Environmental ScienceBites Volume 2

ENVIRONMENTAL SCIENCEBITES VOLUME 2

Edited by Brian H. Lower, Travis R. Shaul, Kylienne A. Shaul, and Ella M. Weaver

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The Ohio State University
Columbus, Ohio

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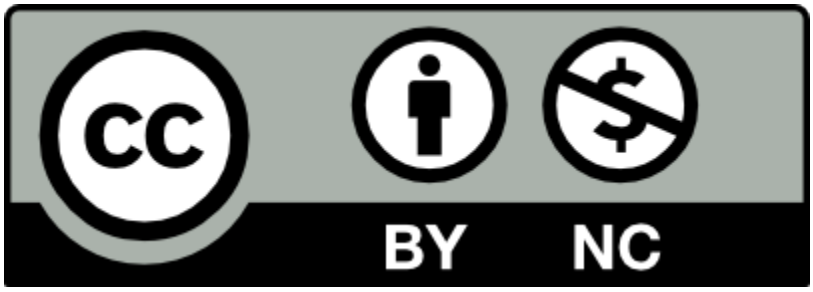

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DEDICATION

This book is dedicated to our students whose earnest curiosity, perpetual energy, and boundless creativity give us hope for the future of Earth and all carbon-based life forms, wherever they may live.

ABOUT THE EDITORS

Brian H. Lower, Ph.D.,

is an Associate Professor at The Ohio State University within the School of Environment and Natural Resources. Over 8,000 students have taken Dr. Lower's "Introduction to Environmental Science" course at Ohio State. Brian's course is also offered for free through Apple iTunes U and Canvas.net. Over 200,000 students have enrolled in these free distance education courses since 2012. Before joining

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Ella M. Weaver, B.S.,

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LETTER TO THE READERS

Dear Reader,

This book was written by undergraduate students who were enrolled in the course "Introduction to Environmental Science", taught at The Ohio State University. All of the students featured in this book are first-time authors and represent nearly two-dozen departments within Ohio State.

This 2nd edition of ScienceBites is broken into five distinct chapters: (i) invasive species, (ii) human-wildlife conflict, (iii) pollution, (iv) climate change and (v) sustainability. Each chapter contains five articles and one poster, each authored by a unique undergraduate student, for a total of 30 contributing student authors. Each work describes an environmental challenge and explores ways that humans are using cutting-edge research to come up with solutions to these problems. Each author has chosen a topic that is of personal importance.

Our goal for this book is to highlight the creative work of our students and to publish a free resource that can be used by other students who are interested in learning more about environmental science. We hope that these articles serve as an inspiration to preserve and protect Earth for all life. We are very proud of the work of our student authors and hope that this book will serve as encouragement for others.

Best,

Brian H. Lower
Associate Professor
The Ohio State University

ACKNOWLEDGEMENTS

We are grateful to The Ohio State University School of Environment and Natural Resources, The Ohio State University Office of Distance Education and eLearning, and the United States National Science Foundation for their generous financial support. We would also like to thank the nearly +120 student reviewers and teaching assistants who provided valuable feedback to our authors.

INVASIVE SPECIES

Courtesy of Suzie Tremmel, 2009, FlickrCommons. CC BY 2.0.

1.2 CANE TOAD: PURPOSEFULLY INTRODUCED, BUT INSTANTLY A REGRET

Delia A. Randolph

A nonnative species, the cane toad (Bufo marinus), has been creating destruction to the environment of northeastern Australia. Was are the effects of a new species coming into an ecosystem? How can the effects be reversed?

Figure 1. Cane Toad (Bufo marinus). Photograph by Alex Popovkin, 2010, FlickrCommons. CC BY 2.0.

The cane toad (*Bufo marinus*) is a type of **anuran** that is **native** to South and Central America, but was introduced to Australia in 1935 in attempt to control the **population** of beetles that was eating sugarcane crops.[7] Humans introduced about three thousand cane toads to protect their crops, and now the population is in the hundreds of millions, which poses a dire problem for Australia.[7] Although the

toad is usually found in South and Central America, they are also able to live in areas both warmer, such as Australia, and cooler.[10] Although the cane toad is a non-native species to Australia, they are able to thrive there due to a lack of **predators** that can survive their poison, and also because they will eat anything, including pet food.[3] Ironically, the toads did not eat the intended problematic beetles.[3]

Although introduced in one area, cane toads have spread all over northeastern Australia at a rapid rate (Figure 2).[5] It is calculated that the toads have spread to over a million square kilometers.[8] Through radio trackers, it was discovered that the toads can travel up to 1.8 kilometers (1.2 miles) in one night, which is more than any other anuran.[8] The toad is also **adapting** by growing longer legs which helps it travel faster and longer, leading to further spread throughout Australia.[2,4,6,8,9,10] Those with longer legs are typically the first to arrive at a new location due to their faster speeds.[8] When first introduced to the land, they were spreading at a rate of about 10 kilometers (6 miles) per year.[3] Now, due to their individual physical growth, the toads are spreading about 60 kilometers (37 miles) per year, and have already covered a land area greater than France and Spain combined.[9]

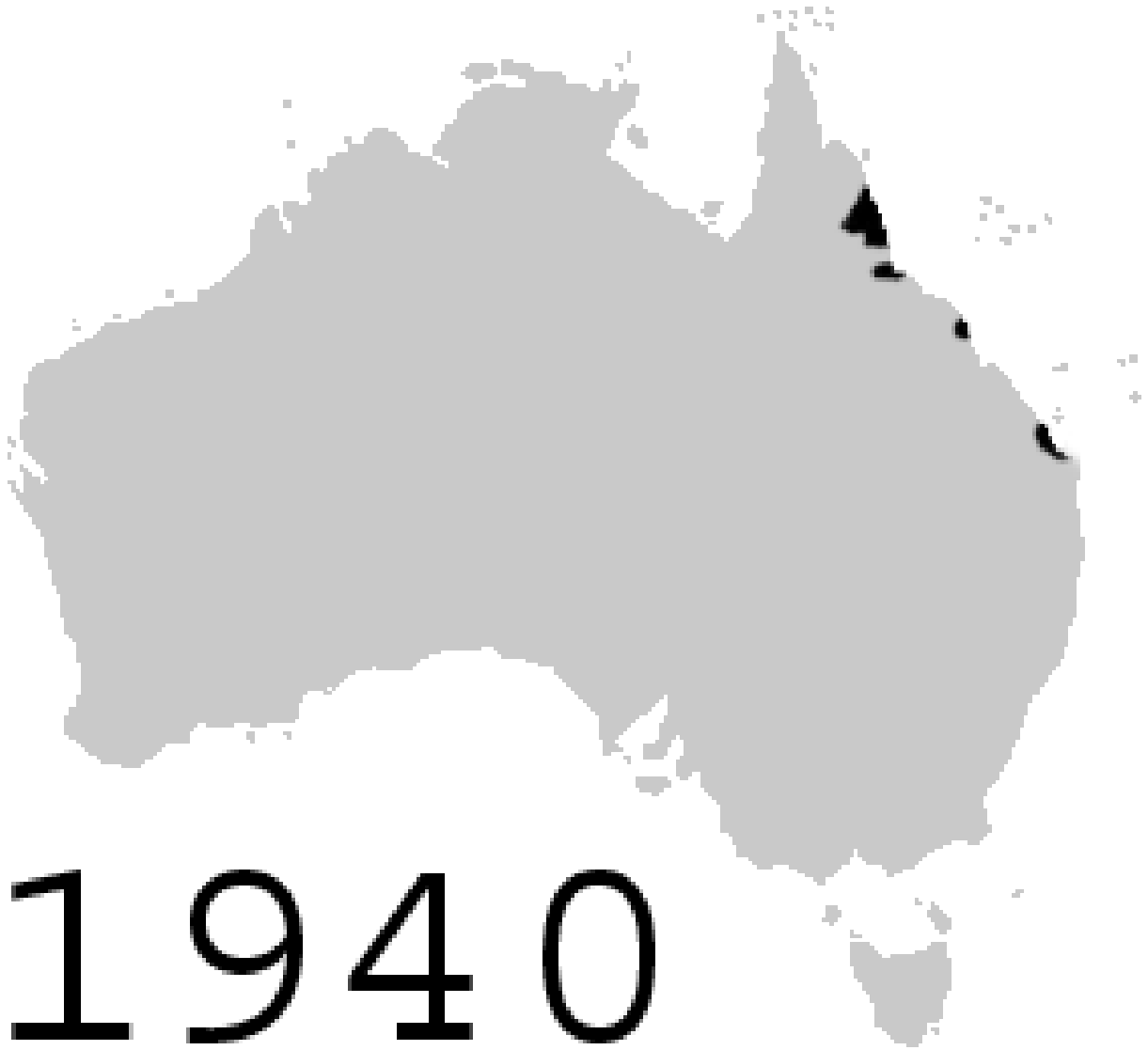

Figure 2. The Cane toad (Bufo marinus) has spread rapidly in the north eastern portion of Australia from 1940 to 1980, and still continues. Courtesy of Froggydarb, 2006, Wikimedia Commons. CC-BY-SA. 3.0.

When the cane toad first established itself as an invasive species, the initial concern was the threat to other animal populations. Some species, such as the goanna lizard, have had a decrease in their population because they eat the poisonous toads.[9] In addition, some native snakes have been negatively affected, but most are not big enough to swallow the larger cane toad.[9] Other species have learned not to eat the toad because of its toxins. There is concern that the native northern quoll (*Dasyurus hallucatus*) would be pushed to **endangerment** by the toad.[1,5] The quoll is a marsupial carnivore and, like the toad, will eat nearly anything.[1,5] Quolls are vulnerable because of their distinct breeding habits in which the males die after the mating season.[1] There are indications that the population of the quoll is decreasing each year. Many quolls have been found dead in Kakadu National Park with reddened gums, which is a sign that they have been poisoned by eating cane toads.[1] Some quolls have been taught by humans to not eat the toads through feeding them a dead toad that was not toxic, however this still made them nauseous.[10] Quoll parents subsequently taught their offspring to stay away from the toad.[10]

An interactive or media element has been excluded from this version of the text. You can view it online here:
https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=32

Figure 3. Northern Quolls (Dasyurus hallucatus). The Northern Quoll has seen a decline in their populations in Australia due to the poisonous Cane toad. The second image shows a map of the Northern Quoll distribution in the country. Courtesy of John Gould, 1863, Wikimedia Commons. Public Domain., and IUCN Red List of Threatened Species, 2010, Wikimedia Commons. CC BY-SA 3.0.

In addition to harming animal populations via their poison, cane toads are also a threat through the taking of shelter and **habitats**.[5] Loss of habitat is often one of the largest threats to a population, and due to the immense amount of cane toads, there has been habitat loss for native anuran.[5] Another species, the rainbow bee-eater (*Merops ornatus*), can lose up to one third of their nesting sites each year due to cane toad invasion and predation on their eggs and young nestlings.[5] There is also harm to many indigenous lizards, because the toad eats many of the insects that serve as the primary prey for lizards.[1,7]

Interestingly, studies of the cane toad indicate that as they grow bigger with longer legs, about 10% of the toads develop spinal **arthritis**.[10] Toads are more likely to develop arthritis if they are faster and have longer legs.[4] The skeletal system of an anuran is meant for little activity, therefore the stress on the spine is thought to cause arthritis.[2] The toads are not meant to have an extremely active lifestyle, but to find more food and shelter, they have spread across Australia, causing great stress on their joints. Although this may seem beneficial to the native species of Australia, it hasn't done much to slow the cane toad's spread. It was discovered that toads with arthritis would only begin to slow down after about fifteen minutes of activity.[2] Despite this, they traveled as far as the healthy toads because of their longer limbs.[6]

Although there have been many efforts and people involved, it seems nearly impossible to eradicate the toads from Australia.[10] Efforts by scientists to remove eggs from ponds and kill as many cane toads as possible have been ineffective.[10] A biological control that is being researched to combat cane toad populations is parasitic lungworms, but this method is not yet ready for implementation.[10] Another study discovered that cane toad tadpoles like to eat cane toad eggs, because the eggs expel a toxin that attracts the tadpoles.[10] Other scientists think the only hope to completely eradicate the toads would be the use of a biological control, however, this is the method that originally brought the species to Australia.[3] If not stopped or controlled, the population of cane toads will have an enormous and detrimental effect on the entire Australian ecosystem.

Figure 4. Distribution of Bufo marinus, as of 2006, with the native range shown in red. The cane toad is an invasive species that has spread rapidly to the country of Australia and continues to spread, due to lack of predators. The cane toad continues to cause harm to the native species of the country. Modified from LiquidGhoul, 2006, Wikimedia Commons. CC BY-SA 3.0.

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1.3 THE INVASIVE AUTUMN OLIVE (ELAEAGNUS UMBELLATA)

The Invasive Autumn Olive (*Elaeagnus Umbellata) within the Midwest*

Paul Acheson (Acheson.18)

The Ohio State University, School of Arts and Sciences , Columbus Ohio 43210

Abstract

Autumn olive (*elaeagnus umbellata*) is an invasive shrub that is distributed throughout the United States, especially in the Midwest.[1] Autumn Olive is native to eastern Asia, but was planted ornamentally, to provide cover, and restore degraded areas.[1,2] Like Many other invasive plant species, autumn olive reduces biodiversity and causes biogeochemical changes in the ecosystem through rapid and dense propagation, hardiness, and nitrogen fixation[1,3,4,5] Nitrogen fixation is the symbiotic relationship between microbes that produce nitrogen and a plant, studies show that plant productivity can increase up to 50%,[6] and nitrogen fixation of *elaeagnus umbellata* leads to higher net nitrogen mineralization and nitrification rates within soil, that can leech into soil water and in turn local watersheds.[5] Similar studies in Illinois streams show that there is a strong connection between autumn olive populations and nitrate levels within the streams.[7] The characteristics of autumn olive, especially nitrogen fixation abilities, creates a need for population control measures to prevent further environmental degradation caused by this invasive plant species. Autumn olive populations must be curbed through manual removal from invaded areas, with methods usually including heavy machinery and pesticides.[2,8] If the population is not controlled, then there will be a reduction in the biodiversity within invaded ecosystems that autumn olive is able to establish a prominent enough presence in.[5]

Invasive Plant Species

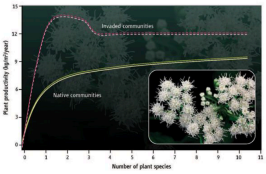


Figure 1 Shows that invading plant species cause an increase in overall plant productivity, but a reduction in plant species diversity[9]

Invasive Plants in Relation to Native Species

To understand the impact of autumn olive it is vital to understand general trends with invasive, exotic, plant species. Plant species can be analyzed in six categories: physiology, leaf-area allocation, shoot allocation, growth rate, size, and fitness. Invasive plants, on average, outperform native plants in these categories. This helps to describe and show how autumn olive is such an effective invader.[10]

Introduction

Figure 2: Pictured above is a stem of the autumn olive while blooming[13]

Autumn olive, or *elaeagnus umbellata*, is an exotic shrub from eastern Asia that was introduced into the U.S. in the 1830's. It can grow to be 7 meters tall, and is recognizable by its leaves. They are dull green on top with brown-flecked silver undersides. They are able to spread rapidly as a single plant can produce up to 10,000 berries per season, which are dispersed by birds. This results in dense clumps of autumn olive that push out and shade out native species.[1,2] Autumn Olive is also able to survive and propagate in drought like conditions.[2,12] However, the most significant attribute of autumn olive is it's ability to fix nitrogen. This increases its competiveness with native species, and has serious ecological impacts.

Where Is It?

Autumn olive (*elaeagnus umbellata)* is distributed throughout much of the United States, as can be seen on the map below. [2] There is a heavy concentration of autumn olive in Midwestern states such as Illinois.

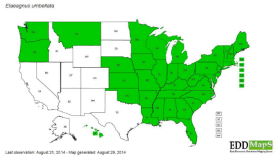


Figure 3: Above is a distribution map of autumn olive[11]

Nitrogen Fixation

Figure 4: Pictured above is a nitrogen fixing root system with root nodules.

Nodulated plants grow significantly better than non-nodulated plants.[4] This is due to the bacteria within the nodules that can contribute up to 50% of the production.[6] Also, nitrogen fixing plants cause biogeochemical changes in the ecosystem.[14] This is due to the increased nitrogen present in the soil. Autumn olive causes N mineralization and nitrification by 50%, this excess nitrogen in the soil is transferred to local watersheds via increased soil water nitrogen levels. This can be a source of non-point pollution within these water systems, such as those in Illinois.[5,7]

Figure 5 above is a growing autumn olive from MyWaldenLabs

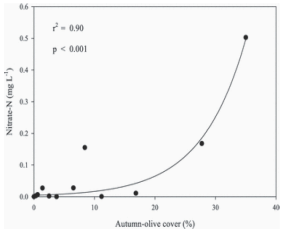
Removal and Control

It is necessary to curb the infestations of autumn olive if the loss of biodiversity and other ecological impacts are to be avoided. It has been studied that the most effective way to clear invaded areas is a combination of chemical and mechanical removal. In a study in southern Ohio showed that foliar herbicide was most effective for the removal of less dense patches. But for dense areas, it is most effective to use a fracture method with follow up herbicide, this technique yielded a 63% mortality rate.[8]

Discussion and Conclusion

Autumn olive has been shown to be an aggressive invasive due to it's traits. It is able to reproduce rapidly and survive in many different ecosystems. The most significant characteristic being the ability to fix nitrogen. This allows it to outcompete native species, and disrupts ecosystems by changing soil nitrogen levels.[3] Because of this, it is necessary to curb the spread and growth of autumn olive. If left unchecked it will continue to spread, reducing biodiversity in multiple ecosystems and wreaking havoc on native species.

Nitrate Levels in Relation to Autumn Olive Cover[7]



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15.

Poster by student author Paul Acheson.

The cane toad is an invasive species that was brought to Australia in hopes of controlling beetle populations. However, the species soon spread across the country and was seen as a threat. Similar to the cane toad, the Autumn Olive was introduced in the Midwestern United States to restore degraded areas. However, a different outcome now plagues this part of the country.

Read the entire transcript of the poster below to learn more about this invasive species.

Abstract:

The Autumn olive (*elaeagnus umbellata*) is an invasive shrub that is distributed throughout the United States, especially in the Midwest. [1] Autumn Olive is native to eastern Asia, but was planted ornamentally, to provide cover, and restore degraded areas. [1,2] Like Many other invasive plant species, autumn olive reduces biodiversity and causes biogeochemical changes in the ecosystem through rapid and dense propagation, hardiness, and nitrogen fixation. [1,3,4,5] Nitrogen fixation is the symbiotic relationship between microbes that produce nitrogen and a plant, studies show that plant productivity can increase up to 50%,[6] and nitrogen fixation of *alaeagnus umbellata* leads to higher net nitrogen mineralization and nitrification rates within soil, that can leech into soil water and in turn local watersheds.[5] Similar studies in Illinois streams show that there is a strong connection between autumn olive populations and nitrate levels within the streams.[7] The characteristics of autumn olive, especially nitrogen fixation abilities, creases a need for population control measures to prevent further environmental degradation caused by this invasive plant species. Autumn olive populations must be curbed through manual removal from invaded areas, with methods usually including heavy machinery and pesticides.[2,8] If the population is not controlled, then there will be a reduction in the biodiversity within invaded ecosystems that autumn olive is able to establish a prominent enough presence in.[5]

Invasive Plant Species:

Figure 1: Shows that invading plant species cause an increase in overall plant productivity, but a reduction in plant species diversity.[9] To understand the impact of autumn olive it is vital to understand general trends with invasive, exotic, plant species. Plant species can be analyzed in six categories, physiology, leaf-area allocation, shoot allocation, growth rate, size, and fitness. Invasive plants, on average, outperform native plants in these categories. This helps to describe and show how autumn olive is such an effective invader.[10]

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Figure 2: Pictures above is a stem of the autumn olive while blooming.[13] Autumn olive, or *elaeagnus umbellata*, is an exotic shrub from eastern Asia that was introduced into the U.S. in the 1830's. It can grown to be 7 meters tall, and is recognizable by its leaves. They are dull green on top with brown-flecked silver undersides. They are able to spread rapidly as a single plant can produce up to 10,000 berries per season, which are dispersed by birds. This results in dense clumps of autumn olive that push out and shade out native species.[1,2] Autumn Olive is able able to survive and propagate in drought like conditions.[2,12] However, the most significant attribute of autumn olive is its ability to fix nitrogen. This increases its competitiveness with native species, and has serious ecological impacts.

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Nitrogen Fixation:

Figure 4: Pictured above is a nitrogen fixing root system with root nodules. Nodulated plants grow significantly better than non-nodulated plants.[4] This is due to the bacteria within the nodules that can contribute up to 50% of the production.[6] Also nitrogen fixing plants cause biogeochemical changes in the ecosystem.[14] This is due to the increased nitrogen present in the soil. Autumn olive causes N mineralization and nitrification by 50%, this excess nitrogen in the soil is transferred to local watersheds via increased soil water nitrogen levels. This can be a source of non-point pollution within these water systems, such as those in Illinois.[5,7] Figure 5. Above is a growing autumn olive from MyWaldenLabs.

Removal and Control:

It is necessary to curb the infestations of autumn olive if the loss of biodiversity and other ecological impacts are to be avoided. It has been studied that the most effective way to clear invaded areas is a combination of chemical and mechanical removal. In a study in southern Ohio showed that folic herbicide was more effective for the removal of less dense patches. But for dense areas, it is most effective to use a fracture method with follow up herbicide, this technique yielded a 63% mortality rate.[8]

Discussion and Conclusion:

Autumn olive has been shown to be an aggressive invasive due to it's traits. It is able to reproduce rapidly and survive in many different ecosystems. The most significant characteristic being the ability to fix nitrogen. This allows it to outcompete native species, and disrupts ecosystems by changing soil nitrogen levels.[8] Because of this, it is necessary to curb the spread and growth of autumn olive. If left unchecked it will continue to spread, reducing biodiversity in multiple ecosystems and wreaking havoc on native species. Figure 6. Nitrate levels in relation to autumn olive cover. A graph shows a y-axis with Nitrate levels (mg/L) and x-axis with autumn olive cover (%).

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1.4 INVASIVE SPECIES BURMESE PYTHON (PYTHON BIVITTATUS) AND ITS EFFECT IN FLORIDA

Lindsey A. Krusling

What started out as a popular pet species, is now threatening an entire ecosystem. Burmese Pythons are an established invasive species in Florida that have no natural predators. Can the Florida Everglades control these populations or will the natural biodiversity continue to suffer?

