nineteenth century, the Great Lakes have been inundated with stressors such as species invasions, eutrophication, harvest, and pollutants. As such, the important fish populations of the Great Lakes have likely experienced significant changes in life history traits, including changes in growth, maturity, reproductive investment (how much energy they devote to reproduction), and offspring size. These changes, in turn, may have influenced the stability of
and recruitment of several valuable fish stocks. My research focuses on two highly valuable fish species in the Great Lakes: yellow perch (Perca flavescens) and walleye (Sander vitreus). Both yellow perch and walleye have experienced drastic population declines and highly unpredictable fluctuations in offspring production in many areas of the Great Lakes. For example, the southern Lake Michigan yellow perch population (which includes the Indiana waters) collapsed to such low levels in the late 1990’s that the entire commercial fishery was closed and the recreational fishery severely limited. My research covers three major questions: 1) How have yellow perch maturation schedules evolved over time and among different populations? 2) How strong are maternal effects on egg size and offspring survival in walleye and yellow perch? 3) How do fisheries-induced evolution and maternal effects interact to control recruitment and population growth in heavily harvested fish species?

Evolution of Maturation Schedules

To investigate the evolution of age- and size-at-maturity in yellow perch from around the Great Lakes, I am collaborating with state and provincial natural resource agencies throughout the region to construct a database of yellow perch sex, age, length, and maturity data from their respective annual fisheries sampling assessments. In total, the database includes information from 14 yellow perch populations over a time period up to five decades in four of the five Great Lakes and one smaller system: Green Bay and southern Lake Michigan; Les Cheneaux, St. Mary’s River, North Channel, Georgian Bay, South Bay, Saginaw Bay, and southeastern Lake Huron; Lake St. Clair, the West and Central Basins of Lake Erie, and Kingston Bay and Bay of Quinte in Lake Ontario. We used the data to assess fish maturity using two measures. To estimate non-genetic changes in maturation schedules, we estimated the length- and age-at-50% maturity (defined as the age or length where 50% of the fish in a population are mature) for each population over time. As an index of long-term, evolutionary change, we estimated the size and age where an individual will become mature technologically, the probabilistic maturation reaction norm (PMRN), which helps us understand the generic basis for changes in maturation age. Initial results indicate that differences in timing of maturation in different lakes are indeed evolutionarily based – fish in warmer, more productive waters reach maturity when they are smaller and younger than fish in colder, less productive habitats. We believe that fish have evolved to reach maturity faster in warmer waters because they grow faster in warmer water and suffer higher mortality rates. Fishing-induced evolution may have occurred or is occurring in several of the Great Lakes. In Lake Michigan, for example, fish are maturing at increasingly larger sizes and older ages (evidenced by increasing PMRNs). This may reflect an evolutionary response to the decline and closure of the commercial fishery in southern Lake Michigan in the mid-1990’s (in effect, the fish are “bouncing back” to their previous pattern of maturation now that the selective pressure caused by fishing has been removed). Alternatively, Lake Erie yellow perch have experienced continued fishing pressure, and in response they appear to be evolving to mature at smaller sizes and younger ages. Thus, it appears that a combination of environmental and harvest-induced changes are influencing yellow perch maturation in the Great Lakes, and that fisheries-induced evolution is not limited to large marine species, which are the subjects of most research.

How Important are Maternal Effects?

Maternal effects are differences in the size, growth, survival or behavior of fish that are the result of their mother’s condition. Why maternal effects are important? If heavy fishing pressure causes fish to reproduce when they are better than others. Many wildflower species, on the other hand, cannot thrive when rainfall frequency and amount is irregular. Consequently, if droughts become more common we might see more grasses and fewer wildflowers in some places. Of course, this change isn’t limited to grasses versus wildflowers, or even to plants. All living things have a niche, and some part of that niche is related to how much water they need. This means that the impacts of precipitation variability are not easily deduced. Plants, animals, and microbes interact and respond differently to changes in rainfall patterns. So, to figure out what types of impacts more variable precipitation might have in the future, we need to conduct an experiment in the field, where our results will be the most representative of nature.

Another crucial aspect of a species’ niche concerns how it acquires and uses nitrogen. Fast-growing species generally require more nitrogen, whereas slower growing species more often use less nitrogen. Historically, nitrogen availability was tightly controlled by natural processes, leading many species to evolve in a way that left them well adapted for past levels of soil fertility. In the last century, nitrogen fertilizers have become increasingly accessible, and humans now produce more plant-accessible nitrogen than all natural processes combined. Runoff from agricultural fields and the deposition of gaseous nitrogen from burning fossil fuels have meant that many terrestrial and aquatic environments are exposed to unprecedented increases in nitrogen availability. This change in the availability of nitrogen, even in areas where fertilizer was not directly applied, has shifted the competitive balance between species and favored the spread of fast growing species, including invasive exotics such as garlic mustard and some weedy natives."