Figure 1. Burmese Python (Python bivittatus) in the Florida Everglades. Courtesy of R. Cammauf, NPS, 2005, FlickrCommons. Public Domain.

The Burmese python (*Python molurus bivittatus*) is a species native to the tropics in South and Southeast

Asia.[3,6,9,11] As a popular pet species, many were brought to the United States.[3,8,9,11] However, many owners did not realize that this species of snake was one of the five largest in the world and may grow to over 5.5 meters (18 feet) in length.[1,2] Many unprepared owners released these snakes into Florida's Everglades after they grew too large to handle.[9,11] Enough of these snakes were released that a large, wild breeding population rooted in Florida.[9,11] The Burmese Python became an established invasive species which is thriving and threatening the **ecosystem** of Florida's Everglades.

An interactive or media element has been excluded from this version of the text. You can view it online here:
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Figure 2. Burmese Python Zones of Inhabitance. Courtesy of Terminija, 2013, Wikimedia Commons. CC BY-SA 3.0. and USGS, 2007, Wikimedia Commons. Public Domain.

Burmese pythons are having a significant impact on the ecosystem and **biodiversity** in the Everglades and surrounding areas. As an invasive species, the python has no natural predator in Florida, making it an **apex predator** in the area.[1,5,8] Therefore, the population of these snakes is not being naturally controlled. Since the invasion of these snakes in 2000, there has been a large decline in many animal populations across the Everglades.[1,2,3,5,8,11] Burmese pythons have the ability to eat prey much larger than itself through unhinging its jaw, and therefore there is no animal safe from this predator in the Everglades. One of the previous top predators, the American Alligator, has been observed being eaten by these huge snakes (Figure 3).[1,3,5,8,11] Road surveys done after the introduction of the pythons, discovered a decrease of 98.9% for opossum, 87.5% for bobcats, 99.3% for raccoons, and a 100% for rabbit observations.[1] This is evidence of **top down pressure** on all the species below the pythons on the food chain.[1] Another study tracked and monitored Marsh rabbits to discover that Burmese pythons were accountable for 77% of rabbit deaths, which was larger than the control group with no pythons where 71% of deaths were caused by native predators.[5] Large numbers of birds, especially songbird populations, have also been in a recorded decline since the introduction of this invasive species.[2] In dissections of these snakes, all variety of wildlife in the Everglades has been found, including household pets.[11] With no natural predators, the pythons are thriving and growing to large sizes. Burmese pythons nearly large enough to break the world record have been recorded.[10] Another impact of these snakes is a lack of food for other animals, especially other predators.

Figure 3. Both the American Alligator and the Burmese Python frequent the Florida Everglades. There have been several documented cases where these large predators predate on one another. Photograph by Lori Oberhofer, NPS, 2008, Wikimedia Commons. Public Domain.

One of the main questions for researchers is how these snakes are surviving the cold temperatures, and if they will spread further into North America.[6] Burmese pythons are **cold blooded** and adapted to the warm weather of the subtropics of South Asia. They are unable to survive in very low temperatures for long periods of time. Burmese pythons need a minimum temperature of 0°C (32°F) for survival and 16°C (61°F) for digestion, and Florida is known to drop below freezing on rare occasions.[4] Florida's average low temperature is about 12°C (54°F), which may prevent the pythons from digesting food in the very cold winter months.[4] However, it was discovered that these snakes are surviving using a unique form of **thermoregulation**, one that the Burmese python has never been recorded using.[9] Temperature data loggers placed in brooding mother's nests showed that the snake was using **shivering thermogenesis** to survive and keep her eggs alive.[9] Temperatures in the nest were measured and showed to be warmer than surrounding temperatures outside, helping to provide insulation for the clutch.[9] Burmese pythons were also discovered using **brumation** as a technique for surviving the cold weather. During brumation the snakes will go to a warmer place, like an underground burrow, and enter into dormancy until the weather warms. These traits are the necessary tools for survival in Florida's relatively cold weather. Yet, the research also concluded that Burmese pythons will not be able to survive winters in sites further north of the Everglades due to their lack of greater behavioral traits that would help them tolerate colder temperatures.[4] These pythons might not be able to spread further into the United States, but they already have a steadily increasing breeding population in Florida.

Extensive research has been conducted to see if these snakes are a threat to humans. Research concluded that these snakes will not prey on humans.[3,7] Most reported bites and injuries were from Burmese pythons kept as household pets.[7] The same study found 5 reported incidents of snake strikes between 2006 and 2012, which were all dealt to biologists moving in the Florida wetlands.[7] There were no reports of constriction and therefore these strikes were considered to be cases of mistaken identity.[7] This study also showed that no strikes have occurred to the nearly 1 million annual Everglades visitors.[7] It was concluded that Burmese pythons, though detrimental to the surrounding ecosystem, are a low risk to humans.

Figure 4. Burmese Pythons have been observed to reach 19 feet in length. Since their immigration to Florida, they can now be found throughout Everglades National Park, including on trails and roads. Courtesy of the National Park Service, Public Domain.

Many steps have been taken to reduce the population of Burmese pythons in the Everglades, but it is a failing endeavor. In the **Lacey Act**, Burmese pythons were listed as an **injurious species**, and bans have been put in place for the transportation of these snakes and other large pythons.[11] Many traps have also been set to capture Burmese pythons and release them into their natural environment or send them to zoos and research facilities. In some instances, snakes are being killed. One research team has radio tagged the pythons to follow them to where the populations gather and hide.[3] Despite all this effort, the Burmese python population is still increasing.

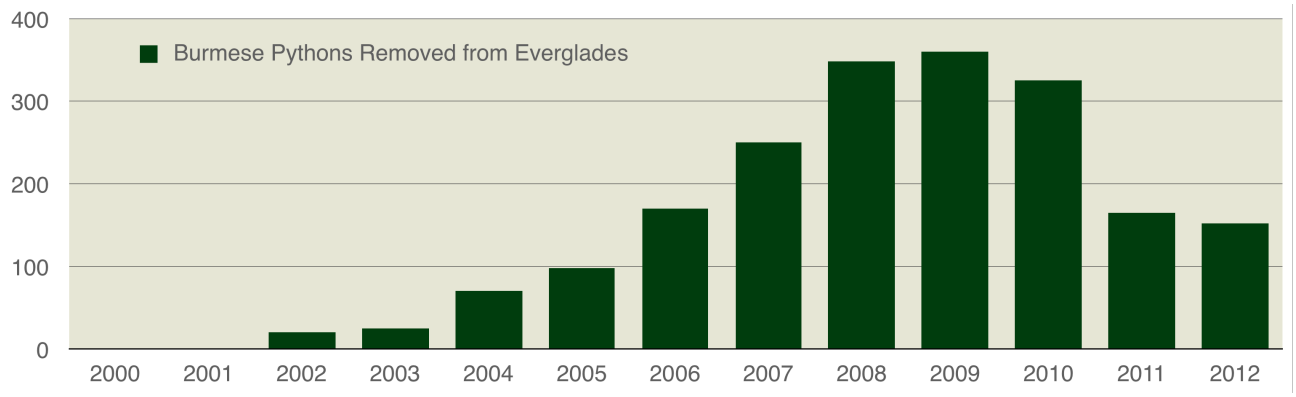

Figure 5. Number of pythons removed from Everglades National Park and surrounding areas from 2000-2012. Everglades National Park employees have help a suspicion for many years that the pythons were reproducing in the area. They have uncovered hatchlings in the park, as well as, captured larger female pythons that were carrying eggs. Scientists first discovered nests in 2006. The reproductive potential and nests of the python are of great concern for those working to limit the python population and protect the Everglades ecosystems. Education, prevention, early detection, and rapid response, are the methods the South Florida Natural Resources Center emphasize to citizens. They also encourage individuals to be responsible per owners with their campaign "Don't Let It Loose." Data obtained from Skip Snow, NPS, 2013. Public Domain.

The Burmese python is an invasive species to Florida's Everglades, released by people who were not prepared to care for them as pets. The pythons are disrupting the natural ecosystem. The biodiversity in these areas has decreased rapidly and efforts to remove them have not been successful. Although not a direct threat to humans, the Burmese python may forever alter the biodiversity of the Florida Everglades.

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1.5 NON-NATIVE MONGOOSE (HERPESTES JAVANICUS): A THREAT TO HAWAIIAN ISLANDS

Katie E. Fineran

In 1883, the Hawaiian sugar cane industry imported the mongoose to control rats. Today it endangers many of Hawaii's endemic species, including the nene. What role does the mongoose play in the Hawaiian environment and how can the mongoose be controlled?

Figure 1. Small Asian Mongoose. Modified from Peter Kraayvanger, 2016, Pixabay. Public Domain.

The Small Indian Mongoose (*Herpestes javanicus*) is a slender weasel-like creature with brown fur, short legs, and a long tail which accounts for about 40% of its overall length. The mongoose is completely **diurnal** and dens in shallow burrows.[3] They move via a brisk gallop or a low slink and are not easily observed by scientists as they make use of dense cover.[1]

Although its native range stretches across Southeast Asia, the mongoose has been introduced by humans to many other regions of the world including at least 45 islands. All of these introductions were intentional as a method to control rats and snakes.[7] The mongoose was first introduced to the Hawaiian Islands in 1883 (Figure 2).[1,2,3,5,7,8] The sugarcane industry imported the mongoose to the islands to control rat populations that were damaging yields.[2] Improved rat-poisoning techniques eventually replaced the need for the mongoose, but mongoose populations were well-established by that time. Although the mongoose does eat small mammals and rodents, like rats and mice, it is **omnivorous** and eats a wide variety of organisms. The mongoose diet varies widely depending on where it is introduced. In Hawaii, the mongoose diet includes birds, reptiles, amphibians, plants, insects, and crustaceans. The mongoose is an aggressive predator and has been observed preying on fawns of white-tailed deer.[3] Its efficient hunting tactics primarily consist of a bite to the back of the head that crushes the victim's skull.[1,3,7] Mongoose have been observed working together to hunt, such as a pair on Oahu that shared tasks: as one overturned rocks, the other attacked emerging crabs.[1]

Mongooses have exceptional vision for a small mammal and they also have the ability to perceive colors.[3]

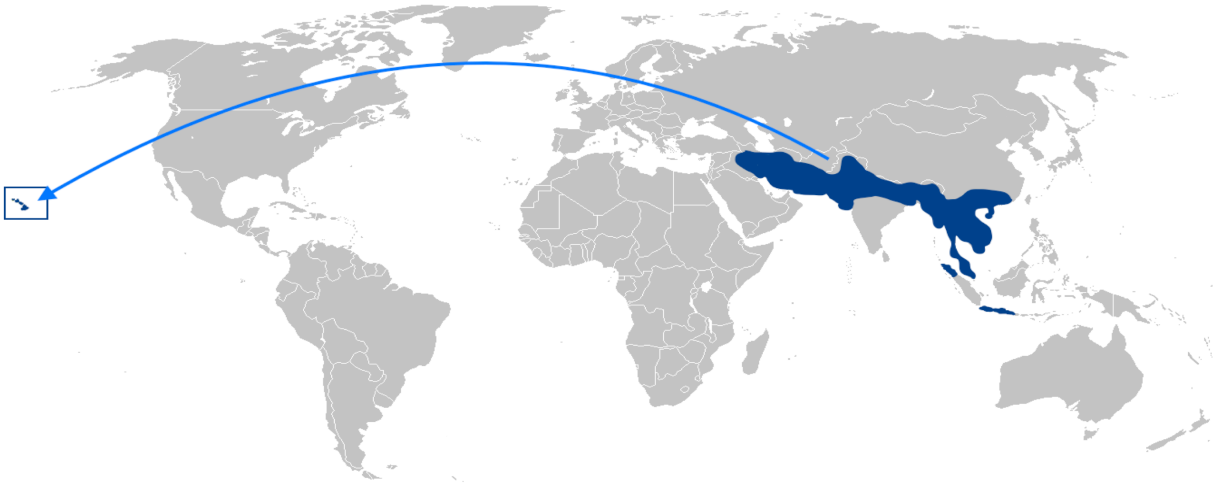

Figure 2. The Small Asian Mongoose (Herpestes javaicus) inhabits areas of Iran, India, Vietnam,, and several other Asian countries. The species traveled to the United States as a result of human interaction and now occupies much of Hawaii. Map data courtesy of IUCN Red List of Threatened Species, Wikimedia Commons. CC BY-SA 3.0. Map modified from NuclearVacuum, Wikimedia Commons. Public Domain.

Once introduced, the mongoose quickly presented new problems for the islands. The species spread rapidly and preyed on the native wildlife. In Hawaii, the mongoose breeding season runs from February through August and gestation takes 49 days, which allow mothers to raise 2 or 3 litters each year.[1,3] Pups are born in litters of 1 to 5 and begin hunting with their mothers at 6 weeks.[1,3,7] They reach sexual maturity at 4 months, giving the mongoose a relatively rapid cycle of reproduction.[3] Mongoose have no natural predators and very few parasites or diseases on the Hawaiian Islands to control their population. A non-native, invasive species and effective predator like the mongoose poses a significant threat to Hawaii's unique ecosystem.[2,4] Of all the species on the U.S. endangered species list, 25% are **endemic** to Hawaii.[4] Hawaiian **biota** is extremely vulnerable to introduced predator species after having evolved over thousands of years without them.[8] Sea turtles, including the loggerhead, hawksbill, leatherback, and green sea turtles, all suffer from mongoose predation of their eggs.[2,3,5] Eight of Hawaii's federally endangered birds suffer heavily from nest-predation by the mongoose, including the nēnē (*Branta sandvicensis*) (Figure 3).[2,8,10] Ground-nesting birds are at particular risk. On other islands, at least two ground-nesting bird species have become extinct due to mongoose predation, including the barred-wing rail in Fiji and the Jamaica petrel.[3] Within the Hawaiian Island chain, the mongoose has stable populations on the islands of Hawaii, Oahu, Molokai, Maui, and most recently, Kauai.[5] The mongoose continues to negatively affect the native biota and presents a significant challenge for conservationists.[6]

One of Hawaii's most well-known and beloved endangered species is the Hawaiian goose, or nēnē (pronounced nay-nay). The nēnē was placed on the very first endangered species list when it was created under the Endangered Species Preservation Act of 1966.[9] Many studies have been conducted to investigate the various causes of nēnē mortality. Leading mortality factors include emaciation, trauma from vehicle-strikes, predation, and disease.[10] Much conservation work has been done to restore the nēnē population in Hawaii.[9] Captive-breeding efforts have been extensively used to restore the population, but more work remains, as nest predation hinders successful reproduction in the wild.[9,10] Average clutch-size is 3 eggs with a lengthy incubation period of thirty days.[9] Once hatched, chicks remain flightless for 10-14 weeks making them vulnerable to mongoose predation for an extensive

period.[9] The largest population of nēnēs was established on Kauai, predictably due to the absence of mongoose there until recently.[10] Discovery of a new mongoose population becoming established on Kauai has many nēnē conservationists concerned. The mongoose makes it difficult for conservationists to reestablish nēnē populations, and that of many other ground-nesting birds to their historical range.

Figure 3. Adult Nene (Branta sandvicensis). Modified from GoodGallagher, 2017, Pixabay. Public Domain.

Researchers are trying to determine the effectiveness of various methods for eliminating the mongoose. Trapping is the main method, and poisoned meat placed in strategic locations is also common.[1] However, many fear that traps and poisons are a threat to other wildlife and advocate that the Hawaiian government should permit hunting of mongoose, or inquire with other island nations who have been more successful with rodent eradication for suggestions. Poisons are also considered more ecologically threatening than beneficial. Other initiatives do not attempt to eradicate the mongoose, but simply try to **mitigate** their impacts by keeping them out of certain areas. Barriers are put in place, or moats are constructed as the mongoose is generally averse to rain and water.[3] Another common control method involves trapping them at key nesting sites prior to nesting season.[3,8] The vast majority of efforts to manage mongoose populations consist of trapping and removing individual mongoose from sensitive areas. Trapping is expensive and laborious, and many times removing mongoose from an area only creates an empty habitat for other mongoose to move into.[3]

ERADICATION TOOLS	ANALYSIS
Bait stations and mechanical traps (live traps, single-kill traps, multi-kill traps)	These are often the first actions taken in controlling the population, but may require considerable human intervention.
Aerial application of rodenticides by helicopters or application by hand	Application of rodenticide has previously been used both locally and globally. Aerial application is often the last resort if trapping, bait stations, and hand application does not work.
Chemosterilants and fertility control agents	The technologies used for these methods are not yet widespread.

Figure 4. Mongoose Eradication Tools. Courtesy of U.S. Fish and Wildlife Service, Public Domain.

At the time of the mongoose's arrival in Hawaii, ecosystems were already significantly damaged. The major issue with the non-native mongoose lies in its persistence on the island, as the mongoose continues to thrive, spread, and prey upon many sensitive species. It is a major hindrance to many reestablishment efforts for endangered species, like the nēnē. A comprehensive strategy for mongoose control needs to be developed and implemented rapidly to prevent these endangered species from becoming extinct. Many scientists remain hopeful that Hawaii's native biodiversity could dramatically recover if only suppression of invasive species, such as the mongoose, can be achieved.[4]

Figure 5. Mongoose basking in the sun on a nature preserve. Courtesy of kolibri5, 2016, Pixabay. Public Domain.

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1.6 HOW THE GREAT BARRIER REED IS BEING AFFECTED BY THE CROWN-OF-THORNS STARFISH

Kaitlyn E. Kelly

The Great Barrier Reef, one of the seven natural wonders of the world, is teeming with species of tropical fish and coral. However, now the reef is under attack by outbreaks of the crown-of-thorns starfish who prey upon the coral that inhabit it. Can reefs recover from this devastative invasive species?

Figure 1. A Crown of Thorns Starfish preys on stony corals in a National Marine Sanctuary of American Samoa. The sanctuary is working with the NOAA Coral Reef Conservation Program to remove the species. Photograph by Greg McFall, NOAA, 2014, FlickrCommons. Public Domain.

The Great Barrier Reef, covering about 347,058 square kilometers (134,000 square miles) along the coast of Queensland, Australia, is home to more than 1,500 species of tropical fish and 400 species of coral.[3] This wonder of the natural world is teeming with so much life that in 1981 it was named a **United Nations Educational, Scientific and Cultural Organization** (UNESCO) World Heritage site.[3,5] Unfortunately, due to various environmental factors that have severely impacted the reef, it is on the list of World Heritage in Danger.[3,5] Nearly half of the reef's coral died between 1985 and 2012, and approximately 42% of this decline can be attributed to **outbreaks** of the crown-of-thorns starfish (COTS).[3,4,6,8]

Figure 2. The Great Barrier Reef as seen from above. Photograph by Tchami, 2014, FlickrCommons. CC BY-SA 2.0.

The crown-of-thorns starfish, or *Acanthaster planci*, is a large **echinoderm** covered in thorn-like spikes that preys upon coral.[2,9] While it is native to the Indo-Pacific region, the starfish has been described as invasive because of its dense populations, and the devastation it is causing to the Great Barrier Reef.[3,10] This predator prefers to feed on fast-growing coral, but will also feed on boulder coral, which are huge coral formations that take hundreds of years to grow.[2] Coral are digested outside of the starfishes bodies, as they coil themselves around their prey and eject their stomachs into the coral.[4]

Scientists have argued over the environmental triggers that have contributed to the outbreaks of these starfish. The two main hypotheses have both emphasized the importance of **anthropogenic** impact.[1,3,5] These are the predator removal hypothesis and the **terrestrial** runoff hypothesis.[10] The predator removal hypothesis states that the population of crown-of-thorns starfish has increased due to the **overfishing** of its predators.[1,10] The proposed solution is a commercial fishing ban that establishes "no-take" regions.[1,4] This solution is thought to work in a trickle-down manner.[4] The large fish protected by these bans prey on smaller fish, which prey on the invertebrates that eat the starfish larvae.[4] If the amount of large fish is decreased due to commercial fishing, the small fish population will grow and the number of larvae eating invertebrates will go down drastically, resulting in more crown-of-thorns starfish.[4] Researchers have found that there were as many as seven times fewer outbreaks of crown-of-thorns starfish in "no-take" regions than in areas without commercial fishing bans.[4]

The terrestrial runoff hypothesis proposes that increases in crown-of-thorns populations can be attributed to an increased amount of terrestrial nutrients in the water from major rainfall or runoff events.[3,5,10] Excessive nutrients allow for denser phytoplankton populations which allow for better

larval survival, yielding more adult crown-of-thorns starfish.[5,10] Both hypotheses provide insight to the potential causes of outbreaks, however testing of these hypotheses has been hampered by the inability to investigate the spatiotemporal distribution of crown-of-thorns larvae, because they resemble other planktotrophic echinoderm larvae.[8] However, a group of researchers were able to develop a genetic marker and tested it on 48 plankton samples collected during the 2014 spawning season in the northern Great Barrier Reef. The genetic marker was verified by **polymerase chain reaction** (PCR) amplification of single larva.[8] Most of the collected samples were positive for crown-of-thorns larvae and these were detected up to 100 km (62 miles) south of current outbreaks at the time of testing.[8] These findings highlight the potential for rapid expansion of outbreaks and the development of a genetic marker will allow for better detection of these outbreaks.[8]

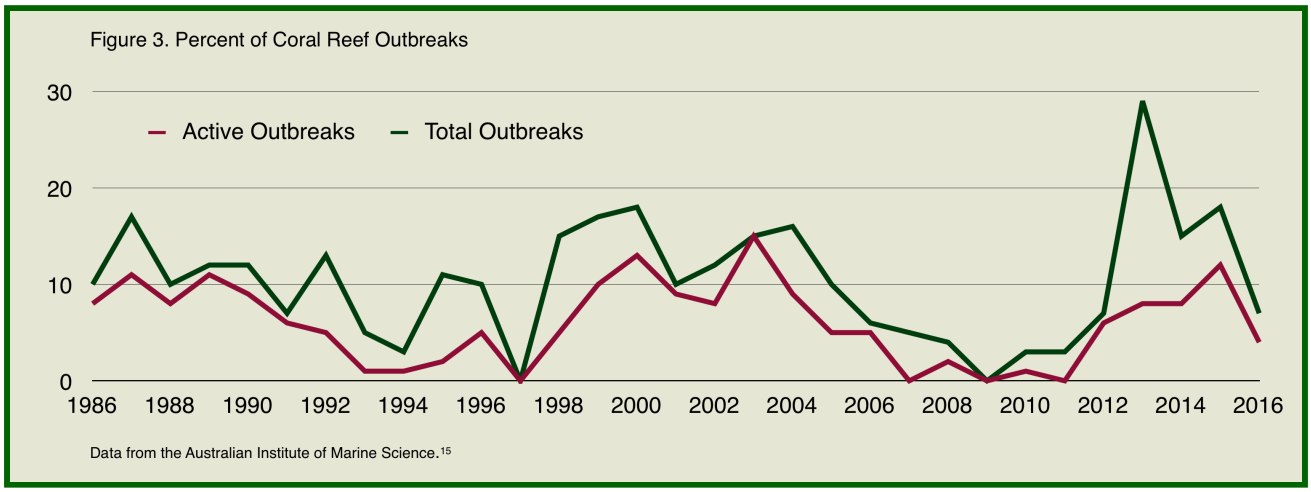

Figure 3. Percent of Coral Reef Outbreaks. Data obtained from the Australian Institute of Marine Science, 2018, CC BY 3.0 AU.

Fortunately, reefs can regain their coral cover. However the process is gradual, taking between 10 to 20 years.[3] This is only possible if the crown-of-thorns populations are kept under control. In the past, this responsibility has been solely placed on divers.[2] Divers have been expected to physically remove these predators from their habitat or inject them with a **lethal** chemical.[2] Now divers will have the assistance of the COTSbot, which is an autonomous vehicle that is programmed to patrol the Great Barrier Reef and kill via lethal injection any crown-of-thorns starfish it detects (Figure 5).[6] The COTSbot follows a preprogrammed path and scans for the crown-of-thorns starfish which can be distinguished by their purplish color and arm/thorn shapes.[6] The bot can operate at night when starfish are more active and swimming is prohibited.[6] It can also operate during stormy weather and high currents, and is programmed to recognize certain positions these starfish take when hiding.[6] When a starfish is spotted, it lowers its arm and injects the starfish with 10 milliliters of poisonous bile salts which effectively digests the echinoderm from the inside.[6] Bile salts have recently replaced sodium bisulfate as the toxin of choice.[7] After researching different options, scientists concluded that along with 12 g l–1 of Oxgall solution, injections of 10 mL of 8 g l–1 Bile Salts No. 3 is the most rapid and effective way to kill off these predators.[7] The starfish will die within 24 hours of injection which prevents opportunities for separation and regeneration.[6,7]

Figure 4. A diver manually injects a Crown of Thorns Starfish with a lethal substance. Photograph by Greg McFall, NOAA, 2014, FlickrCommons. Public Domain.

Efforts to reduce and control the population of crown-of-thorns starfish are vital to the survival of Great Barrier Reef. The Great Barrier Reef is a UNESCO World Heritage Site and vital to Australia's tourism industry.[3,5] Efforts thus far have been somewhat successful, however more work and research needs to be done to ensure the reef has the capacity to regrow its lost corals.

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https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=42

Figure 5. Coral reefs are diverse ecosystems with many species of coral. The Crown of Thorns Starfish is a threat to all of these populations, as they are unable to escape its grasp. Photographs by Bernard Dupont, 2009, FlickrCommons. CC BY-SA 2.0. Tim Sheerman-Chase, 2013, FlickrCommons. CC BY 2.0. Robert Linsdell, 2012, FlickrCommons. CC BY 2.0.

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HUMAN-WILDLIFE CONFLICT

Photograph modified from Jarrod Grammel, USDA, 2013, FlickrCommons. CC BY 2.0.

2.1 LEGALIZING HORN TRADE AS A POSSIBLE SOLUTION TO REDUCE POACHING OF THE SOUTH AFRICAN RHINOCEROS

Jason Cochran

The long-term sustainability of South African rhinoceroses is in jeopardy due to exponential increases in poaching. In an effort to reduce poaching, many approaches have been tried with varying degrees of success. Could legalizing trade of rhinoceros horns reduce poaching in South Africa and foster greater awareness for the species?

Figure 1. Rhinoceros in the Eastern Cape of South Africa. Photograph by Steve Elliot, 2012, FlickrCommons. CC BY-SA 2.0.

Rhinoceros **poaching** in South Africa has significantly increased over the last 15 years and this poses a significant threat to the species.[1] Specifically the number of rhinoceroses poached has increased exponentially, from 13 in 2007, to 668 in 2012.[5,13] If this trend continues, it is predicted that existing rhino populations in Africa may no longer exist within the next two decades.[6,11] While poaching is a threat to both the white rhinoceros (*Ceratotherium simum*) and the black rhinoceros (*Diceros bicornis*), the black rhinoceros is at greatest risk as the species is currently listed on the critically endangered list. It is estimated that approximately 5000 were remaining in the wild as of 2010.[1,5,13]

The majority of poached rhinoceroses are killed for their horns and the profit made through the illegal horn trade. It is estimated that rhinoceros horn can sell for approximately $60,000/kg ($27,215.57/lb) on the black market (exact figures vary by country), making it more valuable than gold by weight.[1,7] This value inherently drives the market and perpetuates the cycle of rhinoceros poaching and illegal horn trade.[1] Beyond the killing of an animal, the act of rhinoceros dehorning is a gruesome and brutal process. The animal is first sedated, immobilized, or shot and then the horn(s) are cut-off, typically using power tools, such as a chainsaw.[16] Once the poachers have removed the horns, if not already dead, the rhinoceroses are often left to bleed to death.[16] If found quickly, the animals can sometimes be treated and saved, though this is uncommon.[16]

In an effort to reduce rhinoceros poaching, many approaches have been tried with varying degrees of success. Proactive **dehorning** is one such approach, in which veterinarians and wildlife officials safely remove the majority of a rhinoceros's horn or horns to make it a less attractive target for poachers.[1,7] The rhinoceros is nursed back to health in a controlled way, with minimal health risks.[1] Another approach that has been used on a small scale is the act of infusing chemicals, such as indelible dye, into rhinoceros horns.[7,8] The assumptions made with this approach are that the horns will be undesirable due to discoloration and therefore will not be used for ornamental purposes, and/or that the chemically modified horn will be more unsafe for end-users or poachers.[8] Although there may be minimal health risks to the rhinoceros, the act of infusing chemicals into rhino horns has many opponents who question the efficiency, ethics, and effectiveness of poisoning or dying rhinoceros horn in an effort to discourage poaching.[8] Notably, results show that dyes injected into rhino horns may not be uniformly distributed throughout the horn which further undermines whether the process is truly effective at all.[8]

The **black market** for rhinoceros horn consists predominantly of Asian countries, specifically south east Asian countries such as China and Vietnam.[9] Vietnam was the primary destination for rhinoceros horns confiscated from 2009 to 2014.[12] In these countries it is considered a status symbol to possess rhinoceros horns or to use the horns in medical remedies.[9] When used medicinally, the horn is often ground into a powder and then added to boiling water before being ingested.[14] Historically, rhinoceros horn has been used in Chinese medicine for illnesses such as fever, headaches, food poisoning, gout, and hallucinations, though there is little scientific evidence of the horn's medicinal benefits.[14,17] Beyond its medicinal uses, in some countries the horn has cultural significance.[14] In Yemen, rhinoceros horn is used to make handles for daggers, called "**jambiya**", which are traditionally given to Yemeni boys at age 12.[14,17,18]

Figure 2. (top) Confiscated Rhino horn. Courtesy of Joanna Gilkeson, USFWS, 2016, FlickrCommons. CC BY 2.0.
(lower left) Boy in Yemen with rhino horn jambiya dagger. Courtesy of Rod Waddington, 2014, FlickrCommons. CC BY-SA 2.0. (lower right) Chinese rhino horn cup. Courtesy of Daderot, 2015, Wikimedia Commons. Public Domain.

While buying and selling of rhinoceros horn continues in many countries, all trade of rhinoceros horn is currently illegal under the **Convention on the International Trade in Endangered Species** (CITES).[1,10] This trade ban has been in place since 1977.[1,4] Some believe this ban only limits supply which increases the value of the horn, and subsequently, these higher prices reinforce the view that

possessing rhinoceros horn is a sign of status and wealth.[1] Neither the CITES ban nor country-specific poaching penalties have been successful in curtailing poaching as the practice continues to increase.[3,17] The penalties that are imposed on poachers vary significantly by country, from years in prison to monetary fines.[6] CITES does not have an effective ability to legislate enforcement in countries where this ban is violated, and an unenforceable mandate is ineffective.[17] Because of the shortcomings of the current management approach, some have proposed legalizing the horn trade may be the best way to ultimately reduce poaching and protect the long-term sustainability of wild rhinoceros populations.[1,6]

Proponents of horn trade legalization argue that by controlling the supply of horns, poaching would become unnecessary.[1,6,11] Individuals looking to obtain rhinoceros horn would have a legal and cheaper means to purchase the product and the demand for poaching would therefore decrease.[1,6] By regulating and legalizing the process, the sales could also be taxed, and some funds could be reinvested into conservation efforts.[6,11] Under this system of legal trade, rhinoceros horn could be harvested from natural deaths, and in a controlled and safe way from living rhinoceroses.[1] Proponents also cite the success of other similar trade legalizations to reduce poaching, such as the trade of crocodile skin.[1] The results of one **cost-benefit analysis** projected that profit as large as $717,000,000/year could be made if legalization occurred, and those funds could be invested into **conservation** efforts.[6] This same analysis also predicts that under the current management approach, the white rhinoceros will become extinct in less than 20 years.[6] In another analysis, five different strategies were analyzed for cost-benefit and the findings indicated that the benefits outweighed the costs for strategies which in some way, provided a legal rhinoceros horn supply.[6,9]

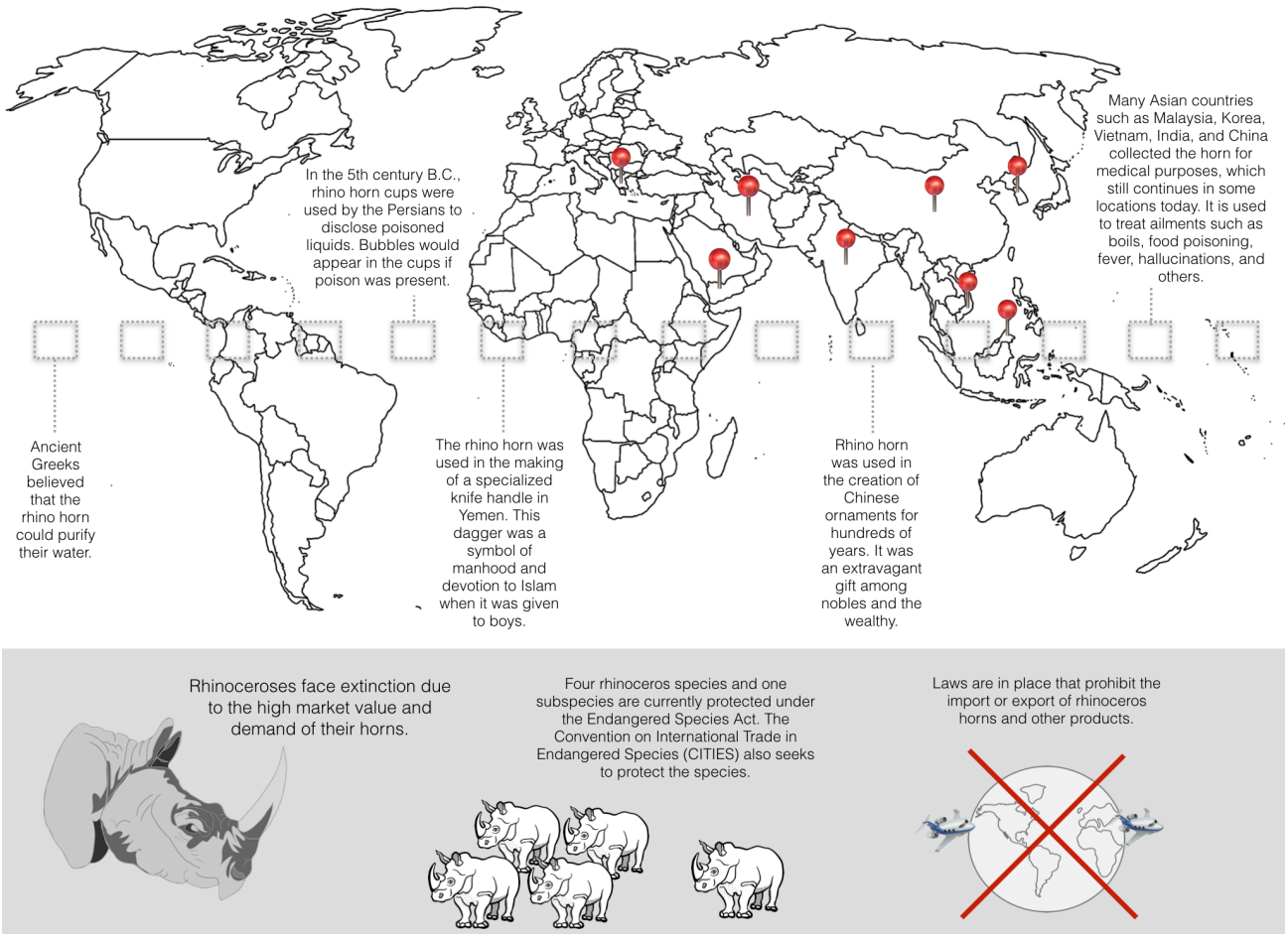

Figure 3. Rhinoceros horn are used in a variety of ways across the globe. Each pin shows a location that currently utilizes the rhino horn in a way such as the text describes. (References below)

Opponents of horn trade legalization have a less optimistic view of a legalized rhinoceros horn market.[2,4,15] They argue that some analyses may be oversimplified as the cost of rhinoceros horn in a regulated and legalized market is unknown.[4,15] Additionally, it is possible that in a legalized market the demand may increase as the **stigma** associated with illegal-trade is removed.[2,15] There is also the risk of reawakening markets in countries where progress has been made to reduce the demand for rhinoceros horn, such as Japan and Taiwan.[9] It may also be considered unethical to legalize trade of rhinoceros horn and there is concern about condoning behavior (selling rhinoceros horn) which has been banned for over 35 years.[6] In another analysis, which modeled the horn market based on different management approaches, the results indicated that alternative methods to trade-legalization, such as increased consumer education, would be more effective.[4,15] Generally, opponents of trade-legalization favor increased awareness and education about the state of rhinoceros populations and more stringent fines and penalties for poachers.[15] Additionally, sanctions and fines against countries unable to curtail the import and/or export of the illegal product may be effective in reducing poaching.[6]

The debate of how to best protect wild rhinoceros populations is complex. Ethical, cultural, and financial decision-making all influence how individuals view the trade of rhinoceros horn. The apparent inadequacies of the current approach, as is evident by the increasing occurrence of poaching, have fueled the conversation around whether legalization of horn trade would ultimately help or hurt conservation efforts. While proponents for legalization of rhinoceros horn trade make a compelling

argument for control through the **supply-and-demand** model, opponents argue that there is insufficient understanding of how the market would react to legalization.[2,6] The results from the various studies are inconclusive and a consensus has not been reached due to various unknowns, such as the price of rhinoceros horn in a legalized market. Research into this topic indicates that both proponents and opponents of rhinoceros horn trade legalization agree that the current policies and practices are inadequate and change is needed. The future of the South African rhinoceros may depend on the ability to compromise in this complex debate.

Figure 4. Southern White Rhinoceroses. Photograph by Ted, 2010, FlickrCommons. CC BY-SA 2.0.

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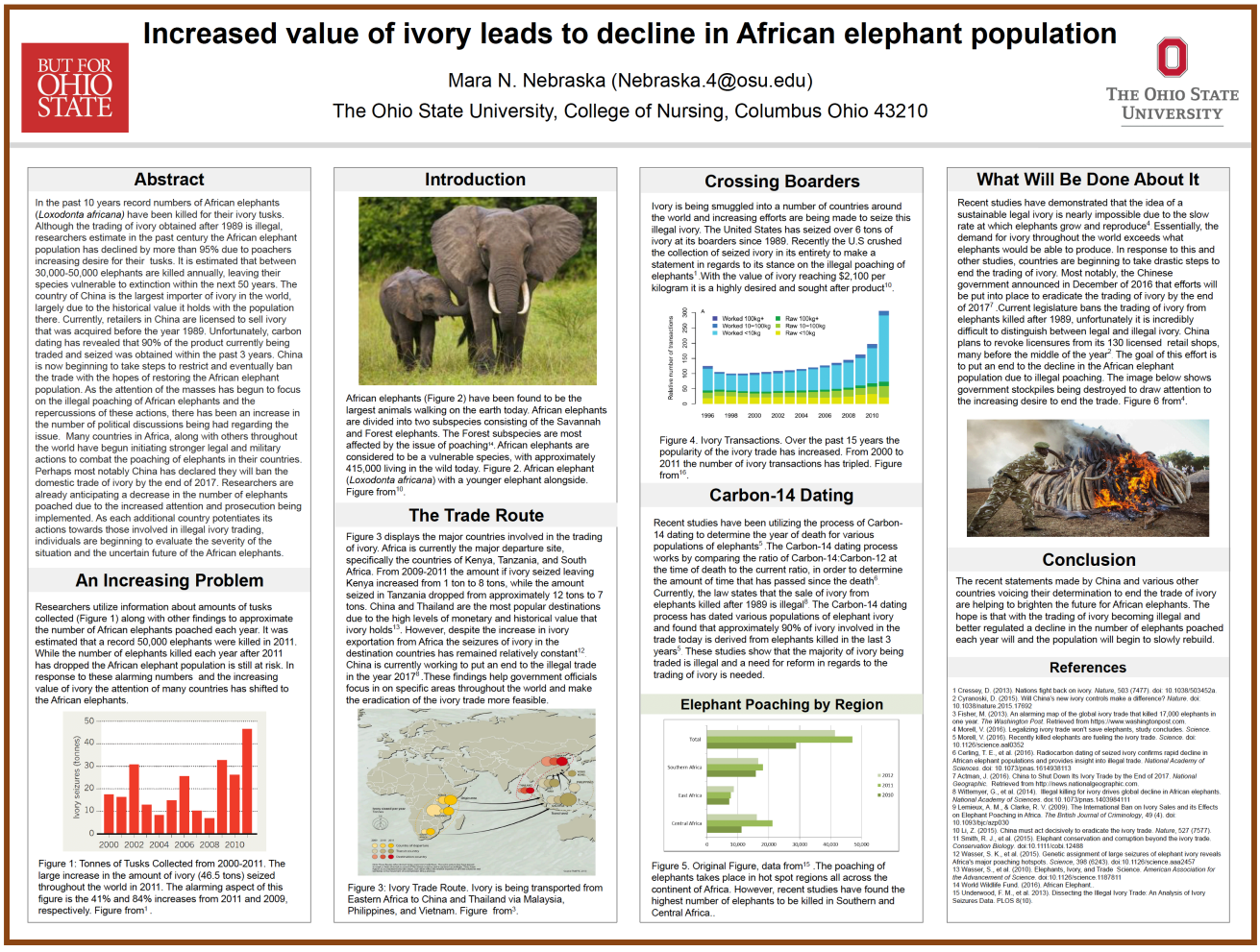
2.2 INCREASED VALUE OF IVORY LEADS TO DECLINE IN AFRICAN ELEPHANT POPULATIONS

image



Increased value of ivory leads to decline in African elephant population

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Abstract

In the past 10 years record numbers of African elephants (*Loxodonta africana)* have been killed for their ivory tusks. Although the trading of ivory obtained after 1989 is illegal, researchers estimate in the past century the African elephant population has declined by more than 95% due to poachers increasing desire for their tusks. It is estimated that between 30,000-50,000 elephants are killed annually, leaving their species vulnerable to extinction within the next 50 years. The country of China is the largest importer of ivory in the world, largely due to the historical value it holds with the population there. Currently, retailers in China are licensed to sell ivory that was acquired before the year 1989. Unfortunately, carbon dating has revealed that 90% of the product currently being traded and seized was obtained within the past 3 years. China is now beginning to take steps to restrict and eventually ban the trade with the hopes of restoring the African elephant population. As the attention of the masses has begun to focus on the illegal poaching of African elephants and the repercussions of these actions, there has been an increase in the number of political discussions being had regarding the issue. Many countries in Africa, along with others throughout the world have begun initiating stronger legal and military actions to combat the poaching of elephants in their countries. Perhaps most notably China has declared they will ban the domestic trade of ivory by the end of 2017. Researchers are already anticipating a decrease in the number of elephants poached due to the increased attention and prosecution being implemented. As each additional country potentiates its actions towards those involved in illegal ivory trading, individuals are beginning to evaluate the severity of the situation and the uncertain future of the African elephants.

An Increasing Problem

Researchers utilize information about amounts of tusks collected (Figure 1) along with other findings to approximate the number of African elephants poached each year. It was estimated that a record 50,000 elephants were killed in 2011. While the number of elephants killed each year after 2011 has dropped the African elephant population is still at risk. In response to these alarming numbers and the increasing value of ivory the attention of many countries has shifted to the African elephants.

Figure 1: Tonnes of Tusks Collected from 2000-2011. The large increase in the amount of ivory (46.5 tons) seized throughout the world in 2011. The alarming aspect of this figure is the 41% and 84% increases from 2011 and 2009, respectively. Figure from[1].

Introduction

African elephants (Figure 2) have been found to be the largest animals walking on the earth today. African elephants are divided into two subspecies consisting of the Savannah and Forest elephants. The Forest subspecies are most affected by the issue of poaching[14]. African elephants are considered to be a vulnerable species, with approximately 415,000 living in the wild today. Figure 2. African elephant (*Loxodonta africana*) with a younger elephant alongside. Figure from[10].

The Trade Route

Figure 3 displays the major countries involved in the trading of ivory. Africa is currently the major departure site, specifically the countries of Kenya, Tanzania, and South Africa. From 2009-2011 the amount if ivory seized leaving Kenya increased from 1 ton to 8 tons, while the amount seized in Tanzania dropped from approximately 12 tons to 7 tons. China and Thailand are the most popular destinations due to the high levels of monetary and historical value that ivory holds[13]. However, despite the increase in ivory exportation from Africa the seizures of ivory in the destination countries has remained relatively constant[12]. China is currently working to put an end to the illegal trade in the year 2017[9]. These findings help government officials focus in on specific areas throughout the world and make the eradication of the ivory trade more feasible.