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SURF student, Raj Lal, during one of PRICLE’s watering events. (Photo provided by PRICLE)
A Prickly Situation: Examining Impacts of Climate Change and Fertilization on Prairies in the Prairie Invasion and Climate Experiment (PRICLE).

by Mike Schuster

Humans impact every corner of the Earth, and every living thing on it, in some way. Some of these impacts are the result of global processes, like climate change, while others are the result of localized activity, such as land management. These processes represent some of the most environmentally damaging consequences of human population growth, and are known as ‘global change factors.’ Many fields of environmental science focus on examining how global change factors influence the natural world. All human activities and all natural processes experience pressure from multiple global change factors simultaneously, so it is important to understand how factors such as climate and soil fertility interact to affect natural environments. In the Prairie Invasion and Climate Experiment (PRICLE) we examine how two global change factors, climate change-induced precipitation variability and nitrogen fertilization, interact to influence a restored prairie ecosystem at the Purdue Wildlife Area (maintained by the Department of Forestry and Natural Resources).

Why are global change factors important?

Many regional and global climate changes are associated with increasing amounts of carbon dioxide (CO2) in the Earth’s atmosphere, a consequence of deforestation and the burning of fossil fuels. Although most people associate climate change with global warming—indeed, global average temperatures are expected to increase somewhere between 1 and 4°C (about 2-7°F) by the end of this century (a trend that we’re already observing today)—rainfall patterns will also change in many parts of the world. Some regions will receive more annual precipitation, while others will receive less, and precipitation patterns are expected to become more extreme; marked by more frequent droughts and rain falling in fewer, more intense storms. As a result, the amount and timing of water availability to plants might be very different 100 years from now than it is today. This could potentially increase the need to irrigate crops and change the makeup of natural plant communities.

The composition of natural plant communities (i.e. which species are present and how abundant they are) is determined largely by when individual species in the community use resources and how much they use, otherwise known as that species’ niche. Some species, like grasses, can survive prolonged droughts and variable precipitation while others will receive less, and precipitation patterns are expected to become more extreme; marked by more frequent droughts and rain falling in fewer, more intense storms. As a result, the amount and timing of water availability to plants might be very different 100 years from now than it is today. This could potentially increase the need to irrigate crops and change the makeup of natural plant communities.

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For example, we measure egg diameter and weight for each female and determine how population and maternal length affected egg traits. Egg size appears to be at least partially genetically determined through adaptation to local environments among populations – fish in warm, productive environments tend to produce smaller eggs than those in cold, unproductive environments. Moreover, maternal effects were weak – larger mothers did produce larger eggs in some years, but not others. To determine whether the observed maternal effects could influence offspring survival, we performed two experiments on yellow perch. In the first, we spawned yellow perch from the Purdue Aquaculture Research Laboratory (ARL) and evaluated the influence of maternal effects on egg size and larval starvation resistance. In a unique finding, larger mothers produced larger eggs, and larger eggs produced larger larvae, but larval starvation resistance was negatively related to maternal size and age. This means that that older mothers may produce larger offspring, but they have more malformations and decreased survival during very early life. We are currently conducting an additional experiment in conjunction with the Michigan Department of Natural Resources Saline Fisheries Research Station to determine how maternal effects influence offspring survival throughout the first year of life, with results expected next spring.

Conclusion

In sum, it appears that harvest pressure causes evolutionary changes in the life history of fish, and that these changes interact with maternal effects to affect population growth and recruitment. In the future, I plan to develop a mathematical model to simulate how harvest affects the maturation, growth, and maternal effects of fish populations and to predict how fish will evolve in response to harvest. This model will also predict how changes in these traits will impact overall population growth, and determine whether reducing or ending harvest can potentially lead to recovery of the original traits and population levels. This research has potentially important implications both for applied fisheries management and basic fisheries ecology. A better understanding of the forces shaping the timing of maturation, egg size, and offspring fitness in yellow perch and walleye can be included in development of management strategies to minimize the effects of fisheries harvest, inform stocking and recovery programs for depleted stocks, and potentially predict the effects of ecosystem stressors, such as invasive species or climate change. By using data from several different sources across the Great Lakes, I may be able to reach stronger, more general conclusions to support decision-making by local managers who must consider multiple species at once. In terms of basic ecology, the interaction of ecological change, evolution, and expression of life history traits is a vital area for research. We hope to link our understanding of Great Lakes species, including under-studied species such as yellow perch and walleye, to broader, world-wide efforts to understand how fish evolve and change in response to human management.

Lake Michigan; Tittawassee River, Saginaw Bay; Maumee Sandusky Rivers, western Lake Erie; Van Buren Bay, eastern Lake Erie; and Oneida Lake, New York. We measured egg diameter and weight for each female and determined how population and maternal length affected egg traits. Egg size appears to be at least partially genetically determined through adaptation to local environments among populations – fish in warm, productive environments tend to produce smaller eggs than those in cold, unproductive environments. Moreover, maternal effects were weak – larger mothers did produce larger eggs in some years, but not others. To determine whether the observed maternal effects could influence offspring survival, we performed two experiments on yellow perch. In the first, we spawned yellow perch from the Purdue Aquaculture Research Laboratory (ARL) and evaluated the influence of maternal effects on egg size and larval starvation resistance. In a unique finding, larger mothers produced larger eggs, and larger eggs produced larger larvae, but larval starvation resistance was negatively related to maternal size and age. This means that that older mothers may produce larger offspring, but they have more malformations and decreased survival during very early life. We are currently conducting an additional experiment in conjunction with the Michigan Department of Natural Resources Saline Fisheries Research Station to determine how maternal effects influence offspring survival throughout the first year of life, with results expected next spring.

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Success Establishing Native Aquatic Plants for Fish Habitat

By Caleb Rennaker

Aquatic ecosystems have been affected by many human and non-human activities that degrade many ecologically important habitats. The loss of aquatic species in recent years has been far greater than that of terrestrial species. As a result, managers are taking a more active role in aquatic habitat restoration activities, with over $1 billion a year being spent in the United States alone in aquatic habitat maintenance and rehabilitation. One method for improving aquatic systems is the establishment of aquatic plants, which add habitat for many species of fish, improve water quality, and provide sources of food for waterfowl. Although the introduction or reintroduction of aquatic plant species provides many benefits to aquatic systems like lakes, streams, and rivers, there are many issues that challenge the success of these types of projects. Two of the major challenges are changes in water level from flood control operations, and heavy foraging on plants by turtles, waterfowl, etc. Although strategies exist for overcoming obstacles involved in introducing aquatic plants into damaged waterways and lakes, information on methods to aquatic systems like lakes, streams and rivers, there are many issues that challenge the success of these types of projects. Two of the major challenges are changes in water level from flood control operations, and heavy foraging on plants by turtles, waterfowl, etc. Although strategies exist for overcoming obstacles involved in introducing aquatic plants into damaged waterways and lakes, information on methods to establish aquatic plants is still lacking. Additionally, many published strategies have not been tested in different types of aquatic habitats. My research focuses on establishing aquatic plants and evaluating these methods in a backwater embayment of the Ohio River. I tried different planting techniques to see if success in establishing aquatic plants can be improved.

My research used the “founder colony” approach for establishing native plants in aquatic systems. I strategically placed species of aquatic plants and protected them with fences, cages or pens. The protection allows plants to establish while reducing many of the challenges that prevent plants from establishing naturally. Over time, these colonies will hopefully become larger and more established, allowing them to survive and spread in their new environment.

Establishing Aquatic Plants

I chose three species of aquatic plants to establish founder colonies, American water willow (Justicia americana), broadleaf arrowhead ( Sagittaria latifolia), and American pondweed (Potamogeton americanus). For protection of American water willow and broadleaf arrowhead, I used ring cages of two different sizes (2 ft diameter and 4 ft diameter), which I constructed using metal wire fencing. For protection of American pondweed, I constructed rectangular pens (15 ft x 30 ft) made from metal wire fencing. A total of 720 aquatic plants were planted into their protective cages or pens in July and August 2012. Because we didn’t know which planting techniques would work best, American pondweed was planted using coconut fiber pots, peat pots, and direct planting of nursery stock. Plants were checked after 8 weeks to see which of the species was growing the best and to see if any of the planting techniques worked better than the others. Plants were then checked 1 year later to see if they were successfully established.

Two high risk and broad coverage weed species at the national scale (goat’s rue, left) and in Indiana (pigeon grass, right).


Where will invasive weeds most likely occur in the U.S.?

Under current climate conditions, parts of the southwestern (especially California, but also regions of Arizona, New Mexico, and west Texas) and southeastern (especially Florida) U.S. were suitable for the highest number of invasive plants. Interestingly, these regions are mostly located on the general pathway of invasion for North America. Historically, human intervention, such as immigration and trading, directly caused the expansion of invasive species introduced in these regions. I observed this effect in my data as well. For example, Florida was among the earliest European colonist, and has always been one of the states with the greatest human population density. In addition, western regions are more prone to accidental plant introductions than eastern regions because agricultural and rangeland practices there create an ideal environment for seed contamination. This corresponds to the results of my study, as non-woody selected in my research were more likely to cause contamination seed lots than vines, shrubs and trees.

What are the implications of my research results?