Figure 3: Ivory Trade Route. Ivory is being transported from Eastern Africa to China and Thailand via Malaysia, Philippines, and Vietnam. Figure from[3].

Crossing Boarders

Ivory is being smuggled into a number of countries around the world and increasing efforts are being made to seize this illegal ivory. The United States has seized over 6 tons of ivory at its boarders since 1989. Recently the U.S crushed the collection of seized ivory in its entirety to make a statement in regards to its stance on the illegal poaching of elephants[1].With the value of ivory reaching $2,100 per kilogram it is a highly desired and sought after product[10].

Figure 4. Ivory Transactions. Over the past 15 years the popularity of the ivory trade has increased. From 2000 to 2011 the number of ivory transactions has tripled. Figure from[15].

Carbon-14 Dating

Recent studies have been utilizing the process of Carbon-14 dating to determine the year of death for various populations of elephants[5].The Carbon-14 dating process works by comparing the ratio of Carbon-14:Carbon-12 at the time of death to the current ratio, in order to determine the amount of time that has passed since the death[5]. Currently, the law states that the sale of ivory from elephants killed after 1989 is illegal[6]. The Carbon-14 dating process has dated various populations of elephant ivory and found that approximately 90% of ivory involved in the trade today is derived from elephants killed in the last 3 years[5]. These studies show that the majority of ivory being traded is illegal and a need for reform in regards to the trading of ivory is needed.

Elephant Poaching by Region

Figure 5. Original Figure, data from[15] .The poaching of elephants takes place in hot spot regions all across the continent of Africa. However, recent studies have found the highest number of elephants to be killed in Southern and Central Africa..

What Will Be Done About It

Recent studies have demonstrated that the idea of a sustainable legal ivory is nearly impossible due to the slow rate at which elephants grow and reproduce[4]. Essentially, the demand for ivory throughout the world exceeds what elephants would be able to produce. In response to this and other studies, countries are beginning to take drastic steps to end the trading of ivory. Most notably, the Chinese government announced in December of 2016 that efforts will be put into place to eradicate the trading of ivory by the end of 2017[7] .Current legislature bans the trading of ivory from elephants killed after 1989, unfortunately it is incredibly difficult to distinguish between legal and illegal ivory. China plans to revoke licensures from its 130 licensed retail shops, many before the middle of the year[7] The goal of this effort is to put an end to the decline in the African elephant population due to illegal poaching. The image below shows government stockpiles being destroyed to draw attention to the increasing desire to end the trade. Figure 6 from[4].

Conclusion

The recent statements made by China and various other countries voicing their determination to end the trade of ivory are helping to brighten the future for African elephants. The hope is that with the trading of ivory becoming illegal and better regulated a decline in the number of elephants poached each year will and the population will begin to slowly rebuild.

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Poster by student author Mara N. Nebraska.

Rhinoceros are not the only species in danger when it comes to the ivory trade. Elephant populations have also seen a large decline due to poaching, as their tusks are a highly sought after source of ivory.

Read the entire transcript of the poster below to learn more about the elephant ivory trade.

Abstract:

In the past 10 years record numbers of African elephants (*Loxodonta africana*) have been killed for their ivory tusks. Although the trading of ivory obtained after 1989 is illegal, researchers estimate in the past century the African elephant population has declined by more than 95% due to poachers increasing desire for their tusks. It is estimated that between 30,000-50,000 elephants are killed annually, leaving their species vulnerable to extinction within the next 50 years. The country of China is the largest importer of ivory in the world, largely due to the historical value it holds with the population there. Currently, retailers in China are licensed to sell ivory that was acquired before the year 1989. Unfortunately, carbon dating has revealed that 90% of the product currently being traded and served was obtained in the past 3 years. China is now beginning to take steps to restrict and eventually ban the trade with the hopes of restoring the African elephant population. As the attention of the masses has begun to focus on the illegal poaching of African elephants and the repercussions of these actions, there has been an increase in the number of political discussions being had regarding the issue. Many countries in Africa, along with others throughout the world have begun initiating stronger legal and military actions to combat the poaching of elephants in their counties. Perhaps most notably China has declared they will ban the domestic trade of ivory by the end of 2017. Researchers are already anticipating a decrease in the number of elephants poached due to the increased attention and prosecution being implemented. As each additional country potentiates its actions towards those involved in illegal ivory trading, individuals are beginning to evaluate the severity of the situation and uncertain future of the African elephants.

An Increasing Problem:

Researchers utilize information about amounts of tusks collected (Figure 1) along with other findings to approximate the number of African elephants poached each year. It was estimated that a record 50,000 elephants were killed in 2011. While the number of elephants killed each year after 2011 has dropped the African elephant population is still at risk. In response to these alarming numbers and the increasing value of ivory the attention of many countries has shifted to the African elephants. Figure 1: bar graph showing Tonnes of Tusks collected from 2000-2011. The large increase in the amount of ivory (46.5 tons) seized throughout the world in 2011. The alarming aspect of this figure is the 41% and 84% increases from 2011 and 2009, respectively.[1]

Introduction:

Figure 2: Mother African elephant with her calf.[10] African elephants (Figure 2) have been found to be the largest animals walking on the earth today. African elephants are divided into two subspecies consisting of the Savannah and Forest elephants. The Forest subspecies are most affected by the issue of poaching.14 African elephants are considered to be a vulnerable species, with approximately 415,000 living in the wild today.

The Trade Route:

Figure 3 displays the major countries involved in the trading ivory. Africa is currently the major departure site, specifically the countries or Kenya, Tanzania, and South Africa. From 2009-2011 the amount of ivory seized leaving Kenya increased from 1 ton to 8 tons, while the amount seized in Tanzania dropped from approximately 12 tons to 7 tons. China and Thailand are the most popular destinations due to the high levels of monetary and historical value that ivory holds.[13] However, despite the increase in ivory exportation from Africa the seizures of ivory in the designation countries has remained delicately constants.[12] China is currently working to put an end to the illegal trade in the

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Elephant Poaching by Region:

Figure 5. The poaching of elephants takes place in hot spot regions all across the continent of Africa. However, recent studies have found the highest number of elephants to be killed in Southern and Central Africa.[15]

What Will Be Done About It:

Recent studies have demonstrated that the idea of a sustainable legal ivory is nearly impossible due to the slow rate at which elephants grow and reproduce.[4] Essentially, the demand for ivory throughout the world exceeds what elephants would be able to produce. In response to this and other studies, countries are beginning to take drastic steps to end the trading of virus. Most notably, the Chinese government announced in December of 2016 that efforts will be put into place to eradicate the trading of ivory by the end of 2017.[7] Current legislature bans the trading of ivory from elephants killed after 1989, unfortunately it is incredibly difficult to distinguish between legal and illegal ivory. China plans to revoke licensure from its 130 licensed retail shops, many before the middle of the year.[2] The goal of this effort is to put an end to the decline in the African elephant population due to illegal poaching. The image below shows government stockpiles being destroyed to draw attention to the increasing desire to end trade.[4]

Conclusion:

The recent statements made by China and various other countries voicing their determination to end the trade of ivory are helping to brighten the future for African elephants. The hope it that with the trading of ivory becoming illegal and better regulations a decline in the number of elephants poached each year will occur and the population will begin to slowly rebuild.

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2.3 THE EFFECT OF LIVESTOCK GRAZING ON THE HIMALAYAN RED PANDA, AILURUS FULGENS

Henry A. Miller-Davis

The red panda is a beloved species across Asia. However, the mammal must coexist with a growing human population and a decreasing habitat range. Can the native people in the Eastern Himalayas learn to coexist with the red panda or will they drive it extinct?

Figure 1. A Red Panda (Ailurus fulgens) occupying a bamboo tree, its primary food source. Photograph by Pexels, 2016, Pixabay. Public Domain.

One of the most interesting and adored species of the diverse fauna of Asia is the red panda (*Ailurus*

fulgens), also known as the lesser panda, which is a reddish-brown **arboreal** mammal about the size of a house cat.[6] The fossils of *Parailurus*, an ancient relative of the **extant** red panda, have been found throughout the world in Europe, North America, and Asia.[7,9] Red pandas, however, only live in Asian temperate forests on mountainous slopes at altitudes between 1,500 and 4,800 meters (4,920 and 15,748 feet) , which limits their distribution mostly to the countries of Nepal, Myanmar, Laos, and China (Figure 2).[4,5,8,9] The red panda population in this region must coexist with a growing human population and has suffered from the detrimental impact humans have on the environment. As a result, the wild population of red pandas has unfortunately declined an estimated forty percent over the past fifty years, leaving around <10,000 left in the wild.[3,9] The main driver behind their declining population is habitat loss from livestock grazing in the region.[2,3,4,8]

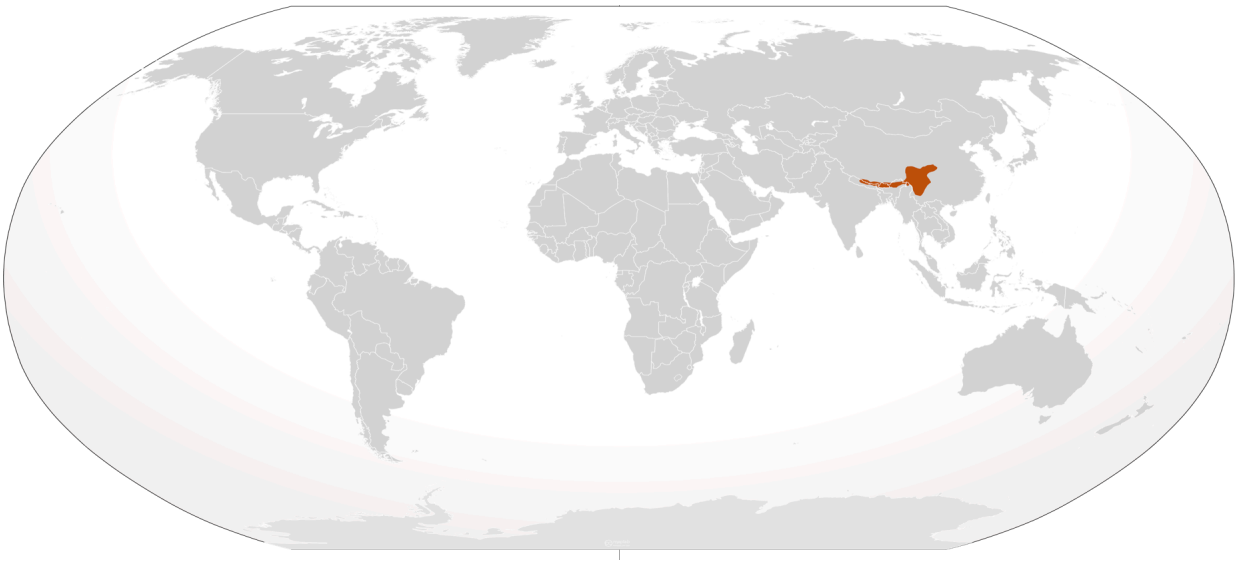

Figure 2. The red panda is native to Bhutan, China, India, Myanmar, and Nepal, however, population numbers are declining. Map courtesy of IUCN, 2012, Wikimedia Commons. CC BY-SA 3.0.

With the exception of China, countries in the Eastern Himalayas are among the least developed in the world and citizens of these nations live in substandard conditions. Nepal, for example, scored 0.540 on the **Human Development Index**, ranking it 145th in the world.[1] Seventy percent of Nepal's population works in agriculture and researchers Sanjay Dorji, Rajaratnan Rajaratnam, and Karl Vernes describe "rural poverty [as] both the cause and effect of much environmental degradation through a reliance on livestock."[3] Formerly, farmers kept livestock to provide food for only their own household, but commercialization in the region has changed this. In recent years, locally produced cheese has become popular with tourists, so large numbers of farmers in the region now raise additional livestock to sell their milk products in this newly established market.[8]

There are several threats to the red panda population caused by this increase in livestock grazing. The first of which is not from the livestock themselves but rather the dogs that accompany the herds, because they attack red pandas and introduce diseases.[2,11] Dogs are a necessary component of herding because they can control the large herds of livestock and protect them from wild predators.[3,8] However, these dogs will also attack and kill red pandas despite the fact that red pandas only eat bamboo, insects, birds, and small mammals.[3,8,11] Furthermore, herding dogs carry infectious diseases that are transferable to red pandas through contact with the dogs' feces and urine or through a bite.[3,8] One of the most fatal of these diseases is **canine distemper**, which is highly contagious and spread simply through contact with infected bodily fluids.[3] Moreover, livestock grazing results in destruction

of the natural habitat and a reduction in bamboo abundance. Livestock grazing has caused **forest degradation** because the environment cannot sustain the increasingly larger herd sizes.[8] Red pandas and livestock do not compete for the same food, but grazing prevents bamboo from growing to the necessary height for red pandas to eat.[11] Red pandas avoid eating low-growth bamboo because they are vulnerable to animals such as leopards while on the ground. The lack of forest cover that results from overgrazing also results in insufficient shelter to support red pandas.[2] The species' very specific habitat already restricts it to a rather small geographic area, so the loss of habitable land in this area is exceptionally crucial because the red panda cannot live elsewhere.

Figure 3. Cow Farming in Nepal. Courtesy of Punya, 2014, Wikimedia Commons. CC BY-SA 4.0.

Although the presence of livestock has long been believed to reduce the presence of red pandas in locations that are otherwise satisfactory habitats, it was only a hypothesis before a scientific study was conducted to determine if there is **statistically significant** evidence of this being true. In 2014, researchers Hari Sharma, Jerrold Belant, and Jon Swenson collected information on the correlation between livestock presence and red panda presence in Rara National Park in Nepal.[8] The researchers created a grid around Rara Lake in the park that consisted of linear lines intersecting every 500 meters, and at each of the intersections they established ten by ten meter plots that they would survey. The team recorded the appearance of **fecal pellets** from red pandas in each plot to determine if they had been living in the area. They also selected five explanatory variables that could perhaps explain the presence or non-presence of red pandas in each location, and they recorded data on each of these

variables at every site. The five explanatory variables were bamboo presence, elevation in meters, direction of the slope, distance to water, and the presence of livestock.[8]

To build a statistical model, the team first had to check for **multicollinearity** among the explanatory variables because for the model to have high predictive power, no two variables can be highly correlated. Since no two variables had a correlation greater than 0.7 (statistical significance is accepted when $\alpha < 0.05$), statistical models developed from the data can be considered fairly accurate.[8] Using various combinations of the five explanatory variables, the team created models predicting the appearance of red pandas based on the data. Models that included bamboo and elevation had the highest **Akaike model weights**, meaning that they best predicted the presence of red pandas in a chosen plot. Models that included livestock presence less supported the presence of red pandas in a plot.[8] To test whether livestock presence was a statistically significant variable in the models, the team averaged the parameter estimates and 95% confidence intervals from the 16 models tested.[8] The results indicate a 97.7% chance that the presence of livestock in a plot has a negative impact on the probability of red panda presence in an area.[8] This research clearly shows that livestock grazing in an area reduces the presence of red pandas in otherwise suitable habitats that have adequate bamboo resources and are at the correct elevation.

Figure 4. Rara National Park sign written in Nepali and English. Rara National Park is a protected area along the Himalayas. Established in 1976, the park is managed by the Nepalese Department of National Parks and Wildlife Conservation. Courtesy of AdwaitComred, 2014, Wikimedia Commons. CC BY-SA 3.0.

The data provides evidence that the expanding livestock herd sizes in areas of the Eastern Himalayas,

such as Nepal, are harming the red panda population. This issue cannot be easily fixed because the people of Nepal and other neighboring nations depend on livestock for their livelihoods. However, there is an option that could allow for the mutual co-existence of the livestock herds and red pandas. The data from Sharma, H., et al. (2014) also shows that aspect (direction of the slope of the mountain) is a statistically significant variable in the models, and that there is a much lower probability of the presence of red pandas on south-facing slopes.[8] Therefore, if livestock were restricted to grazing zones that are established only on the south-facing slopes of mountains, then the livestock herds would reduce their contact with most of the red panda population.[8] Furthermore, the governments in the region should disseminate pamphlets to villagers to inform them about the effect livestock grazing has on red pandas.[8,10] Another team of researchers in the nation of Bhutan discovered through questionnaire surveys that a majority of villagers in the area were completely unaware that their actions were harming the red pandas.[3] While the implementation of these suggestions may prevent further decline in the red panda population, implementation is unlikely in the Eastern Himalayas because it will be difficult for the governments of this region to cooperate to solve the issue. Although extinction is unlikely in the near future, the red panda will reach record low numbers and will likely be reclassified from a **threatened** to an endangered species.

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2.4 HUMAN-COYOTE (CANIS LATRANS) INTERACTION AND CONFLICT

Ashley A. Neal

The adaptability of coyotes to expanding urban landscapes has brought about much concern over the potential consequences of human-coyote conflict. What is causing the urbanization of the species? What management procedures should be in place to prevent attacks?

Figure 1. A coyote (Canis latrans) along a roadside. Modified from Skeeze, 2008, Pixabay. Public Domain.

Coyotes are among the animal species most equipped for adaption in response to human presence.[5] Gravitating more frequently to suburban and urban areas, sightings of coyotes have increased recently as well as concern over their close proximity to human populations.[1,2,3,4,10] Through adaption to their surroundings, such as avoiding heavily populated areas, using land cover for protection, and adjusting their diet to include human-provided nutrition and other smaller domesticated animals, coyotes have successfully adjusted to human **urbanization**.[4,9] Because of this, the number of **human-coyote conflicts** has risen.[2,3,10] Surveys conducted have highlighted the correlation between a lack of education of coyotes and a high level of apprehension about them, indicating a need for more focused educational awareness in areas where coyote populations are common.[2]

A general trend of coyote avoidance of humans was found by Gehrt, et al. (2009), who studied the activity of coyotes in urban areas.[3] Their study of radio collared coyotes showed that although they used urban land for traveling purposes, they did so nocturnally and in areas with low human activity.[3] Ditchkoff, et al. (2006) explored the issue of behavioral changes in animals that acclimate to living in urban areas.[1] Along with modifying their activity to twilight or night hours, their diet shifted to more human-provided food, such as trash dumps and roadkill.[1] Reproductive adaption of coyotes in response to urban living is another important factor to consider.[1,3] Changes in diet, home range size, and urban noise can all adversely affect the reproductive patterns of coyotes in terms of the success of breeding, the likelihood of finding a suitable mate, and raising offspring.[1]

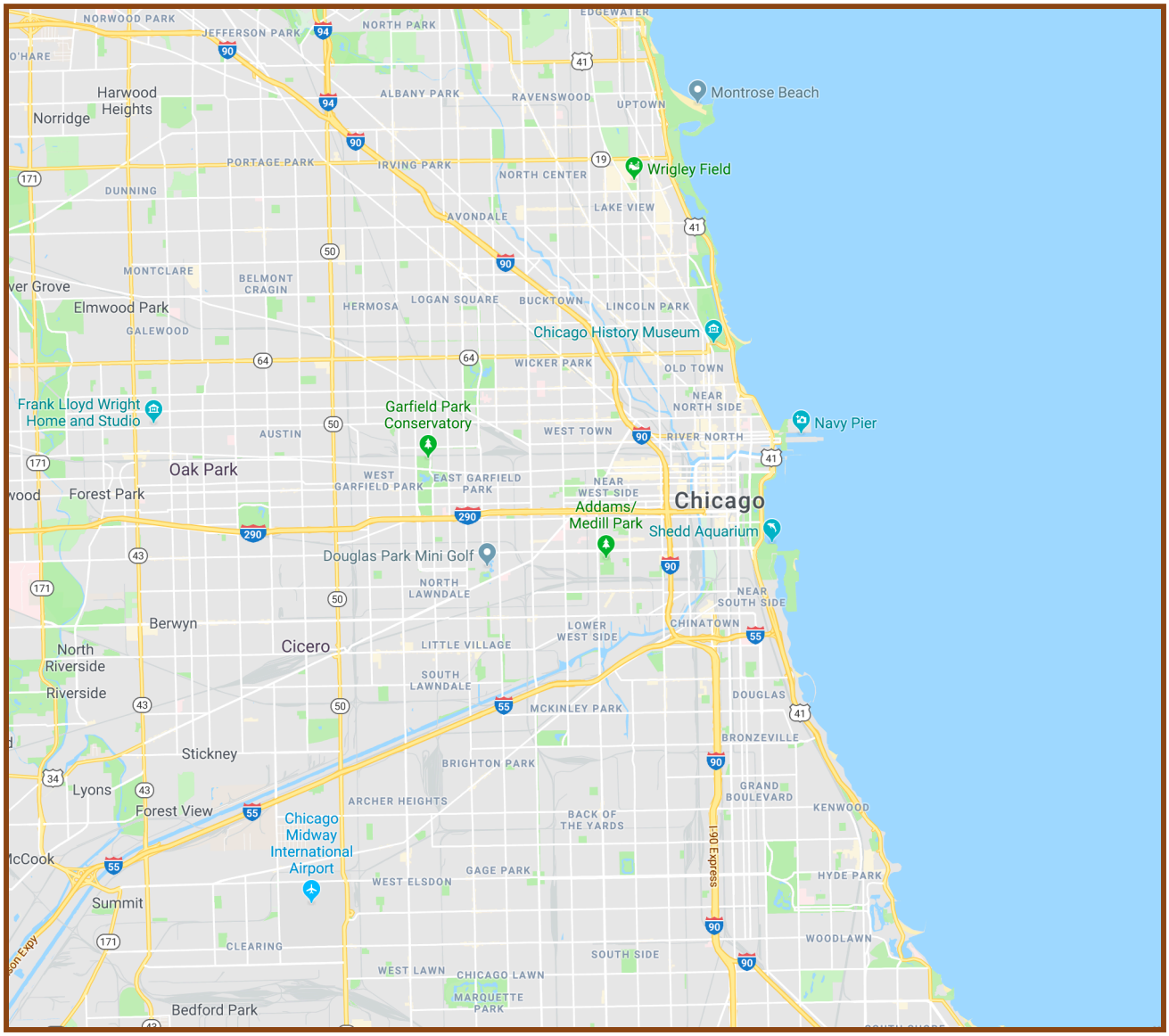

Figure 2. Map of Chicago. Courtesy of Google Maps.