The findings of my research can help prioritize the use of limited resources for invasive plant control. The high-risk invasion regions I identified are high-priority areas for protection of local habitat and implementation of plans by conservation agencies. The predicted ranges of these invasive weeds provides a valuable reference for federal and state agencies to generate effective prevention and control measures, including new regulations and inspection procedures. Regional and local groups can use the information to provide better invasive species management and control for their constituents, stakeholders, landowners, and farmers. Organizations concerned with high risk weed species, such as South Indiana Cooperative Weed Management Area (SICWMA), will be able to share this information to facilitate public education and promote prevention programs. Invasive species management efforts will need to pay special attention to human-facilitated introduction pathways such as the long-distance movement of invasive plants by nurseries, public botanical gardens, and private gardens. For more information about invasive plants control in Indiana, please refer to the Indiana Invasive Species Council (IISC): http://www.inmnr undone. Purdue.edu/IISC/.

Table 1. The 39 invasive weed species I selected for study from the State Natural Weed List. These species were selected based on botanical (ecosystems) diversity, data accessibility and data quality.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
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<tbody>
<tr>
<td>Crotalaria nodosa</td>
<td>Justicia americana</td>
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<tr>
<td>Digitaria sanguinalis</td>
<td>Setaria viridis</td>
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<td>Echinochloa crus-galli</td>
<td>Datura stramonium</td>
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<td>Elymus repens</td>
<td>Solidago gigantea</td>
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<tr>
<td>Euphorbia esula</td>
<td>Urtica dioica</td>
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<td>Fallopia japonica</td>
<td>Dahlia pinnata</td>
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<td>Ficus carica</td>
<td>Solanum lycopersicum</td>
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<tr>
<td>Fragaria vesca</td>
<td>Solanum melongena</td>
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<tr>
<td>Gleditsia triacanthos</td>
<td>Triticum aestivum</td>
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<tr>
<td>Glycine max</td>
<td>Vitis vinifera</td>
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<tr>
<td>Helianthus annuus</td>
<td>Zinnia elegans</td>
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<tr>
<td>Ipomoea purpurea</td>
<td>Zea mays</td>
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<tr>
<td>Ipomoea quamoclit</td>
<td>Zea mays var. x intermedia</td>
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<tr>
<td>Ipomoea tricolor</td>
<td>Ziziphus jujuba</td>
</tr>
<tr>
<td>Justicia pectoralis</td>
<td>Znoma esculenta</td>
</tr>
</tbody>
</table>

(American pondweed plants grown in pea pot prior to planting. (Photo by Caleb Rennaker) | Photo by Caleb Rennaker)
Where will Potentially Invasive Weed Species 'Take Over' in the United States?

By Feng Yu

Why invasive weeds?

Have you experienced weedy troublemakers when gardening in your backyard? Yes, they are invasive (or noxious) weeds, and you would never want them to accompany your beloved plants. If you have had this experience and felt that way, you are not alone! The introduction of invasive species has triggered increased attention because of their detrimental—and possibly irreversible—impacts on many local-scale ecosystems. Not to mention the significant economic loss they may bring. Globalization exacerbates the problem of exotic invasion by accelerating the spread of invasive species across regional boundaries, over especially long distances and between continents. Blocking the pathway and closing the ‘door’ for invasion is usually a more achievable and cost-effective control strategy than eradicating already established populations of invaders. In practice, the implementation of a “closed door” strategy requires forecasting potential invasion ranges for invasive species. In other words, we need to know where in the world unwelcome invasive ‘guests’ will come from and where will they go once they arrive? Predicting the potential distribution of invasive species is essential to the strategic prevention of invasion and their control by region-wide management.

Insights from my research: predictions from modeling work

My research predicts the potential distribution of invasive plant species in the United States using species distribution models (SDMs), which are widely used for both practical and research purposes. Simply put, the idea of SDMs is to analyze where species occur and associate the occurrence data with environmental conditions, including climate, terrain, soil factors, and other geographic characteristics. If we know what kind of environment a plant grows best in, then we can look at other regions to see how closely they match the plant’s needs. This type of correlation can be expressed as the probability that an invasive species will occur in a particular local environment, or the likelihood that it will thrive in potential new homes. Among all the environmental factors associated with species distribution, climate is the most important at the regional level. Scientists use many different types of SDMs to understand where species currently live and to predict where they might live. The SDM I use was chosen because it only relies on current information without and to predict where they might live. The SDM I use was chosen because it only relies on current information without any other factors. Using this type of SDM I was able to map reliably and accurately the potential U.S. distributions of 39 invasive plant species selected from the State Noxious Weeds List (Table 1). My choice of species to map was based on how strongly they affect the economy, local ecosystems and human health. In particular, 39 species were selected because they represent different groups (i.e. genera) of noxious weeds, and all had sufficient data for analysis. Native ranges of study species are distant from North America under current climate conditions.

What are the invasive weeds’ favorite environments?