Chicago is one city in which coyotes have pervaded the urban center and established their residence.[3,4,6,10] Gese, et al. (2012) studied the space use of coyotes in urban Chicago and their use of different levels of developed areas (Figure 2).[4] Using radio collars on the coyotes over the course of two years, they found that most coyotes inhabited the less developed areas due to the increased availability of prey and resources, and to avoid humans.[4] Coyotes in developed areas had home ranges twice the size of coyotes in less developed areas, suggesting that they need to cover more space to account for the lower density of prey and necessary resources.[4] These coyotes had home ranges stretching to less developed areas, which supports this notion.[4] The researchers found no differences in the use of urban land between day and night for coyotes, suggesting either human activity constrained coyote activity to strictly **nocturnal** hours, or coyotes used urban land regardless of the **temporal patterns** of human activity.[4] Their use of urban land was restricted to only traveling on paths to less developed areas, showing a deliberate intent to avoid humans.[4,5,9]

More recently, Magel, et al. (2014) used motion-triggered cameras to study coyote distribution and **patch occupancy** in Chicago's urban center (Figure 3).[6] They found that coyotes select habitat

patches based most strongly on canopy cover.[6] Human and pet visitation of the camera sites was found to be negatively connected to patch occupancy and colonization of coyotes, although there was a positive relationship between coyote patch occupancy and the distance to Chicago's urban center.[6] The researchers also found a negative correlation between the housing density and amount of roads of a particular site to colonization that of that site by coyotes.[6] Their results suggest coyotes go to high density areas, such as the urban center, but avoid areas with high human activity, like industrial sites or cemeteries.[6] Their results align with Gese et. al. (2012) in that coyote use of urban land depends heavily on the avoidance of humans and the availability of land cover and resources.[4,6]


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Figure 3. Wildlife Trail Camera. Many studies focusing on coyotes behaviors use trail cameras to track and locate the coyotes in urban areas and at night. Photograph by sandid, 2017, Pixabay. Public Domain.

One important contributor to the species' population increase was the reduction of wolf populations across the country. Replacing the wolf as the apex predator in many ecosystems, and by becoming more of a **mesocarnivore**, coyotes have demonstrated their ability to pervade and thrive within urban human boundaries.[7] Despite this, many challenges still exist on how to handle the increasing human-coyote conflicts and to develop new wildlife management procedures to decrease the risk involved with human-wildlife interactions.[10] One of the most significant risks of the increased interaction between coyotes and humans is the potential for harmful attacks.[10] White and Gehrt (2009) analyzed reports of coyote attacks on humans in the United States and Canada and found that the greatest proportion of attacks were either predatory or investigative.[10] Children made up the greater part of victims and interestingly, children were the victims of predatory attacks significantly more often than non-predatory attacks.[10] This could be a result of various factors, including their smaller size, or it may be due to a child's lack of appropriate awareness of the danger of wild animals as compared to an adult's.[10] One of the most noteworthy findings of this study was that of all the reports analyzed, 30% involved an accidental or intentional feeding of the coyote by a human preceding the attack.[10]

Many methods have been implemented all over the world to handle conflicts with carnivores such as coyotes. These include eradication, **harvesting**, and prevention.[8] Although eradication and harvesting, which is systematic hunting of the problematic species, were effective in decreasing the population of the species, they created imbalance in the local ecosystems by removing key predators needed to manage the populations of other animals.[8] While many species were saved from extinction, the costs of doing so were high.[8] This includes the expenses of managing these populations and dealing with problematic individuals using non-lethal methods such as **translocation**.[8]


COYOTE ALERT
COYOTES HAVE RECENTLY BEEN SEEN IN THIS AREA
SF Parks are an urban refuge for several hundred species of wildlife. You may even encounter a coyote, a native to California and still present in natural areas in the greater Bay Area. Just like the other creatures which live here, coyotes are naturally wary of people but are wild animals and should be treated with appropriate respect. By following park rules, people can co-exist harmoniously with wildlife.
PARK WILDLIFE GUIDLINES
THE PARK'S RULES AND REGULATIONS FUNCTION TO PROTECT PEOPLE, PETS, AND WILDLIFE
Keep your distance from coyotes. Neither adults nor children should approach or feed wildlife of any kind.
Coyotes are typically more active in the evening and early in the morning. You may want to be especially aware during those times.
If you are a pet owner, keep your pet on-leash and under your control when it is outdoors.
If you have an encounter with a coyote within 50 feet please scare off the animal by loud shouting or clapping aggressively.
Report sightings and aggressive behavior to Animal Care and Control at (415) 554-9400 or acc@sfgov.org

Figure 4. Coyotes have been increasingly seen in more public places in the cities. They have been spotted in parks, such as Lincoln Park near Belmont Harbor in Chicago. Now, park goers see coyote alert signs in these public areas. Courtesy of Steve Walling, 2014, Wikimedia Commons. CC BY-SA 3.0.

To minimize the risk involved with the increased interaction between humans and coyotes without jeopardizing the wellbeing of the species, education and awareness about wild animals and actions to take in an encounter with them is necessary. Previous methods of managing the growing population of coyotes, especially in urban Chicago, have had both positive and negative consequences. Further research is needed to find a solution to these human-coyote conflicts.

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2.5 THE IMPACT OF URBAN GREENSPACE ON BIRD POPULATIONS

Kristin J. Harpster

Large cities are often located in areas that are naturally species rich. As urbanization increases globally, what is the impact on biodiversity and species richness of birds? Can cities be designed to preserve biodiversity and the inhabitants learn to coexist with the bird species that dwell in them?

Figure 1. Gardens, foundations, art, and plazas make up the 17 acre Rose Fitzgerald Kennedy Greenway in downtown Boston. Courtesy of Hellogreenway, 2008, Wikimedia Commons. CC BY-SA 3.0.

As nations become more industrialized, cities and urban areas are expanding at a rapid rate. The percentage of the human population living in cities is expected to reach 70% by 2050.[4] Cities are made for the benefit of humans and often have detrimental effects on other species. Large urban areas have become biological deserts, with decreasing biodiversity and fewer native species.[8] All cities have a certain amount of **greenspace**, such as public parks, woodlots, gardens, or just strips of vegetation along roads or highways. These spaces are essential for maintaining **species richness** and biodiversity of modern urban areas.[7] Birds often act as indicators of habitat quality, and are used as a model group to assess the effects of urbanization on the environment.[4]

Large cities are often located in areas that are naturally species rich, which allow urban areas the potential to have significant impacts on biodiversity in the region.[1,3] This enhances the responsibility of **urban planning** in designing cities that are environmentally sustainable as well as convenient for the human residents of the city. In Stockholm, Sweden, areas of vegetation have been found to be nesting and breeding locations for seven forest bird species on the national **red list**.[7] This demonstrates the environmental importance of creating and sustaining similar areas. Not only do greenspaces have value for birds and other wild animals, they also provide health benefits to the humans.[2,3]

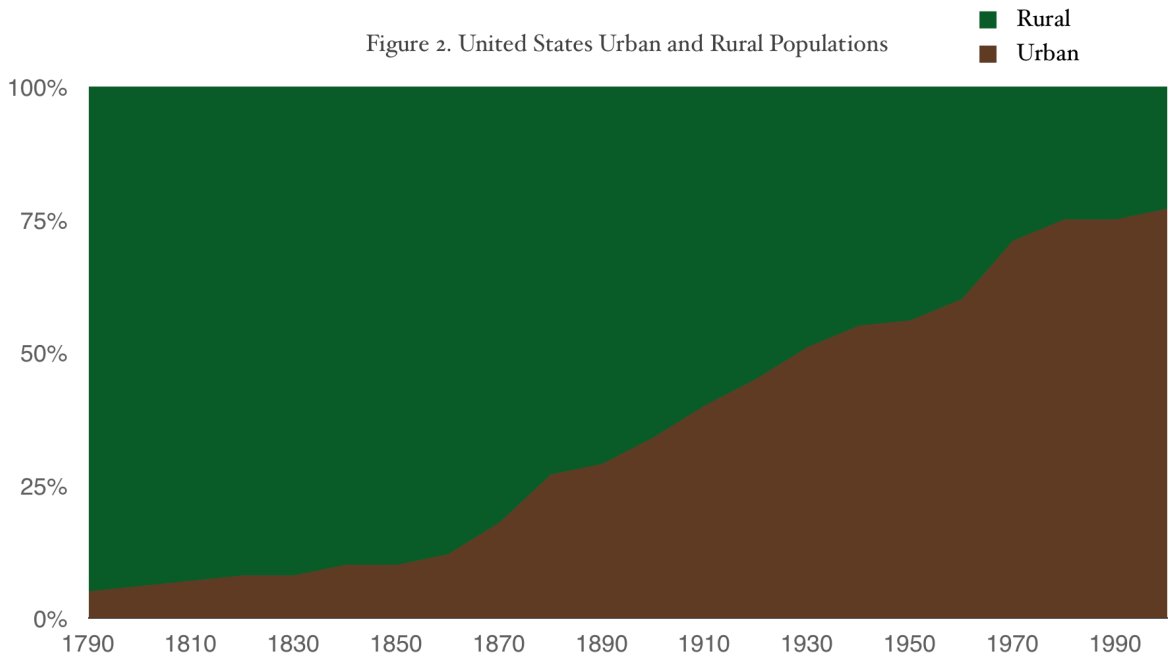

Figure 2. The United States Census Bureau completes statistical analyses on the country's populations. The urban population of the United States reached over 50% in the mid 1900's, and continues to grow. The world's urban population is also growing rapidly. Data obtained from Historical Statistics of the United States, U.S. Census. Public Domain.

One challenge of creating and maintaining greenspace is the limited amount of area in a city. **Urban sprawl** is a common response to create more land area in major cities, but this can be problematic for bird species. Species diversity and richness is lower in urban areas than rural areas, and the spread of urbanization can decrease potential habitat for native bird species.[9] To avoid urban sprawl, some Swedish cities have adopted the strategy of **compaction** as recommended by the Commission of the European Community. Compaction is building on land already within city limits.[8] This poses another challenge as existing greenspace, other than public parks, may be used for new building locations.

Research has focused on what effects these urban greenspaces have on bird diversity and species richness, and which factors are the most important in providing habitat for birds. There is some variation in the type and size of greenspace being studied. In a study conducted by Carbo-Ramirez & Zuria (2011), the researchers studied small urban greenspaces in Pachuca, Mexico.[2] As many Latin American cities have few and small areas designated for vegetation, the study concentrated on parks, gardens, and **road strip corridors**, each consisting of less than 2 hectares.[2] A study conducted by Ikin et al. (2013) also focused on smaller areas of vegetation.[5] The locations of the experiment were neighborhood **pocket parks** which are common in the city of Canberra, Australia.[5] In Boston, Strohbach et al. (2013) studied the effects of the city's greening program by surveying the new greenspaces created by the program in contrast to other established areas of vegetation in the city.[9] Boston's "Grow Boston Greener" program gives donations to non-profits for tree plantings, focusing on areas with little to no greenspace.[9]

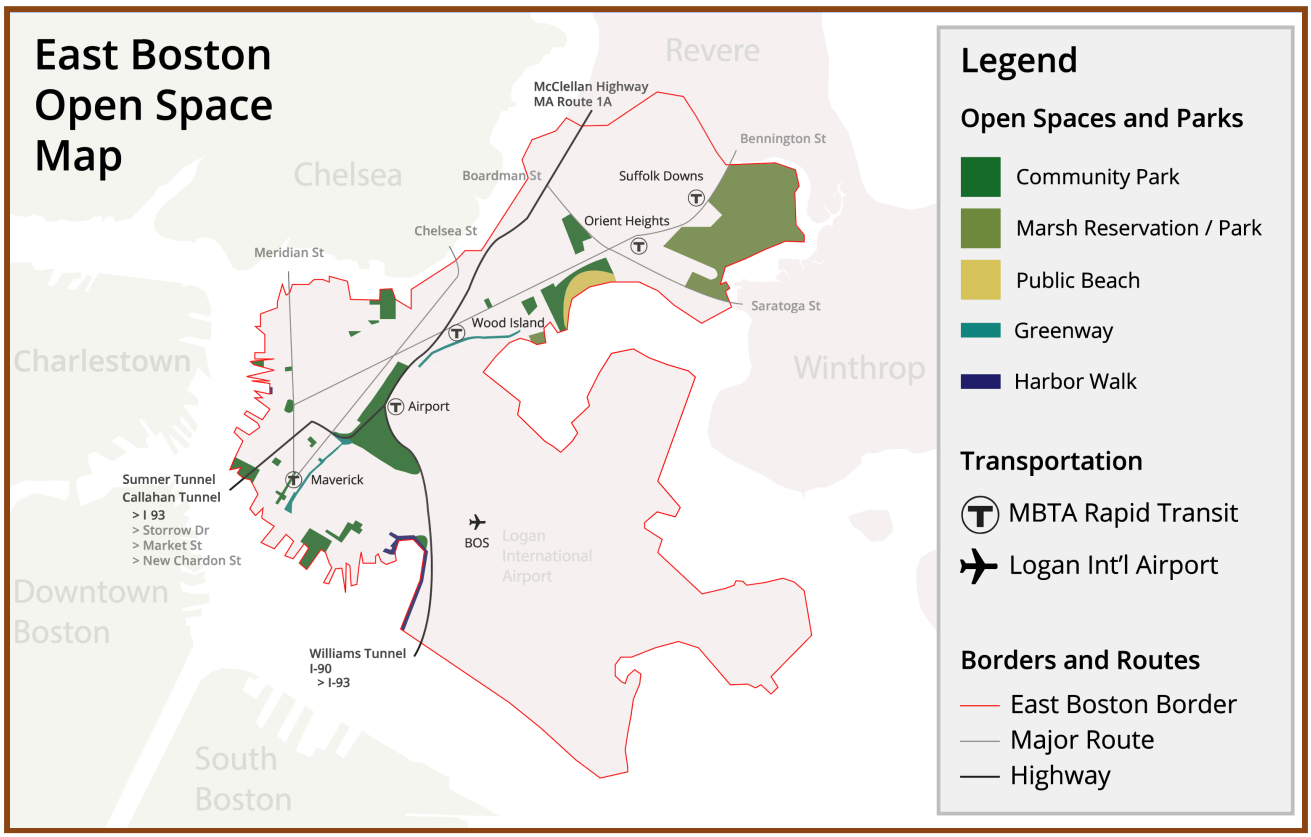

Figure 3. Map of parks and open spaces in East Boston, Massachusetts. Courtesy of MrJARichard, 2014, Wikimedia Commons. CC BY 4.0.

Other studies in urban greenspace did not limit the scope of research to program or size. The methodology of research for these studies included selecting several locations throughout a city, and monitoring of these areas at regular intervals over a period of time. Chosen greenspaces were analyzed for factors that could have potential effects on the bird population. These factors included size and **connectivity**, density of trees and brush, and human disturbance.[2,5,7,8] The most common method used for recording birds in the designated areas was the **point count method**.[2,4,5,8,9] There were several methods used to avoid bias or missed birds during the study period. In the study conducted by Ikin et al. (2013), the sites were not visited in the same order each day, and the studies were repeated on separate days.[5] To account for missed birds, Strohbach et al. (2013) assigned a different observer to the morning and evening shifts, and varied the observers over the two-year study period.[9] The data collected on the number of individual birds and the number of species was then statistically analyzed using a variety of methods. In these studies, birds that were flying overhead without any sign of using the area for nesting or feeding were disregarded.

Research discovered several important factors which make urban greenspaces better habitats for bird species. Size of the greenspace is one of the most important factors in the amount of individual birds and species living in the area.[2,6,7,9] Connectivity, or the amount of nearby habitat for birds, was also found to have an effect on birds.[7] In relation to connectivity, a high number of buildings or increasing **residential density** has a negative impact on bird diversity.[2,5,10] Tree and other vegetation density is also an important variable in bird habitat.[4,5,6,8] The size of the trees and the cavities provided by them also influence bird population.[5,6]

Figure 4. Native East Coast Urban Bird Species. A male Baltimore oriole, a female Hairy woodpecker, and a male Cardinal

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https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=53

can all be found in large east coast cities such as Chicago or Boston. These birds face challenges as urban sprawl grows in these environments. (References below)

There is not a universal solution for the decrease in bird habitat in urban areas. On the individual level, homeowners can take steps such as planting trees and shrubs in their yards to provide nesting places for birds. To promote compaction, zoning laws are suggested which regulate the amount of greenspaces in a city.[8] Boston is home to the "Grow Boston Greener" program, which hopes to grow the amount of **urban forest** in the city from 29% to 35% by 2030.[9] The city of Delhi, India, has an intensive greening plan created by the state government, which has increased the greenspace in the city, even though Delhi is experiencing rapid growth.[6] Further research can be used to improve the quality of the greenspace in urban areas, and to aid in urban planning of future communities in a way that is conducive to improving the habitat quality for birds.

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2.6 THE CONSERVATION OF THE EASTERN MASSASAUGA (SISTRURUS CATENATUS) RATTLESNAKE

Kyleigh T. Godsey

The Eastern Massasauga has been extirpated from much of its historic range due to many anthropogenic threats. Can new research into the causes of decline of the species lead to its recovery? Will new conservation measures preserve the habitat that the species still occupies?

Figure 1. Eastern Massasauga Rattlesnake (Sistrurus c. catenatus) in Ohio. Courtesy of James Chiucchi, 2007, FlickrCommons. CC BY 2.0.

For many species, extinction due to anthropogenic causes is a looming threat. There are many threats that make survival difficult for the animals including habitat destruction, culling or hunting, prey items being killed due to pesticides or pollutants, non-native diseases, or competitors being introduced. For some species, the survival threat was overwhelming and caused their extinction. For others, like the Eastern Massasauga rattlesnake, there is still hope.

The Eastern Massasauga rattlesnake (*Sistrurus c. catenatus*) was originally a subspecies of the more widespread Massasauga rattlesnake (*S. catenatus*), a thick-bodied species of snake which inhabits a large range.[3,8] Through efforts to conserve both this species and its unique genetic mark, the Eastern Massasauga was designated its own species in 2011.[3] These rattlesnakes are considered pygmies when compared to the larger genus *Crotalus*, which are generally longer and rounder.[4,11] Massasaugas typically reach an average length of 52-61 centimeters (20-24 inches).[2,11] The Eastern subspecies has a historical range from eastern Iowa to western New York and from southern Illinois to southern Ontario.[6,11] Despite having such a large range, populations are typically sparse and fragmented, with the majority in decline.[3,6,11]

The major causes of the decline of *S. catenatus* are habitat destruction and road mortalities.[3,6,9,11] The eastern subspecies has been **extirpated** from most of its historical range, now existing in pockets along the Midwest.[1,6,8] In states such as Minnesota, the possibility of a surviving population is **infinitesimal**, whereas Michigan has only experienced a loss of 33 percent of the original estimated population.[1,8]

CAUSES OF DECLINE	CONSERVATION MEASURES
Eradication • People fear the snake and therefore the species if often killed when it appear in areas that people also inhabit. • High mortality rates are often seen near and along roadways.	**Research** • Massasauga habitat use, habitat management, life history and other factors contributing to the snake's population decline are continuing to be studied.
Habitat Loss • Wetlands have been drained that are essential Massasauga habitat. • Fragmentation between habitats caused by urbanization isolates populations.	**Habitat Management** • Management of land is possible while still preserving Massasauga habitat. To achieve this balance, land managers must implement and share these techniques.
Management • The vegetation that makes up Massasauga habitat requires strict management such as prescribed burning and mowing. Invasive plants need to reduced, as well. If these management options are performed at the wrong time, the snakes may be caught in the fire or mowing.	**Education** • Although individuals may be frightened of the species, a strike is usually only seen when the snake is cornered or feels threatened. It is important to educate the public of its important role in the ecosystem, so that they may become more comfortable with the Massasauga.

Figure 2. Causes for Eastern Massasauga decline and management. Data adapted from U.S. Fish and Wildlife Service. Public Domain.[19]

The Eastern Massasauga survives in a variety of habitats including open-canopy forested regions for hibernation season, and wetlands such as shore marshlands, shrubby swamps, and **fens** in their active season.[5,11,12] A seasonal habitat use pattern can be observed, as well as, habitat selection differing by the sex of the snake.[5,12] Different habitats can result in different diets for the Eastern Massasauga.[13] The rattlesnake occupies a predatory niche within each habitat.[12,13] The diet of this species is typically small rodents with **neonates** sometimes preying on other snakes and adults preying on squirrels or rabbits.[8,13] Eastern Massasaugas are preyed upon by raptors, carnivorous mammals, and other snakes.[8]

The destruction of the Eastern Massasaugas' habitat is typically associated with urbanization or agricultural development, which fragments remaining habitats with roadways.[2,11] All reptiles are **ectothermic** or, more specifically, **poikilothermic**, which makes roads dangerous because basking on a blacktop is a quick way for the animals to warm up.[9] Other than providing a hazardous basking spot for the reptiles, roads divide multiple habitats forcing animals to cross at their own peril.[9] For slow-moving rattlesnakes such as the Eastern Massasauga, this poses an even greater risk.[9,11] A study conducted in reptile road mortality showed that there is a correlation between the number of deaths and the time of year in which the snakes are traveling.[9] In mating season (August and September), males are typically killed more often.[9,11] In the spring months, when Eastern Massasaugas move from their **hibernacula** to their summer habitats, there is also a spike in road related mortalities.[9] While road sign indicators do not seem to help, reducing speed limits along roads within close proximity to high or medium-level Eastern Massasauga habitat may help drivers avoid hitting the snakes.[9] Other solutions could involve making a passage beneath the road for the snakes, as well as other reptiles to use, but this also has its own risks such as an increased threat of predation.[11]

Along with the fragmentation of habitats on the small scale, the Eastern Massasauga is also

fragmented in population.[2,3,4] For most species, this is a cause for concern as it limits the gene pool of each population and **deleterious** genes can arise through inbreeding, a major pitfall for many endangered species.[4] However, in a study conducted on small Eastern Massasauga populations, it was found that their numbers have not been greatly affected by inbreeding, and there is little evidence to suggest any negative effects have arisen.[4] This may be because Eastern Massasaugas have historically low migration rates, thus making these isolated populations less at risk due to their secluded locations.[3]

An interactive or media element has been excluded from this version of the text. You can view it online here:
https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=55

Figure 3. Eastern Massasauga Rattlesnake Research.

Image 1: Eastern massasauga numbers are being monitored across the midwest, as the species has critically declined. The U.S. Fish and Wildlife Service works to complete surveys of the rattlesnakes to better manage their habitats and populations.

Image 2: To trap snakes, fences may be constructed to contain the snakes. The fences are temporary and guide the snakes to an area accessible by the researchers.

Image 3: Because the massasauga is a poisonous reptile, precautions must be taken when in close contact. Tools such as this are used by wildlife biologists to collect the snakes.