My results showed that potentially invasive weed species in the U.S. are normally restricted by annual temperature consistency (i.e., the ratio of daily temperature range to annual temperature range) and the annual water supply. The majority of species demonstrated an increase in habitat suitability when annual temperature consistency increased. In other words, U.S. regions with wider daily shifts in temperature or milder annual temperature ranges will have higher invasion risks when annual water supply is sufficient. Why? A possible explanation is that invasive species may have higher adaptability to extreme environmental conditions than native species. If significant temperature shifts occur in a single day in comparison with annual temperature variation, it could constrain native species, but have less impact on the survival of established plants.

After 8 weeks, I found American water willow and American pondweed had done well, with more than 90% of plants still present. I found broadleaf arrowhead was not doing as well, less than 20% of the plants still present. Overall, the planting technique for American pondweed with the highest success was coconut fiber pots (100% of plants still present after 8 weeks) and lowest for peat pots (88% still present). American pondweed plants grew and were beginning to fill their protective pens. Many leaves of broadleaf arrowhead had bite marks from turtles, which may explain why their short-term success was much lower compared to the other two species of plants.

After 1 year, survival of American water willow and American pondweed was high; about 70% of American water willow plants were still alive, and 100% of rectangular pens contained at least some American pondweed plants. American pondweed plants grew to fill nearly 100% of their protective pens in some cases. Survival of broadleaf arrowhead was very low, with less than 5% of plants still present. After we analyzed the data, we found that all the planting techniques we tried (coconut fiber pots, peat pots, and direct planting) produced similar results as measured by the survival and growth of American pondweed. Although establishment of American water willow and American pondweed was successful, plants were typically not seen growing beyond their protective cages/pens. Turtles were commonly seen in nearby areas, and it is likely that they were feeding heavily on any plants growing beyond protected areas. The ability of American water willow and American pondweed to establish successfully in the embayment where our study took place is a promising step in the right direction. The results of my research has shown that current strategies for establishing founder colonies of aquatic plants for the purposes of restoration or enhancement in backwater embayments of large rivers is possible.

Impacts on Overwintering Structures

I have promising results from experiments that demonstrate the ability of aquatic plants to persist in degraded aquatic systems. Species such as American pondweed and broadleaf arrowhead produce special structures called winterbuds or tubers. These structures remain dormant over winter months, and act as a source of plant growth the following spring. I grew these structures under different levels of suspended sediments. Suspended sediments are small particles that cause water to look cloudy, turbid or muddy, and they reduce the light needed by aquatic plants to survive. I found that survival and growth of the overwintering structures of American pondweed and broadleaf arrowhead were not different between clear water and the highest level of suspended sediment (i.e., lowest light) I tested. This result provides hope that plant restoration efforts can be successful even when a river or stream has high levels of suspended sediments, an all too common occurrence these days. It also shows that American pondweed and broadleaf arrowhead are promising candidates for future restoration efforts involving the establishment of aquatic plants.

Overall, my research adds to the growing level of information related to habitat restoration and enhancement efforts using aquatic plants. These efforts will improve upon existing habitats within fisheries by adding structure and improving water quality. My research is a first step in the use of aquatic plants to restore or enhance backwater embayments of large rivers such as the Ohio. Continued work on these strategies and techniques will provide tested tools and information to natural resource and fisheries managers who hope to improve the quality of Indiana’s rivers and lakes.
Round Goby Feeding Interactions in Lake Michigan: Are there Spatial, Seasonal, and Size-based Trends?

By M. Lee Henebry

Most people today are aware of invasive species, whether it is a species of fish that has become established in a pond or a plant species that is overgrowing a garden. By preying upon and outcompeting native species, invasive species thrive outside of their home range at the expense of native competitors. Unfortunately, in many cases, little can be done to completely ameliorate the damage caused by invasive species, but our goal in studying the ecology of native species is to provide a basis for their control and management.

Invasive species have become a focus of research because they thrive outside of their home range at the expense of native species, but our goal in studying the ecology of native competitors. Unfortunately, in many cases, little can be done to completely ameliorate the damage caused by invasive species, but our goal in studying the ecology of native species is to provide a basis for their control and management.

In 2010 and 2011 I collected round gobies of many sizes from throughout Lake Michigan during spring, summer, and fall. I wanted to evaluate the fish for three characteristics that shed light on feeding interactions: 1) stomach contents, 2) fatty acid composition, and 3) stable isotope composition. Each analysis gives us a snapshot of feeding interactions that take place (roughly) daily (i.e., stomach contents), weekly (i.e., fatty acids), and monthly (i.e., stable isotopes), three different time scales. These analyses revealed significant spatial, temporal, and size-based feeding patterns, with spatial patterns presenting some of the strongest and most compelling trends.