Image 4: An eastern massasauga rattlesnake captured from a survey is placed in a cloth bag for transport.

(Reference below)

Habitat destruction continues to disrupt Eastern Massasauga populations.[1,3,4,11] Wetlands have been historically drained for agriculture in the Midwest, reducing the amount of space which these snakes can use for their summer hunting grounds.[10,11] Non-native species of plants also pose a threat to the snakes' open-canopy preference in forests.[10] The Eastern Massasauga relies on these open canopies for sunlight, which gives the forest floor spots of warmth helping snakes regulate their body temperatures.[10,11] With foreign shrubs now growing in these patches, the amount of basking locations is reduced.[10] For the **viviparous**, **gravid** females, this could threaten survival rates when overwintering, if the neonates and mother cannot find adequate hibernacula.[10,11]

While steps should be taken to preserve the habitats in which populations of Eastern Massasauga survive, another approach, reintroduction, could help increase the numbers of this species. In a **repatriation** study, gravid females were removed from one stable population to give birth.[7] Their neonates were raised in captivity while half, along with their mothers, were returned to their original population.[7] The remaining neonates were released at a restored habitat which historically supported Eastern Massasauga populations.[7] An autumn clutch was released as well as a summer group.[7] While there were high mortality rates for each group, this study aligned with prior studies of mortality among wild Eastern Massasaugas, suggesting that this method of repatriation, rather than transplanting populations, could be an effective tool to help repopulate former Eastern Massasauga habitats.[7]

While efforts to save this declining species have had some success, there is still much to be done. Preserving natural habitats as well as rehabilitating old historical habitats will create more spaces for the species to occupy, thus reducing the risk of a **bottleneck effect**.[3] Educating the public not only about the rattlesnakes and their importance to the ecosystem, but also on how to react when one is discovered while camping, hiking, or on one's own property could significantly reduce the risk of mortality due to human exposure and prevent humans from being bitten. Educational outreach may help to preserve this species and create a more positive reaction with the public when increased repatriation attempts are pursued.

Figure 4. Eastern Massasauga Rattlesnake warning sign placed on a boardwalk in Cedar Bog Nature Preserve. Courtesy of Dakota Callaway, 2012, FlickrCommons. CC BY 2.0.

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POLLUTION

Courtesy of alinajyrkinen, 2016, Pixabay. Public Domain.

3.1 POLYCHLORINATED BIPHENYLS IN WATERS PRESENT HEALTH RISKS FOR ORCAS

Rachel E. J. Dalke

Orcas are just one of the most recent species to be affected by PCBs. What are PCBs and how are they entering water systems? How serious is it and will it affect the overall Orca population?

Figure 1. Orcas jumping from water. Courtesy of Robert Pittman, NOAA, 2006, Wikimedia Commons. Public Domain.

The killer whale (*Orcinus orca*) has long been an icon used in promoting environmental movements aimed at protecting Earth's oceans. Located in few areas, their populations are dwindling and at risk

of being extirpated. Numerous studies have been conducted along the west coast of North America to discover why the populations are suffering.[1,3,4,5] These studies focus on the three main groups of orcas living in the Northeastern Pacific Ocean: northern residents, southern residents, and transients.[1,3,4,5] These whales make their home in waters ranging from the coasts of Oregon to British Columbia, and during migration, their habitat extends down to the southern tip of California.[4] Scientists researching their behavior have used data from different groups of whales throughout these three groups and have combined results to make generalizations about their behavior and health. However, due to the limited number of orcas and their restricted habitat, they are difficult to locate and study.

Southern resident whales have been listed as endangered under the U.S. Endangered Species Act (ESA), and both the southern resident and northern resident whales have been listed as endangered under the Canadian Species at Risk Act (SARA).[1,3,4,7] Transient whales are listed as threatened under SARA.[1,4] A major reason for these classifications is due to contamination from **polychlorinated biphenyls** (PCBs), which are fat soluble synthetic organic compounds that accumulate in animal fat tissue.[9] Killer whales are just one species specifically and heavily impacted by PCB contamination and they are among the most PCB contaminated marine mammals in the world.[3]

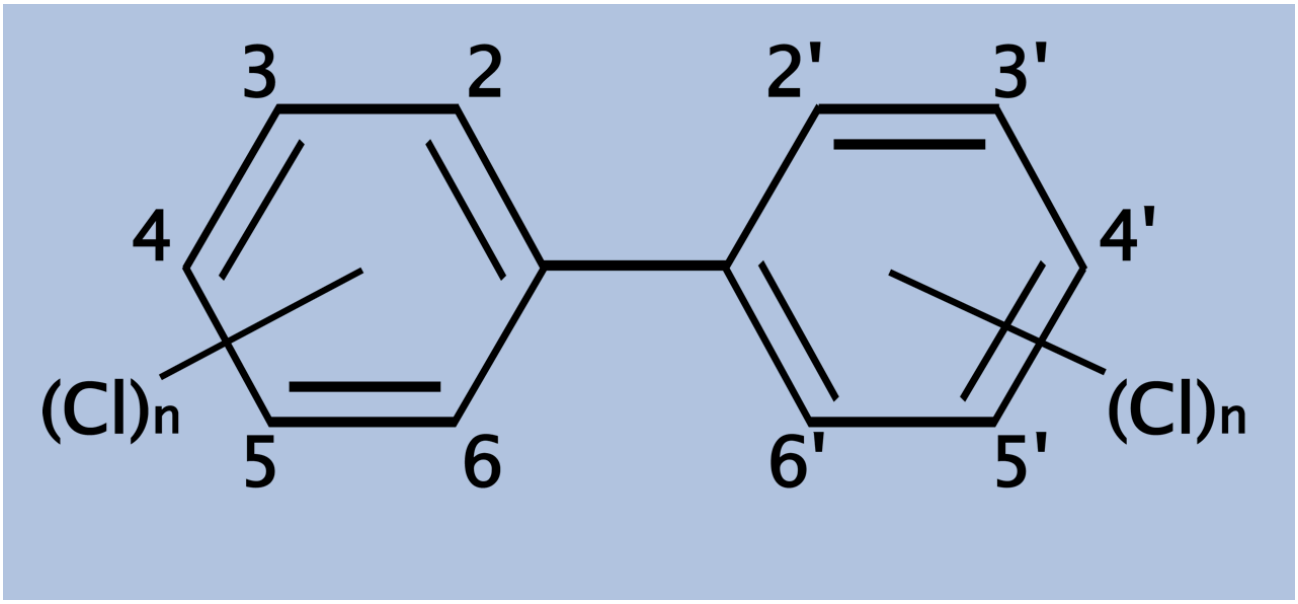

Figure 2. Chemical structure of polychlorinated biphenyl. Courtesy of D.328, 2006, Wikimedia Commons. CC BY-SA 3.0.

PCBs are **synthetic** compounds once used in industrial coolants and as insulators for numerous types of electrical equipment, as well as in the making of many plastics.[9] The compound itself is composed of two benzene rings and several chlorine atoms (Figure 2).[9] In the past, manufacturing plants would purposefully discharge PCB-contaminated waste into nearby waterways, polluting the surrounding environment. Eventually PCB's hazardous attributes were realized, and their production was banned by the United States Congress in 1979.[9] Despite this ban, PCB-containing materials still leak from waste management facilities and other contaminated sites.[2] There is significant evidence from numerous studies that indicate PCBs are a significant threat to both humans and wildlife.[6]

PCBs are "one of the most widely studied environmental contaminants."[9] According to the **US Environmental Protection Agency** (EPA), PCBs have been demonstrated to cause numerous health problems, including, but not limited to, effects on the immune system, nervous system, endocrine system, and reproductive system.[9] The EPA has conducted several studies on the potential effects of

PCBs as a carcinogen, and according to their research, "studies in animals provide conclusive evidence that PCBs cause cancer."[9]

Figure 3. Environmental awareness sign against PCBs. These signs must be attached to equipment that tests positive for the chemicals, as PCBs pose numerous health risks to individuals if they are exposed. Photograph courtesy of Bob Harvey, CC BY-SA 2.0.

Along with many other fat soluble synthetic compounds, PCBs are persistent pollutants, and are still present in marine environments, 30 years after being banned.[2] Fat soluble toxins are particularly problematic for mammals in higher trophic levels due to **bioaccumulation** and **biomagnification**, or the increase in concentration and toxicity as one travels higher up in the food chain.[1,3,5,8,9,10] Results from research have shown that elevated PCB concentrations observed in killer whales are likely a result of their ingestion of highly contaminated prey.[5] Scientists studying the relationship between PCBs and marine mammals have presented two main problems: "(1) how to characterize current health risks associated with contaminant exposure, and (2) how to determine the extent to which contaminant inputs into their [marine mammal] habitat must be reduced to protect their health."[3] By studying its prey, scientists are able to see how contaminants move up the food chain and bioaccumulate in the killer whale, which is the apex predator of its food chain.[2] The variation in PCB concentrations caused by **environmental degradation**, and as a result, concentration levels at the time the chemicals were released into the environment, is drastically different from the concentration after they have been present in the water for a period of time.[10] Studies have shown that a large percent of killer whale populations have already surpassed their contamination threshold.[1,3,4,5]

To examine PCB levels in killer whales, scientists collected and examined blubber samples from whale communities living in polluted waters.[1,5] In one study, a lightweight dart system was designed to take small skin samples from whales to see PCB levels in fat tissue, where it is known to accumulate

due to its hydrophobic nature.[5] These blubber biopsies were examined at a microscopic level for DNA research on the impacts of PCBs.[5] DNA in these samples have shown changes in mRNA transcript abundance, and further research on this by another group of scientists found a positive correlation between the concentration of PCBs in fat tissue and the relative abundance and behavior of mRNA in killer whale genes.[1] This influence on mRNA is extremely important in understanding how such a small compound can have such a massive impact on an organism's ability to function properly. Proteins in cells perform their proper biological function through coiling and folding into a specific three-dimensional shape, and disruption of this process manipulates the regulated release of hormones in an organism.[10] Because of this disturbance, PCB is known as an **endocrine disruptor** that has serious effects on an organism's overall biological function.[8] In a 2011 study, statistical analyses were performed for a **null hypothesis** of no correlation existing between concentration levels of PCBs in fatty tissue and mRNA protein folding.[1] A **probability value** (p-value) was set at 0.05 (5%) to determine significance of the results.[1] Their analysis revealed a p-value of $p < 0.001$ ($p < 0.1\%$) for five different types of mRNA examined, and therefore the null hypothesis was rejected in favor of the alternate hypothesis.[1] Through rejection of the null hypothesis, this study shows the relationship between the concentration of PCBs in tissue and protein folding, and furthermore, demonstrates how PCBs can manipulate biological functions at the cellular level.[1]

Through studies scientists found that PCB levels vary in killer whales depending on age and the levels of contamination can vary from the highest point to the lowest point measured in just one year.[5] Whales in different stages of life have been shown to have varying PCB levels.[5] Scientists have used data of PCB levels in fat tissue of whales to show points in their lives when their fluctuating levels of contamination reach peaks as well as the general progression they follow throughout an average life span. Due to breast milk from female whales being high in fat and PCBs being fat soluble, breast milk has a high toxicity and there is a spike in PCB contamination level for whales at a very young age.[5] After a calf is weaned, the contamination level drops, but then slowly climbs again as a result of bioaccumulation in their food source.[5] Studies have also shown that males become increasingly contaminated as they grow older, while females pass contaminants to offspring during pregnancy and while nursing.[5]

Figure 4. This male Orca whale, located in Friday Harbor, Washington is a member of the L pod of Puget Sound. Courtesy of Erik Stockdale, 2009, Wikimedia Commons. Public Domain.

Detailed research has shown high levels of PCBs impede normal growth and development by hindering reproductive development through manipulation of the endocrine system, changing immune function, and increasing vulnerability to disease and other health problems. For example, studies of whale family trees of whales in Puget Sound (Seattle, Washington) show a growing number of stillborn births and premature deaths in orca populations, both of which are problems likely caused by PCBs. In this area, 7 whales died in one year, which brought their population down to only 86 individuals.[8] If this population decline continues, killer whales are expected to be locally extinct in just twenty years.[8] As an **indicator species**, the current condition of killer whales is important in relation to the overall health of the environment, and trouble for killer whales implies trouble for other marine species.[7] PCBs are likely the number one **persistent pollutant** in the northern hemisphere.[8] Killer whales are only one of many marine mammals impacted by PCBs, and although these toxins are persistent pollutants, steps can and should be taken to save the remaining whales and protect the lives of new whales being born into polluted waters.

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3.2 OCEAN PLASTIC DISAPPEARANCE PRESENTS UNTOLD DAMAGE TO SEA LIFE

Tiana L. Ahmed

One of the largest collections of human waste, the Great Pacific Garbage Patch, is affecting ocean life. Plastics in the waste are breaking down into small beads and are consumed by marine creatures. Will international action occur to reduce this waste and prevent further harm to these species?

Figure 1. Plastic waste washed up on the coastline. Courtesy of Justin Dolske, 2016, FlickrCommons. CC BY SA 2.0.

Through years of overconsumption, humans now face the large problem of how to efficiently reuse and

dispose of the seemingly endless amount of waste. When garbage is improperly disposed of, objects are often found stuck in trees, consumed by wildlife, or floating in bodies of water. One of the largest collections of human waste affecting ocean life is the Great Pacific Garbage Patch.[7]

First discovered by Charles Moore in 1997, the Great Pacific Garbage Patch is a **gyre** of marine debris that traps primarily human garbage.[5,6,8,9] This patch was created by garbage sucked directly into the ocean or through smaller bodies of water. There are several gyres labeled garbage patches in Earth's oceans, and while they are difficult to measure, the Great Pacific Garbage Patch remains the largest known patch with a size larger than the state of Texas.[3] Most think of the garbage patch as a blanket of trash that can be easily collected, however the area is in constant motion and changes with the ocean **currents**.[7] Scientists have estimated the mass of the patch at 3.5 million tons, and it is mostly composed of millions of pieces of **microplastic** trapped in a vortex of water.[9] Ocean currents follow a very circuitous route, taking five years for a piece of trash to exit the gyre.[9]

The presence of the debris already poses a danger to marine life since the floating plastic primarily consists of **polyethylene**, **polypropylene**, and other toxic pollutants, ranging from polychlorinated biphenyls (PCBs) to mercury, that cling to the object's surface.[2] The problem with plastic is that it does not **biodegrade**, but rather breaks down into increasingly smaller pieces.[9] Marine life confuses the microplastic with food and scientists have found that nearly 50% of fish being examined contain plastic in their stomachs.[9] The larger pieces of garbage are also being consumed by wildlife. This is evident on the island of **Midway Atoll**, which is known as an albatross graveyard, for upon opening the stomachs of dead albatross', scientists have consistently found large quantities of garbage in their system (Figure 2).[1,6]

Figure 2. Albatross chick at Midway Atoll Refuge. Albatross feeding grounds have become littered with waste, specifically plastics. As the albatross feed, they mistakenly consume these larger pieces of plastic. Plastics are also fed to chicks by parents, as can be seen by examining the stomach contents of this deceased Albatross chick. Photograph by Chris Jordan, 2009, FlickrCommons. CC BY 2.0.

Recently, a new study has found that 99% of the ocean's plastic is missing.[2] **The National Academy of Sciences** estimates that of the 300 million tons of plastic humans produce each year, only 0.1% washes into the oceans.[2] To track this garbage, four ships of the Malaspina expedition, fished for plastic among the main five subtropical gyres believing that they would uncover millions of tons of debris.[2,3] However, much less plastic was discovered.[2] Based on their collection, the researchers calculated that the global sum of plastic in the oceans equated to 40,000 tons.[2,6] This discovery failed to answer where the is plastic going. The plastic is somewhere, either ingested by ocean life, in the depths of the ocean, or broken down into fine particles undetectable by nets.[2,8]

Many studies conducted have begun to trace the disappearance of microplastic due to its consumption by fish. The most frequent plastic size ingested by fish in all studies examined was between 0.5 and 5 mm.[3] This ingestion has detrimental effects to fish populations due to the contents of the plastic. The Malaspina expedition's analysis confirmed the identity of all the plastic particles collected, and polyethylene was found to be the most common polymer type.[3] This polymer composes 29% of plastic production globally.[10] These plastic contents are known to affect the liver and induce **hepatic stress** in fish.[10] Another concern with the consumption of toxic plastic debris is the affects it will have on the food chain. **Pesticides** and organic pollutants such as polychlorinated biphenyls (PCBs) are consistently found attached to plastic waste at harmful concentrations; 100 times those

found in sediments, and 1 million times those occurring in sea water.[11] These chemicals disrupt the main biological processes such as cell division and immunity, which may cause disease, reduce an organism's ability to escape from predators, or affect reproduction.[11] Other organisms connected to the ocean, such as seabirds, have consumed plastic waste and have PCBs in their tissues at 300% greater concentrations than in those that have not eaten plastic.[11] The food chain is also harmed by the imbalance between predator and prey. Recent evidence suggests that the sea skater (*Halobates sericeus*) is utilizing floating debris as a new protective solid to lay eggs.[4] With more opportunities to lay eggs, the sea skater population will increase, and may lead to the depletion of the plankton they feed on, disrupting the food chain.[4]

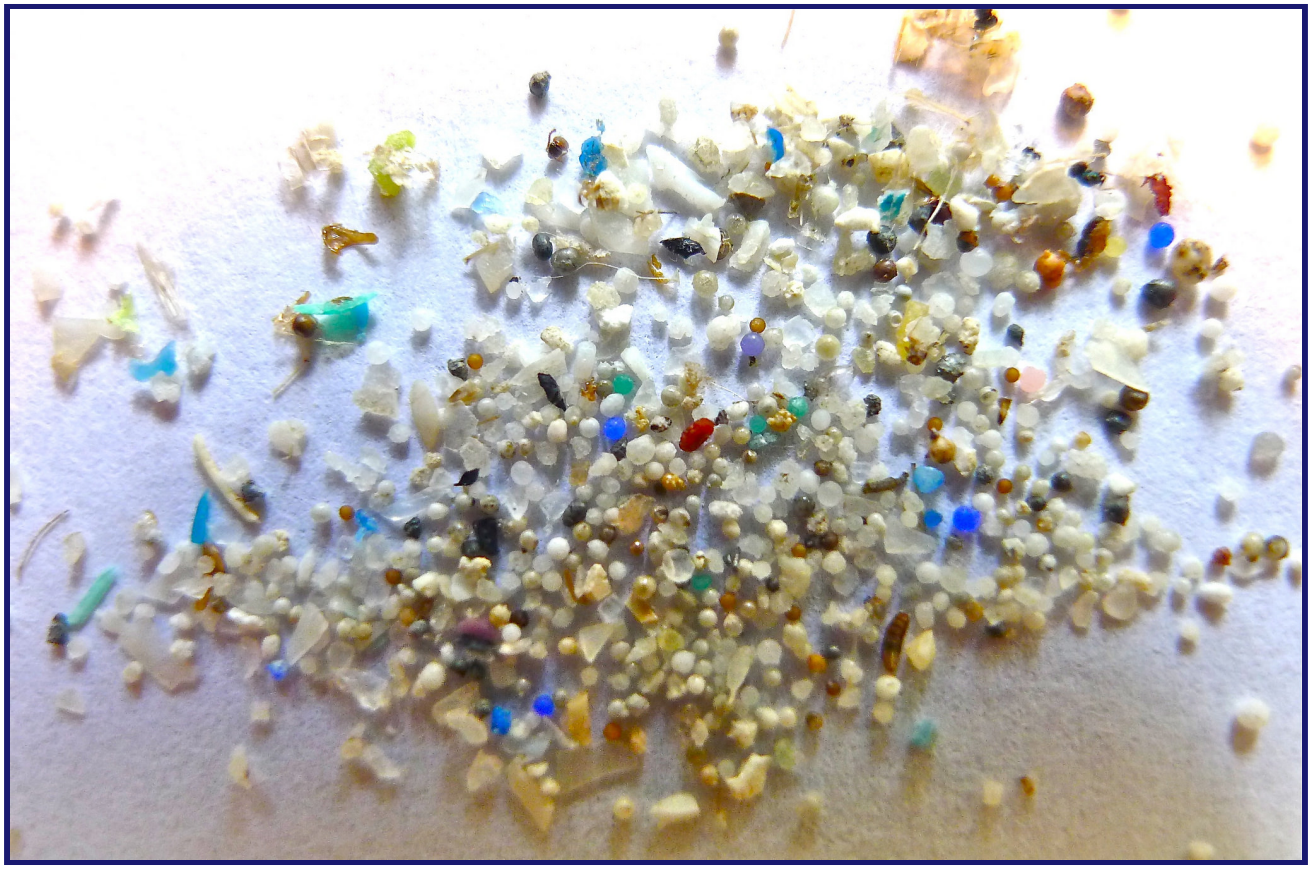

Figure 3. Microplastics occur when large pieces of plastic waste degrade and break down. A piece of plastic is classified as a microplastic when it is less than 5 millimeters long. These small plastic pieces originate from a variety of plastic products. Despite their small size, they can still be extremely harmful when ingested. In formal studies, scientists have found that nearly 50% of fish examined have plastics within their stomachs. Courtesy of 5Cyres, 2012, FlickrCommons. CC BY-SA 2.0.

Another explanation for the disappearance of plastic in the oceans is that the microplastic debris is falling to the ocean floor.[2,3,6] The plastic fragments ingested by small fish can be transferred to larger predators, sink with the bodies of dead fish, or be defecated.[3] Deep-sea marine life may be enduring long term harms that humans have yet to discover, since much of the ecosystem is too deep to be thoroughly researched.

The issue of microplastic plaguing the oceans needs to be addressed at an international level. **The International Convention for the Prevention of Pollution From Ships** (MARPOL) was signed in 1973, although a complete ban on the disposal of plastics at sea was not enacted until the end of 1988.[11] Despite 134 nations agreeing to eliminate plastic disposal at sea, governments have struggled for decades to reduce dispersion of plastic debris and oceanic sampling suggests that the problem has

persisted or worsened since MARPOL was signed.[11] Despite numerous studies, the long-term issue remains that scientists cannot trace where all of the plastic particles have moved and therefore cannot collect all the particles that filter into the ecosystem. The only way to prevent future harm to marine life is to reduce human consumption and enact better disposal methods. If it is not possible to reverse the damage that has been done, prevention needs to start at the source.

An interactive or media element has been excluded from this version of the text. You can view it online here:
https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=61

Figure 4. Garbage Patch Visualization Experiment. Courtesy of Greg Shirah and Horace Mitchel, NASA Scientific Visualization Studio. Public Domain.

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3.3 PLASTIC CONSUMPTION LINKED TO HIGHER MORTALITY AND TOXIC TRACE ELEMENT LEVELS IN ALBATROSSES

Plastic consumption linked to higher mortality and toxic trace element levels in Albatrosses

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Abstract

For over fifty years now numerous tons of plastics have been building up in the world's oceans causing both Black-footed and Laysan Albatrosses to consume mass quantities at Midway Atoll in the North Pacific Ocean.[3] Studies done by the Institute for Marine and Antarctic Studies in Australia have shown that high concentrations of many toxic trace elements including lead, chlorine, and iron are occurring in these seabirds due to their consumption.[5] Further studies have shown that the plastics present in the Albatrosses tend to cause physical damage to internal organs and trigger inaccurate sensation of fullness leading to nutritional deprivation.[4] Recently deceased Albatross fledglings were collected around the Midway Atoll during the month of June and autopsies were performed in order to remove ingested plastic and breast feathers. The feathers were placed in acid to determine the concentrations of trace elements using a PerkinElmer ELAN DRCII Inductively Coupled Plasma Mass Spectrometer (ICP-MS). Linear regression was then used to determine the relationship between the concentrations of trace metals and the amount of plastic ingested.[5] Results showed that low chick survival rates were strongly related to the concentrations of trace metals, specifically lead, detected in feathers beyond 4 µg/g. The average albatross examined surpassed the Ecological Quality Objective (EcoQO) with at least six times the amount of plastic considered acceptable, making up about 8.4% of each bird's body mass.[5] These high concentrations and large ingestion volumes have reduced fledgling weights and survival to around 5.7%. The results indicated that increased plastic consumption in albatrosses leads to higher concentrations of toxic trace elements contributing to lower chick survival rates and an overall lower population.[5] The plastic present in these seabirds also takes up a significant amount of space in their bodies, reducing the space available for nutrient rich foods.[1,3,4,5,6]

Plastic in Decaying Albatross

Figure 1: This picture shows a Laysan Albatross carcass decomposing at Midway Atoll. Note the immense amount of plastic present in this seabird in relation to its size.[7]

Hotspots for Waste

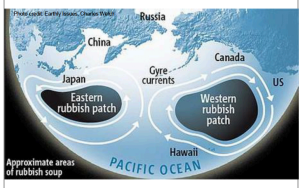

Figure 2: Shown here is what is commonly referred to as the Great Pacific Garbage Patch. This is a gyre of marine debris that encompasses much of the North Pacific Ocean, including Midway Atoll.[8]

Introduction

Plastic production and waste have been increasing at alarming rates in the past few decades and its effects can be directly observed in Albatrosses at Midway Atoll.[1] Albatrosses are especially susceptible to ingest plastic due to the chemical DMS that is emitted by the plastic after exposure to salt water for less than one month.[2] This chemical tricks the Albatross into thinking the plastic is food and thus is ingested by the seabird. When enough plastic starts to build up in the bird's stomach, it will prevent them from consuming nutrient rich food and trick them into thinking they are not hungry. While in the Albatrosses body, many plastics will bond to other pollutants present and increase their concentration to upwards of 106-fold.[3] These extreme concentrations and leaching toxins often lead to organ damage and eventual death.[4] [1,2,3,4]

Top Producers of Waste

Figure 3: This countries filled in with pink represent the top 10 producers of the ocean's plastic waste. Although the majority of these countries are in the Eastern hemisphere, there waste travels around the globe. Figure adapted from Parker, Laura (February 13, 2015) National Geographic.[9]

Results

Numerous studies have been conducted examining the effects of plastic on black-footed and Laysan Albatrosses. Several of these studies have shown that survival rates of juvenile seabirds have decreased due to the toxins present in plastics typically leading to decreased weight of fledglings.[4] Concentrations of toxic trace elements such as iron and chlorine have been observed at high concentrations in Laysan Albatrosses especially in relation to the amount of plastic ingested. Large amounts of plastic consumption often led to starvation and ruptured organs in observed Albatrosses.[5] Increased levels of polychlorinated biphenyls (PCBs) and long chain perfluoroalkyl acids (PFAAs) have shown higher bioaccumulation values and indirect contributions to the mortality of the seabirds.[6, 4,5,6]

Plastic as Number One Threat to Chicks

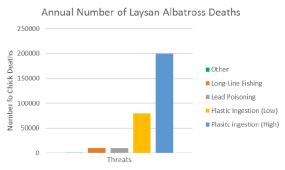

Figure adapted from William Foster

Figure 4: This graph shows the number of Laysan Albatross chick deaths in relation to their biggest threats to their survival. This graph shows just how much of an impact plastic consumption has on survival of the Laysan Albatrosses.[10]

Surface Level Ocean Pollutants

Figure 5: This image highlights just how extreme the issue of plastic is in the ocean. Thousands of micro plastics also exist just below the surface and all throughout the ocean.[11]

Conclusion and Discussion

Plastic production is at an all time high and if we do not cut back on the waste produced or find a new solution more and more species will be affected.[1] We are already seeing a decline in survival rates and overall population for Albatrosses indicating that some sort of action needs to be taken.[5] Unfortunately due to the fact that the ocean is not stagnant and debris can travel anywhere in the world, it is going to take the cooperation of the whole world to solve this issue.[6] It is not enough for a few countries to decrease plastic waste, everyone must be on board. The chemicals and toxins present in the Albatrosses and various other species due to plastic consumption has already started to bioaccumulate in the food chain and will eventually start to affect humans.[6, 1,5,6]

Trace Element Concentrations

Figure adapted from J.L Lavers

Element	µg/g ± S.D.
Mercury (Hg)	1.74 ± 0.66
Lead (Pb)	1.61 ± 3.39
Cadmium (Cd)	0.08 ± 0.09
Arsenic (As)	0.06 ± 0.07
Manganese (Mn)	0.72 ± 0.96
Iron (Fe)	46.34 ± 85.32
Zinc (Zn)	66.16 ± 19.01
Bromine (Br)	40.21 ± 10.83
Rubidium (Rb)	0.09 ± 0.07
Strontium (Sr)	5.68 ± 3.72
Silver (Ag)	0.04 ± 0.17
Calcium (Ca)	682.02 ± 386.04
Chlorine (Cl)	7913.90 ± 3017.13

Figure 6: This figure represents the various trace element concentrations found in Laysan Albatrosses. The data was collected from juvenile Albatross feathers during a 2012 study. Figure adapted from Lavers, J.L. (September 15, 2016) Marine Pollution Bulletin.[5]

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Poster by student author Katie A. Quinlin.

Plastic waste affects a plethora of marine and terrestrial organisms. In the previous section you learned about one affected seabird, the albatross.

Read the entire transcript of the poster below to discover more about how the consumption of plastic materials is altering the albatross' life cycles.

Abstract:

For over fifty years now numerous tons of plastics have been buildings up in the world's oceans causing both Black-footed and Laysan Albatrosses to consume mass quantities at Midway Atoll in the North Pacific Ocean. Studies done by the Institute for Marine and Antarctic Studies in Australia have shown that high concentrations of many toxic trace elements including lead, chlorine and iron are occurring in these seabirds due to their consumption. Further studies have shown that the plastics present in the Albatrosses tend to cause physical damage to internal organs and trader inaccurate sensation of fullness leading to nutritional deprivation. Recently decreased Albatross fledglings were collected around the Midway Atoll during the month of June and autopsies were performed in order to remove ingested plastic and breast feathers. The feathers were placed in acid to determine the concentrations of trace elements using a PerkinElmer ELAN DRCII Inductively Coupled Plasma Mass Spectrometer (ICP-MS). Linear regression was then used to determine the relationship between the concentrations of trace metals and the amount of plastic ingested. Results showed the low chick survival rates were strongly related to the concentrations of trace metals, specifically lead, detected in feathers beyond 4 ug/g. The average albatross examined surpassed the Ecological Quality Objective (EcoQO) with at least six times the amount of plastic considered acceptable, making up about 8.4% of each bird's body mass. These high concentrations and large ingestion volumes have reduced fledging weights and survival to around 5.7%. The results indicated that increased plastic consumption in albatrosses leads to higher concentrations of toxic trace elements contributing to lower chick survival rates and an overall lower population.6 The plastic present in these seabirds also takes up a significant amount of space in their bodies, reducing the space available for nutrient rich foods.

Plastic in Decaying Albatross:

Figure 1: This picture shows a Layman Albatross carcass decomposing at Midway Atoll. Note the immense amount of plastic present in this seabird in relation to its size.[7]

Hotspots for Waste:

Figure 2: Shown here is what is commonly referred to as the Great Pacific Garbage Patch. This is a gyre of marine debris that encompasses much of the North Pacific Ocean, including Midway Atoll.[8]

Introduction:

Plastic production and waste have been increasing at alarming rates in the past few decades and its effects can be directly observed in albatrosses at Midway Atoll.[1] Albatrosses are especially susceptible to ingest plastic due to the chemical DMS that is emitted by the plastic after exposure to salt water for less than one month.[2] This chemical tricks the Albatross into thinking the plastic is food and this is ingested by the seabird. When enough plastic starts to build up in the bird's stomach, it will prevent them from consuming nutrient rich food and trick them into thinking they are not hungry. While in the Albatrosses body, many plastics will bond to other pollutants present and increase their concentration to upwards of 106-fold.3 These extreme concentrations and leaching toxins often lead to organ damage and eventual death.[1,2,3,4]

Top producers of waste:

Top 10 source of ocean's plastic waste: 1. China 2 Indonesia 3. Vietnam 4. Phillippines 5. Sri Lanka 6. Thailand 7. Malaysia 8. Egypt 9. Nigeria 10. Bangladesh. Figure 3: These countries filled in with pink

represent the top 10 producers of the ocean's plastic waste. Although the majority of these countries are in the Eastern hemisphere, their waste travels around the globe. Figure adapted from Parker, Laura (February 13, 2015) National Geographic.[9]

Results:

Numerous studies have been conducted examining the effects of plastic on black-footed and Laysan Albatrosses. Several of these studies have shown that survival rates of juvenile seabirds have decreased due to the toxins present in plastics typically leading to decreased weight of fledglings.[4] Concentrations of toxic trace elements such as iron and chlorine have been observed at high concentrations in Laysan Albatrosses especially in relation to the amount of plastic ingested. Large amounts of plastic consumption often led to starvation and ruptured organs in observed Albatrosses.[5] Increased levels of polychlorinated biphenyls (PCBs) and long chain perfuoroalkyl acids (PFAAs) have shown higher bioaccumulation values and indirect contributions to the mortality of the seabirds.[4,5,6]

Plastic as Number One Threat to Chicks:

Figure 4: This graph shows the number of Laysan Albastross chick deaths in relation to their biggest threats to their survival. This graph shows just how much of an impact plastic consumption has on survival of the Laysan Albatrosses. It is a bar graph of annual number or Laysan Albatross deaths with the number of chick deaths on the y axis and the type of threats on the x axis.

Surface Level Ocean Pollutants:

Figure 5: This image highlights just how extreme the issue of plastic is in the ocean. Thousands of microplastics also exist just below the surface and all throughout the ocean.

Conclusion and Discussion:

Plastic production is at an all time high and if we do not cut back on the waste produced or find a new solution more and more species will be affected. We are already seeing a decline in survival rates and overall population for Albatrosses indicating that some sort of action needs to be taken.[5] Unfortunately due to the fact that the ocean is not stagnant and debris can travel anywhere in the world, it is going to take the cooperation of the whole world to solve this issue.[6] It is not enough for a few countries to decrease plastic waste, everyone must be on board. The chemicals and toxins present in the Albatrosses and various other species due to plastic consumption has already started to bioaccumulate in the food chain and will eventually start to affect humans.[1,5,6]

Trace Element Concentrations:

Figure 6: This figure represents the various trace element concentrations found in Laysan Albatrosses. The data was collected from juvenile Albatross feathers during a 2012 study. Figure adapted from Lavers, J.L. (September 15, 2016) Marine Pollution Bulletin.[5]

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6. Chu, S., et al. (2015). Chemosphere, 138(1): 60-66.

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3.4 IMPACTS OF CYANIDE FISHING ON CORAL BLEACHING EVENTS

Mitchell J. Johnson

Corals play a pivotal role in marine ecosystems, as well as, impact humans in significant ways. These marine species face threats as temperatures rise, and humans utilize fishing techniques that stun fish and release harmful chemicals into the oceans. Will cyanide continue to be problematic for corals or will new research lead to alternative fishing practices?

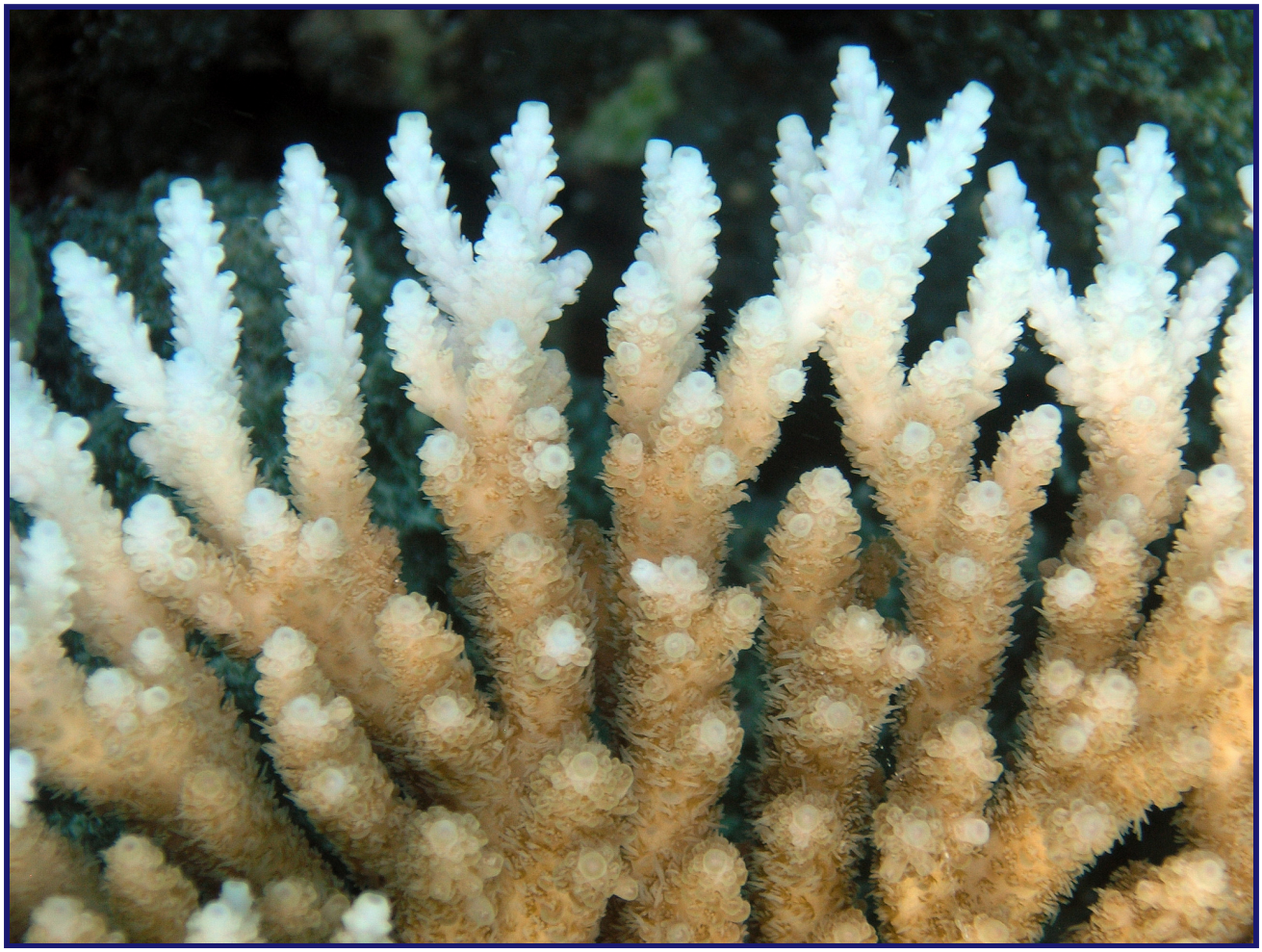

Figure 1. Corals show signs of bleaching as they begin to turn white. This effect can severely harm the coral and eventually lead to its death. Photograph courtesy of Oregon State University, 2012, FlickrCommons. CC BY-SA 2.0.

Corals are marine animals whose polyps form **endosymbiotic** relationships with algae in the genus Symbiodinium.[5] These dinoflagellates, known as zooxanthellae, are critical to coral health as they photosynthesize and provide energy in the form of sugars.[2] **Coral bleaching** is a process whereby the coral expel their algal symbionts to increase their chances of survival, resulting in discoloration of coral colonies (Figure 1).[2] The algae can be replaced, but the coral will die soon after the event if they do not acquire new algae.[4]

Corals play a pivotal role in marine ecosystems. They provide shelter and substrate for many different species of fish and invertebrates. Furthermore, their impact on humans is significant. Coral reefs mitigate damage to beachside properties by damping waves, which would otherwise erode the beach. In addition, coral reefs are estimated to provide billions of dollars in revenue through fishing, biomedicine, and tourism.[4] As such, maintenance of coral reefs is critical in oceanic conservation.

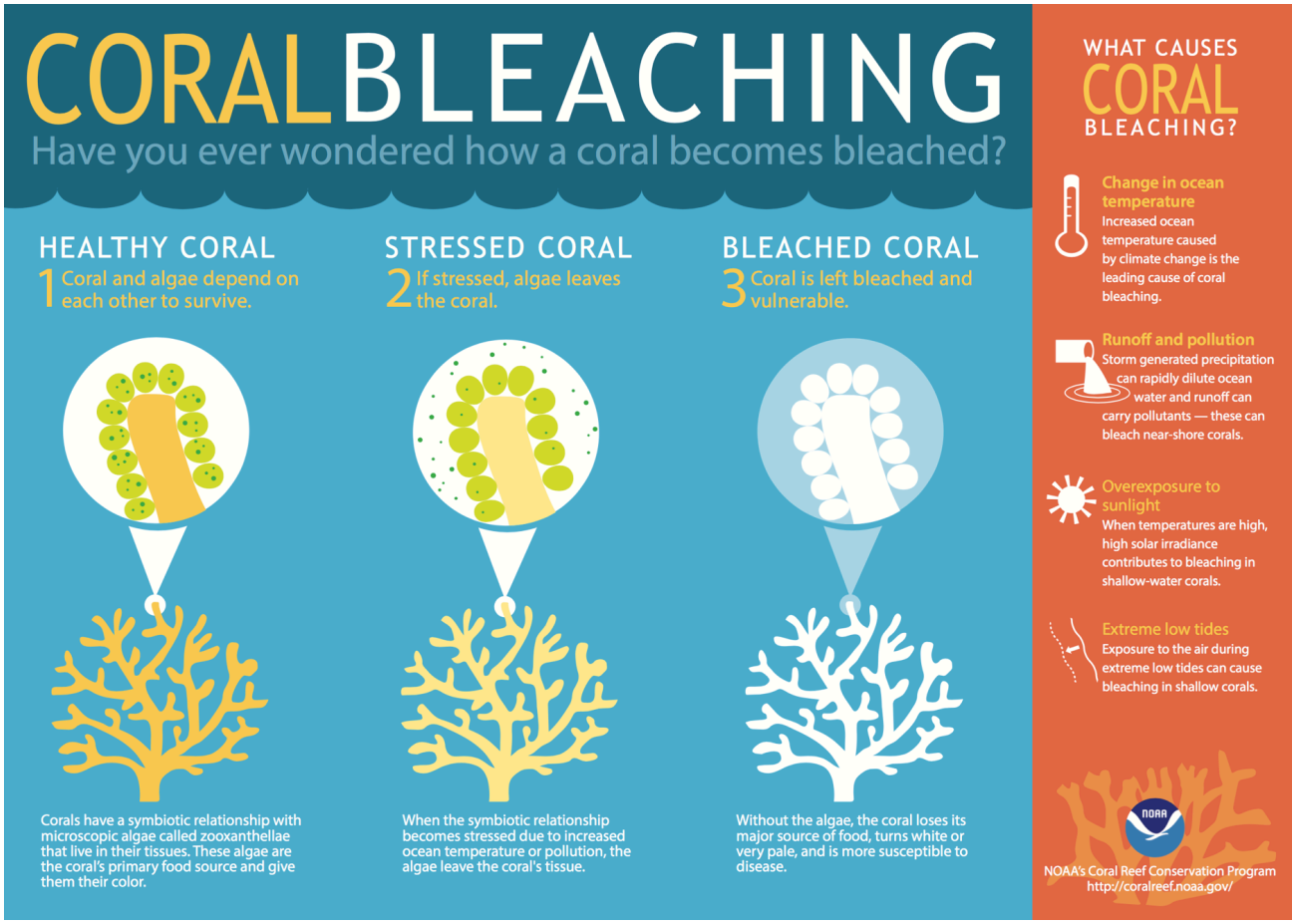

Figure 2. What Causes Coral Bleaching? Courtesy of NOAA, 2017. Public Domain.