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Once they were introduced, round goby began to displace several species, including logperch (Perca caprodes) and mottled sculpin (Cottus bairdi)."
Geospatial Analysis of Woody Biomass as Renewable Energy Resources

By Gang Shao

Benefits of woody bioenergy

A use of biofuels in Indiana’s future? The answer may depend on what researchers at Purdue can do to clear up important uncertainties about biomass production and distribution. Sustainability, energy independence and security, and other social and environmental concerns have led many in government and other policymakers to strong interest in bioenergy. In particular, woody biomass has great potential as a source of bioenergy. Woody biomass is flexible, it can be burned directly instead of fossil fuels to produce heat and electricity, or converted to woody pellets and torrefied wood to increase burning efficiency. If the lignin in woody material is removed or broken down, woody biomass can also be a feedstock (the raw material) for biofuel production. Using woody biomass to produce bioenergy can reduce greenhouse gasses and other emissions, reduce energy costs, increase the utilization of woody wastes, and promote economic development (EPA, 2009). Utilization of woody biomass can also benefit forest health by making thinning more economically viable and thereby reducing the risk of fire and disease. Dedicated forests planted for bioenergy with species such as hybrid poplar can create revenue on marginal sites.

Objectives

I have two objectives in my research, A) Analyze the types and amounts of woody biomass available for the production of bioenergy, and B) Develop a more complete understanding of bioenergy supply chain logistics—for example, how will biomass be moved from forests to bioenergy production facilities?

A) Feedstock analysis of woody biomass for energy

Every year, the U.S. Department of Agriculture develops predictions for the amount of corn and other crops that will be harvested. To understand the potential of biofuels, we need to develop good predictions of what types of biomass might be harvestable, and how much of each type is present in the woodlands of Indiana. To do this, I will incorporate remote sensing and GIS with forest growth models or ecological models to estimate the volume of woody biomass that is and will be available in Indiana. I will also classify the woody bioenergy feedstock into different types based on the wood quality. To have a comprehensive understanding of the potential inventory of woody bioenergy, we need to figure out the current forest composition and distribution, and its potential for furnishing bioenergy feedstock. Light Detection and Ranging (LiDAR) and Geographic Information System (GIS) data for Indiana and the surrounding states will be used to develop this inventory. The LiDAR data will provide information about forest age, density, biomass, and species composition. The LiDAR data will be used to create a digital elevation model (DEM) that can be used to estimate the amount of woody biomass in the forest.

Analysis of the gobies stomach contents showed that gobies on the west side of Lake Michigan consumed mostly benthic (i.e., associated with the bottom of the lake) food items, such as chironomids, amphipods, isopods, ostracods, and benthic microcrustaceans. Gobies on the east side of Lake Michigan consumed mostly pelagic food items (i.e., free swimming organisms) but also retained some benthic food items in their diets. Analysis of the fatty acids of the other two analysis methods; fish from sites on the west side of Lake Michigan showed benthic stable isotope signals and those from the east side of Lake Michigan had pelagic stable isotope signals.

From these results, I conclude that gobies feed in different ways on different sides of Lake Michigan. Round gobies on the east side of Lake Michigan consumed mostly benthic prey items and gobies on the east side of the lake consumed more pelagic prey items. We suspect the reason for this difference in feeding behavior is caused by 1) differences in lake bed composition between the east and west sides of the lake, and 2) water upwelling and downwelling events. The composition of a lake bed can determine what round goby food items can survive and thrive; since round gobies have such a small home range, they mostly consume what is immediately available in their environment. There is substantially rockier habitat on the west side of the lake, and rocky habitat often supports more benthic food types. Second, upwelling and downwelling events, which force cold bottom water or warm surface water into the nearshore, are not evenly distributed throughout Lake Michigan. Western Lake Michigan is characterized by frequent upwellings, which bring material up from the depths of the lake for round goby prey to feed upon. This is probably reflected in round goby fatty acid composition. The opposite is true for eastern Lake Michigan; food near the surface of the lake is forced downward where round goby prey feed. Round gobies on the east side of the lake then consume these prey and their fatty acid profile reflects a pelagic food web.

I have found evidence of the emerging, but important, feeding interaction roles round goby play in nearshore Lake Michigan. One thing is for sure: round goby are here to stay, at least for a while. The more we know about how they find food and how they interact with one of their relatively new, non-native environments, the better our ability to control their impact.
The Decline of Cisco in Indiana

By Andrew E. Horsey

The cisco (Coregonus artedi) is a silvery, coldwater fish species that was once very common throughout much of the Great Lakes region. A close relative of the whitefish, the cisco has all but disappeared from a large portion of the lakes in the Midwest, due primarily to overfishing and habitat degradation. Climate warming and changes in agricultural and urban land use have had especially detrimental effects on cisco populations in the glacial lakes of northern Indiana. There has been a drastic decline in the number of lakes containing cisco within the state.

History of Cisco in Indiana

Since the 1950s, the number of glacial lakes in Indiana containing cisco has precipitously declined. From 42 in the 1950s, to 24 in 1975, 13 in 2001, and, according to our current study, 7 in 2012-3. Although cisco are sometimes hard to catch using standard sampling methods (which may cause an underestimation of the number of lakes in which cisco are present), it is clear that many populations have gone extinct. The most likely cause for this decline is habitat degradation due to nutrient loading. Runoff from agricultural and urban areas often contains high concentrations of nutrients (phosphorus and nitrogen). The loading of these nutrients into lakes is a form of water pollution that enhances growth of many organisms, especially algae. During the summer, many of the algae die, sink to the bottom of the lake, and undergo decomposition, a process that depletes the oxygen in the lake, especially near the lake bottom. Cisco are particularly sensitive to low levels of oxygen and are often forced to avoid deep, oxygen-poor waters. Unfortunately the warm water at the surface of Indiana’s lakes in the summer can be lethal to cisco. The interaction of these two effects (oxygen forcing cisco up, temperature forcing them down) causes a habitat “squeeze” that restricts cisco to very specific regions within a lake. In some cases, adequate habitat disappears entirely, which can cause significant fish kills and even population extinction.

Estimating Extinction Risk-Implications for Management

Though many of the cisco populations in Indiana appear to have gone extinct, some of the 7 lakes I sampled for my research contained healthy cisco populations. Will those populations go extinct as well? Or will some lakes in Indiana likely contain cisco for the foreseeable future? My research will try to answer these questions by estimating the extinction risk of the cisco populations we sampled over the past two years. Together with the Indiana Department of Natural Resources, I have examined cisco populations for characteristics including sex ratios of fish, their size and age distributions, and their diets. I am now working on estimating the genetic diversity of these populations. Quantifying the genetic diversity of ciscoes within each lake will allow me to calculate the effective population size of the ciscoes in each lake. Effective population size is a good indicator of whether a population of ciscoes will persist. By combining all the data I have gathered in the field and in the lab, I will be able to generate valuable estimates of the risk that ciscoes will become extinct in each of the lakes. These estimates will provide a basis for future management decisions. Money and effort can be directed toward preserving healthy cisco populations and, if possible, rehabilitating the populations at high risk of extinction.

Project Outlook

So far, I have completed simulations for 3 of my 15 beaches, and my findings are promising. One of the things I am most interested in during this project is trying to pinpoint certain beach characteristics that moderate or exacerbate the impacts of disturbance on Piping Plovers. With just three completed beaches, I have already found that, everything else being equal, plovers respond differently to disturbance on different beaches. Factors like beach width can have a sizable impact on the ability of plovers to avoid or escape disturbance, and modify how much space around nests can be fenced off to deter human disturbance. This gives me 20 combinations of different beaches, and test them more than just once per empirical season.

An adult Piping Plover incubating a nest on the open beach. (Photo by Alex Cohen)

As I analyze beach characteristics in relation to disturbance, I hope to be able to make case-specific recommendations for plover management based on environmental characteristics. For example, a wide beach with inhabited plovers and minimal predator presence may not need much management intervention, while a skinner beach with sensitive plovers and high expected human use may require generous allocation of space to plovers, efforts to deter urban predators, and restrictions on certain activities (i.e. kitesurfing, dog-walking) which are highly distressing to plovers.

Piping Plovers are still considered a threatened species despite many years of intense management and research. Given the major conflicts that can arise between plovers and humans using the same beach environment, it will be important to understand how plovers respond to human presence, how behavioral adaptations may modify this response, and how local factors influence interactions between birds and humans. There is still a very long way to go before plovers and other shorebirds will be able to sustain major populations without intervention. I am hopeful that my research will help make management practices more efficient and contribute to our understanding of the coastal environment. The beach is a unique environment, and hopefully we as humans can learn to coexist with the many other species that use it.
For this project, I am using an individual-based model developed in my (Dr. Patrick Zollner’s) lab called SODA (Simulation of Disturbance Activities). SODA has been used to study bat, bird, and butterfly species, and is built to investigate how changes in temporal and spatial human use of areas will impact focal wildlife species present there. By creating virtual worlds in SODA, I am able to explore questions not possible in a field setting. I can’t go out to a beach and regulate how many people come onto the beach for a month, or ask plovers to behave in a certain way around people. However, using an individual-based modeling approach, I can do exactly that.

Of course, simulations are built to realistically represent beach environments. Using SODA, I give virtual plovers rules for how and where they move around. I can also characterize things like when they actively forage throughout the day, how they react to human presence, and so on. This is based on data gathered from the scientific literature, as well as my own personal experience working with Piping Plovers. Similarly, my virtual beaches are representations of actual beaches on the coastlines of Massachusetts, where Piping Plover monitoring programs have been established for some time. Using aerial imagery, I take a beach of interest and make my own map of it, delineating different sections of the beach (i.e. dunes vs. open beach) and populating the map with Piping Plover adults and chicks, nest locations, and different kinds of human recreationists like joggers, dog-walkers and sunbathers.

In my simulations, I am modeling disturbance of both plover chicks and adults. When undisturbed, adults will incubate nests, while chicks will move around and forage or rest depending on the time of day. However, when a simulated human comes within certain distances of a plover, the plover changes behavioral state. At the first distance threshold (i.e. 50 meters), an animal will become alert towards the human, which is associated with reduced energy gain for chicks (i.e. reduced pecking rates while foraging and more vigilance behavior). At the second distance threshold (i.e. 25 meters), an animal starts moving (“flushing”) in response to the human threat. Adult Piping Plovers will get off their nests and come out to “greet” humans and try to lead them away from the nests, while plover chicks will often try to run around humans to escape them. These thresholds can be modified to represent plovers habituating to human presence. A “normal” adult plover may flush off of its nest when a human is 40 meters away, but I can create habituated virtual plovers that flush at 10 or 20 meters.

In order to explore the interactions of changing patterns of human presence on beaches and varying sensitivities of plovers to disturbance, I have created 5 different scenarios for human intensity of beach use and 4 different scenarios for how sensitive or habituated plovers

One of my study beaches: Joseph Sylvia State Beach, Martha’s Vineyard, MA. On the left is Google Earth imagery, on the right is a digitization for input into SODA. (Images provided by earth.google.com)
Modeling the Impacts of Human Disturbance on Beach-nesting Piping Plovers

By Alex Cohen

If you have ever been to a beach on the Atlantic coast in the summer, or perhaps a beach on Lake Michigan or Lake Huron, you may have come across areas that were closed off due to Piping Plovers (Charadrius melodus) or other birds nesting there. Most people think of seagulls like the Herring Gull (Larus argentatus) or Ring-billed Gull (Larus delawarensis) as common (and annoying) avian beach inhabitants, but all kinds of different bird species use the beach for feeding, socializing, resting, and even nesting and raising young. However, humans also have an affinity for the beach, and use it for many recreational activities, like walking, boating, fishing, dog-walking, sunbathing, running, and more.

When humans lay claim to beaches, they come into conflict with birds that nest there. As a result of beach development and use, most coastal bird species have declined in the last century. Habitat loss and degradation are the top threats to beach species. Conflict between humans and birds can occur on a much smaller scale. Birds nesting on the beach often have extremely well-camouflaged nests, so people may accidently step on a clutch of eggs or run over nests or chicks when driving vehicles on a beach. Even walking near a nest can disturb adults from incubating their eggs, escaping predators, and the elements. In many shorebird species (Charadrius spp.), chicks are mobile within hours of birth, running around the beach and feeding themselves while their parents keep watch for threats and provide protection by brooding the young or showing aggression towards predators. When chicks are repeatedly disturbed from foraging by beachgoers, they may gain less weight than they need to survive, and be exposed to threats as their parents are busy responding to human presence.

Piping Plover Management

The Piping Plover is a small beach-nesting shorebird which has become an icon of beach management in the last 20 years. Due to major population declines, the Piping Plover has been listed as an endangered species in the Great Lakes and a threatened species throughout the rest of its breeding range, including the Atlantic Coast. Major programs are devoted towards monitoring and protecting plover nests each breeding season, including stringing off areas around nests to keep people from wandering too close and making efforts to educate beachgoers on their potential impacts on nesting birds.

Management of Piping Plovers can be highly controversial. Even the pronunciation of “plover” is surprisingly contentious -- is it pluh-vor or ploh-ver? More seriously, a lot of money, time, and other resources go into shorebird conservation. Plover management often goes hand in hand with management of other species, benefiting the coastal environment as a whole and allowing for lots of educational and research opportunities. However, the dual goals of conserving wildlife and providing humans with recreational opportunities can conflict when human beach access is restricted because of nesting birds.

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Many scientific studies have shown a negative correlation between intensity of human beach use and bird reproductive success. Fortunately, some studies have also shown that plovers are able to alter their behavior and become habituated to human presence over time, somewhat like university campus tree squirrels. Indeed, some of the busiest beaches are home to successfully breeding plovers that show little fear towards people, while plovers at more pristine beaches may not fledge any chicks in a particular breeding season.

Piping Plovers are given protection by law; yet there are many stakeholders in the beach environment. Management of any given beach requires flexibility on the part of all stakeholders and attention to the local factors affecting both plovers and humans. Consequently, there is no simple rubric for when a plover will or will not successfully raise any young in a given breeding season. Environmental characteristics, plover behavior, and human presence all interact to create a frustrating and costly situation to manage. Piping Plovers are given protection by law; yet there are many stakeholders in the beach environment. Management of any given beach requires flexibility on the part of all stakeholders and attention to the local factors affecting both plovers and humans.