Three major stressors are commonly evaluated pertaining to coral bleaching events. Firstly, rapid warming of oceans is often cited as the major factor contributing to massive coral bleaching events.[3,4,5] As temperatures rise, corals expel their endosymbionts. **El Nino** occurrences, a major trigger of previous bleaching events, are expected to increase in frequency as global temperatures increase.[2] This could elicit drastic changes in conditions which corals may not be able to withstand. Blast fishing may also negatively affect corals. Blasting involves stunning fish with explosives in order to make them easier to capture.[10]

Potassium nitrate is often used in local communities as a cheap method for producing desirable explosive effects.[10] This process often results in fragmented corals originating from the source of the explosion and can have significant impacts on reef health.[10] Finally, cyanide fishing is a common practice where **cyanide** is used to stun fish and make them easier to capture.[1,2,3,6,8,9,10,11] It can also kill fish which cannot tolerate higher doses used to stun larger fish. About 70% of fish caught for aquariums are captured using sodium cyanide.[3] It is illegal in many countries but is still widespread in regions lacking regulations.[9] Cyanide may trigger local bleaching events by inhibiting photosynthetic activity of the Symbiodinium.[1,5,7,8]

There is a substantial amount of research underway investigating the impacts of the aforementioned stressors. In particular, many researchers are interested in learning how chemical stressors may impact coral health. Much of the research referenced focuses on cyanide's impact on hard corals and their endosymbiotic dinoflagellates. In one experiment, researchers exposed corals to varying concentrations of cyanide ion.[1] These concentrations were lower than those typically used by fishing

operations.[1] Corals responded by expelling their **zooxanthellae**. Analysis of the data described the reduced density of zooxanthellae and increased cellular division of zooxanthellae for groups exposed to cyanide.[1] Some of the dinoflagellates exposed to cyanide died, while others appeared discolored.[1] These results demonstrate the severe impacts cyanide may have on photosynthetic activity and coral health.[1]

Similar experiments support these results and have shown that cyanide specifically inhibits the **Calvin cycle** of photosynthesis in dinoflagellates.[5,6,7,8] Concentrations for these experiments were carefully selected to find the level of cyanide which inhibits the Calvin cycle but does not affect other processes in either organism.[5,6,7,8] In addition, some findings do not support the hypothesis that thermal stress alone can inhibit the Calvin cycle.[8] Other research has shown that cyanide has a significant impact on the coral itself as well as other organisms which are exposed to high concentrations. Evidence suggests that cyanide inhibits mitochondrial activity, and therefore reduces availability of ATP (adenosine triphosphate) in cells.[3] Together, this data presents a legitimate concern for coral health where cyanide is used. Both corals and their dinoflagellate symbionts are adversely affected by cyanide, which may exacerbate bleaching events.

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https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=67

Figure 3. Alternative fishing techniques can be detrimental to aquatic species, such as the coral in coral reefs. Blast fishing utilizes explosives underwater to stun fish, making them easier to catch. Sodium cyanide is often used in a practice known as cyanide fishing in which fish are stunned with the substance and are then easier to capture for use in aquariums. Major factors contribute to major coral bleaching events such as in specific areas of the Great Barrier Reef in Australia. Courtesy of Drajay1976, 2013, Wikimedia Commons. CC BY-SA 3.0., Ella Weaver, 2017., and Oregon State University, 2016, Wikimedia Commons. CC BY-SA 2.0.

Researchers are searching for more pragmatic approaches to addressing cyanide fishing because it is difficult to regulate. One proposal is the use of clove oil in fishing operations.[4] Clove oil causes fish to lose consciousness and may serve as an alternative to cyanide.[4] In a study exposing corals to varying concentrations of clove oil solution, researchers found that low concentrations were not harmful to the coral used in the experiment.[4] In contrast, low concentrations of cyanide were found to be significantly damaging.[1] Thus, clove oil may be a viable alternative in the fishing industry because it does not have a significant ecological impact on local coral populations.[4]

Besides alternatives to cyanide fishing, it is important to develop new techniques which allow for detection of cyanide when it is used illegally.[9,11] This two-pronged approach may offer an alternative while providing punishment for those who do not cease illegal activities. One of the ways to do this is through detection of thiocyanate anion, which is excreted by marine fish after they neutralize cyanide ion.[11] **Optical fiber** is used in addition with liquid **chromatography** technology to detect thiocyanate.[11] This new technique could be used for detecting aquarium fish which have been caught illegally and consequently would eliminate the benefits of using cyanide in fishing practices.[11]

In addition to mechanical methods of detecting cyanide, several biological methods exist. Bacteria are capable of metabolizing cyanide ion and converting it to cyanate through the use of oxygen.[9] As more cyanide is degraded, oxygen levels decrease.[9] Decreasing oxygen levels can be monitored using Clark oxygen electrodes, which would indirectly measure cyanide levels in seawater.[9] Other biosensors utilizing properties of enzymes have been proposed for detection of cyanide, and can often provide precise measurements of cyanide concentrations.[9]

Figure 4. Healthy coral reef are decreasing in number as coral bleaching events become more prevalent. Courtesy of NOAA, 2011, FlickrCommons. Public Domain.

While there is still a need for more research concerning the causes of coral bleaching events, the effects of cyanide on corals are becoming well understood. Highlighting this cause allows for policies to address cyanide fishing through new methods of detection and screening of aquarium fish in countries with the infrastructure to do so. An understanding of the physiological impact cyanide has on corals and marine life will also allow for a broader view of toxicology of trophic levels within ecosystems. As more research highlights the impact of warming temperatures on coral bleaching, it is critical that more easily addressed issues are resolved to relieve local coral populations from some of these pressures.

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3.5 ALTERING DAIRY CATTLE FEED TO REDUCE METHANE PRODUCTION

Jennifer L. Satterfield

Methane is a greenhouse gas that dairy cattle produce due to enteric fermentation. But, why is methane mitigation important to the dairy cattle industry and the environment? Is too much methane being released to the atmosphere?

Figure 1. Close up of a heifer in a free stall barn during feeding time. Photograph by Lance Cheung, USDA, 2011, FlickrCommons. Public Domain.

Methane (CH_4), a **greenhouse gas**, is considered to be a major cause of climate change due to its ability to trap 25 times more heat in the atmosphere than carbon dioxide (CO_2).[3,4,11] One of the major contributors to worldwide methane production is the dairy cattle industry.[1] Cattle possess a **microbial population** in their gut to **ferment** otherwise indigestible feeds.[7] One of the byproducts of this process

is methane, which is released in the form of flatulence.[8] The average adult dairy cow can belch 400-500 liters of methane in a single day.[8] One way researchers are attempting to mitigate methane production is by altering feed by means of adjusting silage ratios, forage mixtures, supplementation, and/or the addition of certain acids.[1,3,4,5,9,12] Although some studies have found potential in these dietary changes, more research needs to be conducted to find the best balance between the reduction of methane, cost effectiveness, animal welfare, and dairy cattle productivity.

Dairy cattle are ruminants, which means that they have a compartmentalized stomach that contains a microbial population that allows them to digest cellulose in the form of pre-gastric fermentation.[10] During digestion, many gasses are released. The most prevalent is methane (CH4), which is considered the largest on-farm contributor to greenhouse gas emissions.[6] Within the **rumen**, a process called **methanogenesis** takes place to eliminate hydrogen by utilizing **methanogens**.[1,5,7] Methanogens then produce methane as a metabolic byproduct.[5] Therefore, due to their digestive makeup, dairy cattle produce an excess of methane (Figure 2). The dairy industry has already undergone a massive overhaul of production and efficiency within the United States (U.S.) since the 1940s, especially after the development of **Concentrated Animal Feeding Operations** (CAFO) that can house large amounts of dairy cattle while maintaining maximum production efficiency.[6] Yet, the U.S. dairy industry is under harsh criticism from social and environmental groups due to their management practices, the growing concern that the dairy industry is unsustainable, and the environmental impacts of the industry from greenhouse gas emissions.[6]

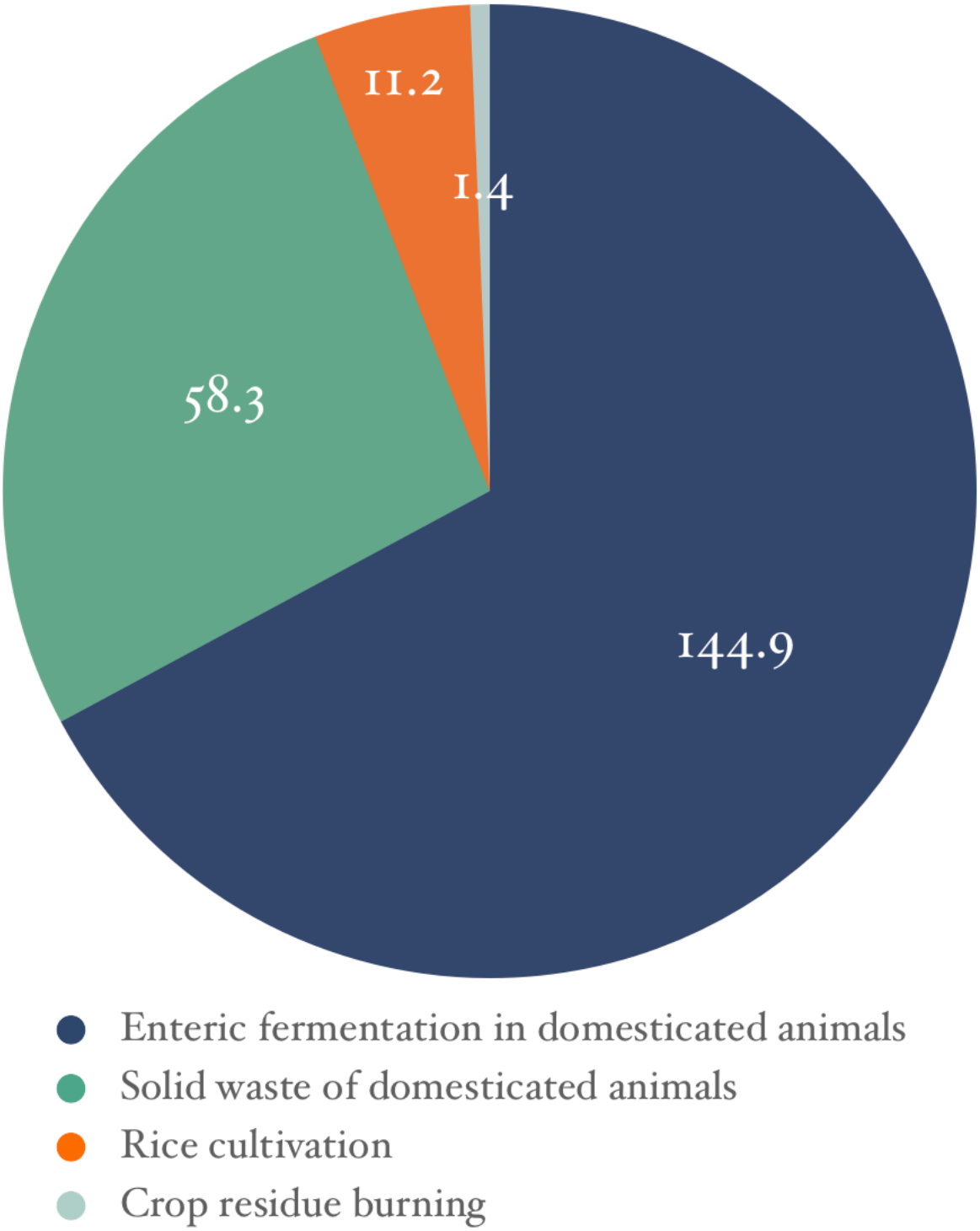

Figure 2. United States methane emissions from agricultural sources, 2009. Total =215.9 million metric tons carbon dioxide equivalent. Data courtesy of the U.S. Energy Information Administration., 2011. Public Domain.

Rising levels of greenhouse gasses like methane are causing more of the sun's heat to be trapped within Earth's atmosphere.[2] Greenhouse gasses naturally trap the sun's heat to keep the planet at a hospitable temperature for life. However, increasing levels of greenhouse gasses attributed to human activity are causing the Earth to trap more heat, leading to disastrous impacts such as rising sea levels, extreme weather, and an increase in natural disasters such as forest fires and drought.[2] Furthermore,

enteric methane constitutes 17-30% of methane from human activity, and 11-17% of methane produced globally.[1] Since the dairy industry contributes such a large amount of methane on a global scale, developing methods to reduce the industry's contribution is necessary. Therefore, by mitigating its methane emissions, the dairy industry can do its part to lessen human contribution to climate change while increasing the sustainability and efficiency of an industry that is deeply embedded within the culture, community, and economy of the United States.

Although many different approaches are being made to decrease greenhouse gas emissions from dairy cattle (such as upgraded housing systems, genetically modifying dairy cattle, and new ventilation systems), one of the most prominent solutions has been dietary changes that mitigate methane production by either directly impacting the methanogens, or by indirectly changing the substrates available in the rumen.[7] Nevertheless, the best methane mitigation strategy will depend on the geographic location of the animals, the style of dairy farm, and the feed available.[7] One method attempted by researchers from the School of Agriculture, Policy, and Development at the University of Reading and the Institute of Science and the Environment at the University of Worcester is to adjust dairy cattle diets by looking at the impacts of **forage** mixtures on methane production in growing dairy heifers.[3] Two techniques were used to measure methane emissions: staggered rotations within respiration chambers for five days, and four day methane measurements using the sulfur hexafluoride tracer technique.[3] Based on their experiments, the researchers concluded that heifers fed flowers, legumes, or forages containing **secondary plant compounds** had lower methane emissions.[3] This result was considered to be due to the lower digestibility of the feed. However, the lower feed intake and lower overall production would be a problem if the dairy industry is to implement this feeding method. Therefore, more research is necessary on this method before it can be successfully utilized.

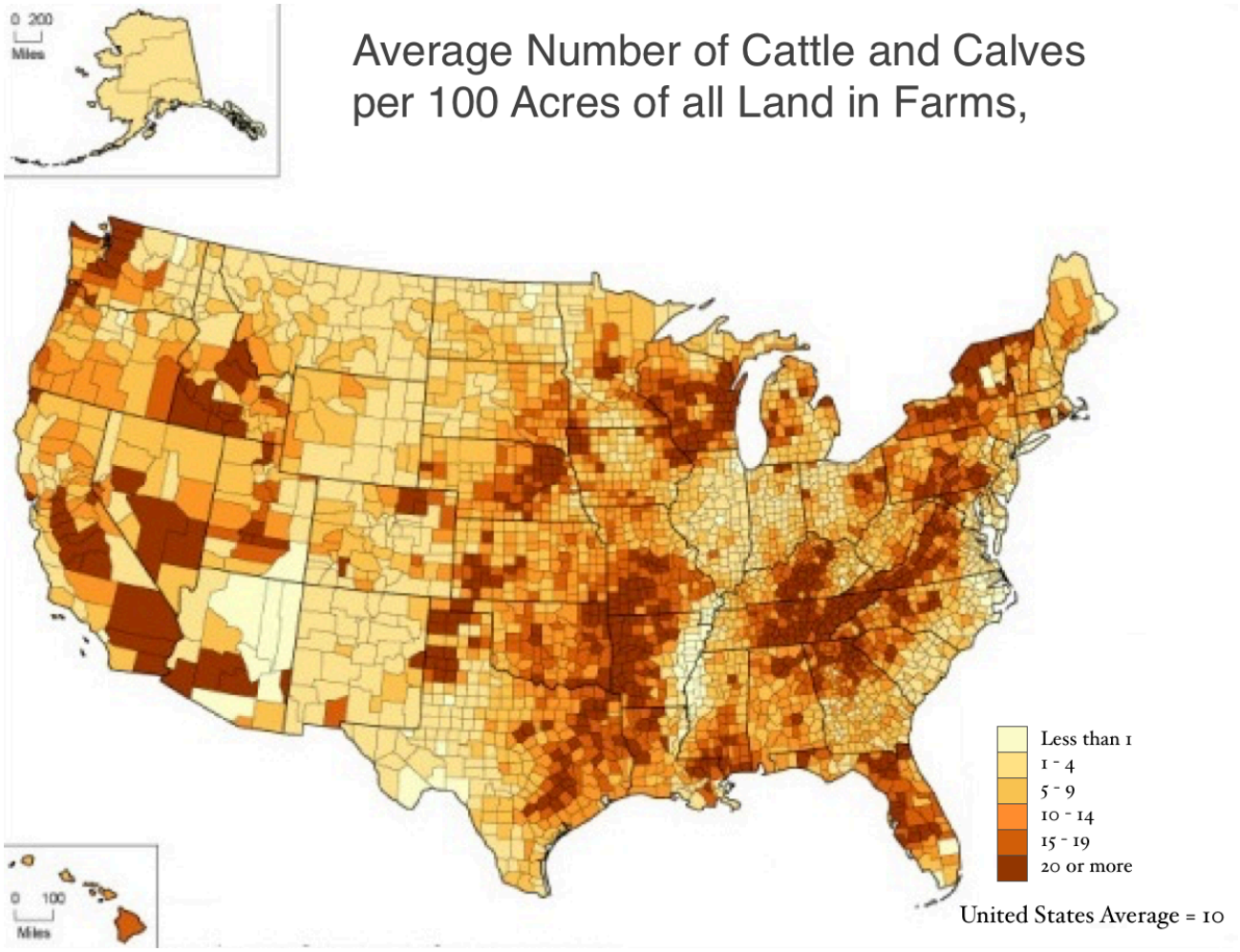

Figure 3. Density of cattle and calves in the United States by county in 2007. Original figure modified from Manore et al., 2013, Wikimedia Commons. CC BY 3.0.

Another experimental mitigation method was the effect of dietary **starch** concentration on ruminal fermentation and methane production in dairy cattle.[9] Scientists at the Research Center of the Department of Agriculture and Environmental Sciences at the University of Milan, Italy found that high starch diets decreased methane production, and low starch diets with fish oil supplementation showed potential for methane reductions, but failed to have decisive results. Fish oil supplementation also showed a negative impact on milk fat.[9] Therefore, high starch diets are a possible method to mitigate methane when applied in the proper situation. Fish oil supplementation could be problematic for dairy farmers due its negative impact on milk fat.[9] In a study completed in 2015 by researchers from the Animal Nutrition Group at Wageningen University in the Netherlands, it was discovered that diets higher in starch in place of fiber in lactating dairy cows also reduced methane production per unit of estimated rumen-fermentable organic matter.[4] This result was due to the fact that starch favors the production of **propionate**, which follows an alternate path of hydrogen removal rather than methanogenesis.[4] Similar to the other studies, more research is needed on the impact this dietary change has on milk production, dairy farms, and the farmers themselves. Lastly, another study published in 2011 looked at the use of dietary nitrate supplementation in cows to reduce methane production.[12] The researchers observed 20 Holstein-Friesian dairy cows, sorted them by parity, lactation stage, and milk production. After a four week adaptation period, they measured the amount of methane produced, energy balance, and the diet's digestibility using open-circuit indirect calorimetry

chambers.[12] The results indicate that the inclusion of nitrate decreased methane production by 16% and reduced overall energy losses. However, the diet did not improve milk production.[12] Although many of the results of these experiments are promising, they cannot act as a uniform solution for every dairy operation due to differing conditions and varying needs. By conducting more research using different situations, enhanced mitigation methods can be achieved. Therefore, more research must be conducted to properly assess the benefits of methane mitigation methods to find the best possible means to reduce emissions while maintaining a productive, welfare-oriented environment for the dairy cattle.

Figure 4. Cattle feeding on corn sillage. Photograph courtesy of Peter Van den Bossche, 2008, Wikimedia Commons. CC BY-SA 2.0.

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3.6 MYCOREMEDIATION: STUDIES IN MYCELIUM AS AN AGENT OF BIOREMEDIATION

Nathan M. Watson

Methods to reverse contamination and clean up pollution are often expensive and inefficient. Can pollutants be remediated in a practical, efficient, cost-effective and eco-friendly way using fungi? Is bioremediation the future of ecosystem restoration?

Figure 1. Pholiota aurivella mushroom. Photograph courtesy of furtwangl, 2009, FlickrCommons. CC BY 2.0.

In the 2005 book *Mycelium Running* by Paul Stamets, the author proposes ways in which "mushrooms

can help save the world."[10] **Mycelium** is the vegetative heart of fungus. It creates a network in soils for nutrient exchange among plants. A fungi life cycle includes many stages, including hyphae that extend underground. These tubular structures are responsive, hearty, diverse, ancient, and very complex in their behavior. Stamets believes, "that mycelium is the neurological network of nature."[10]

Although often a membrane only one cell thick, the world's largest organism is a mycelial mat in Oregon's Blue Mountains that encompasses an area of nearly four square miles, and could be up to 8,650 years old.[5] Fungus serves as nature's recycling agent. It typically secretes digestive enzymes into its environment that break down molecules for use as a food source.[5] This process is the central concept to one of the ways that Stamets suggests mushrooms can help save the world: **mycoremediation**.[10]

Mycoremediation is the process of bioremediation using mycelium.[3] **Bioremediation** is defined as the method of "cleaning up contamination in the environment through the activities of living organisms."[13] One category of bioremediation is **bioaugmentation**, which involves introducing organisms that can degrade contaminants.[13] Mycelium has been degrading molecules for hundreds of millions of years, so employing it for bioaugmentation is a natural fit.

Figure 2. Hyphae visible under an overturned log. Hyphae reform a variety of functions in guns and serve as the main structure in vegetative growth. Courtesy of TheAlphaWolf, 2006, Wikimedia Commons. CC BY-SA 3.0.

Pollution is an unfortunate consequence of the technological advances made by mankind, and the methods to reverse contamination are often expensive and inefficient. The earliest well-known use of fungi in bioaugmentation came in 1985, when J.A. Bumpus and his team used a fungus called

Phanerochaete chrysosporium to degrade **dichlorodiphenyltrichloroethane** (DDT), a popular pesticide that proved to be harmful to several aspects of the environment.[4] Bumpus and his team also showed that *P. chrysosporium* degraded other organic pollutants.[4] The use of DDT has been banned for many years, but other pollutants are more ubiquitous than ever.

The compounds known as **polycyclic aromatic hydrocarbons** (PAHs) are fairly common compounds that are largely produced when organic matter is burned.[8] Some are harmless, but the National Toxicology Program lists fifteen of them as "reasonably anticipated to be human carcinogens."[8] A 2002 study of two PAH-contaminated soils used two types of white rot fungal cultures to degrade twelve PAHs, and examined the effects that mycoremediation had on the toxicity of the soils.[3] Seed germination tests were also performed before and after the mycoremediation.[3] Results showed that germination rates for mustard seeds were related to soil contaminant concentrations, with higher concentrations being more limiting to growth.[3] After fourteen weeks of incubation, the fungus *Irpex lacteus* removed 67% of the PAH fluorine, and 57% of fluoranthene among others.[3] Not all of the PAHs being examined were degraded, but the results suggest that mycoremediation is effective in treating PAH-contaminated soil.[3]

Mycoremediation of PAH contaminated soil is more complex when practiced in situ. When mobilizing agents are introduced in a laboratory setting, the ability of mycelium to degrade compounds can be less effective.[7] This is the result of lower availability of the PAH in the soil.[7] Another approach to in situ contaminated soil occurred in 2007 on a condemned industrial site in Italy.[2] Heavy metals were first **leached** out with citric acid, and then the soil was treated with fungal mycelium of the genus Allescheriella to degrade the remaining organic pollutants.[2] This in situ study resulted in the remediation of 63.8% of organic pollutants.[2] Integrated techniques such as this could prove most useful when contaminants are less available for remediation.[2]

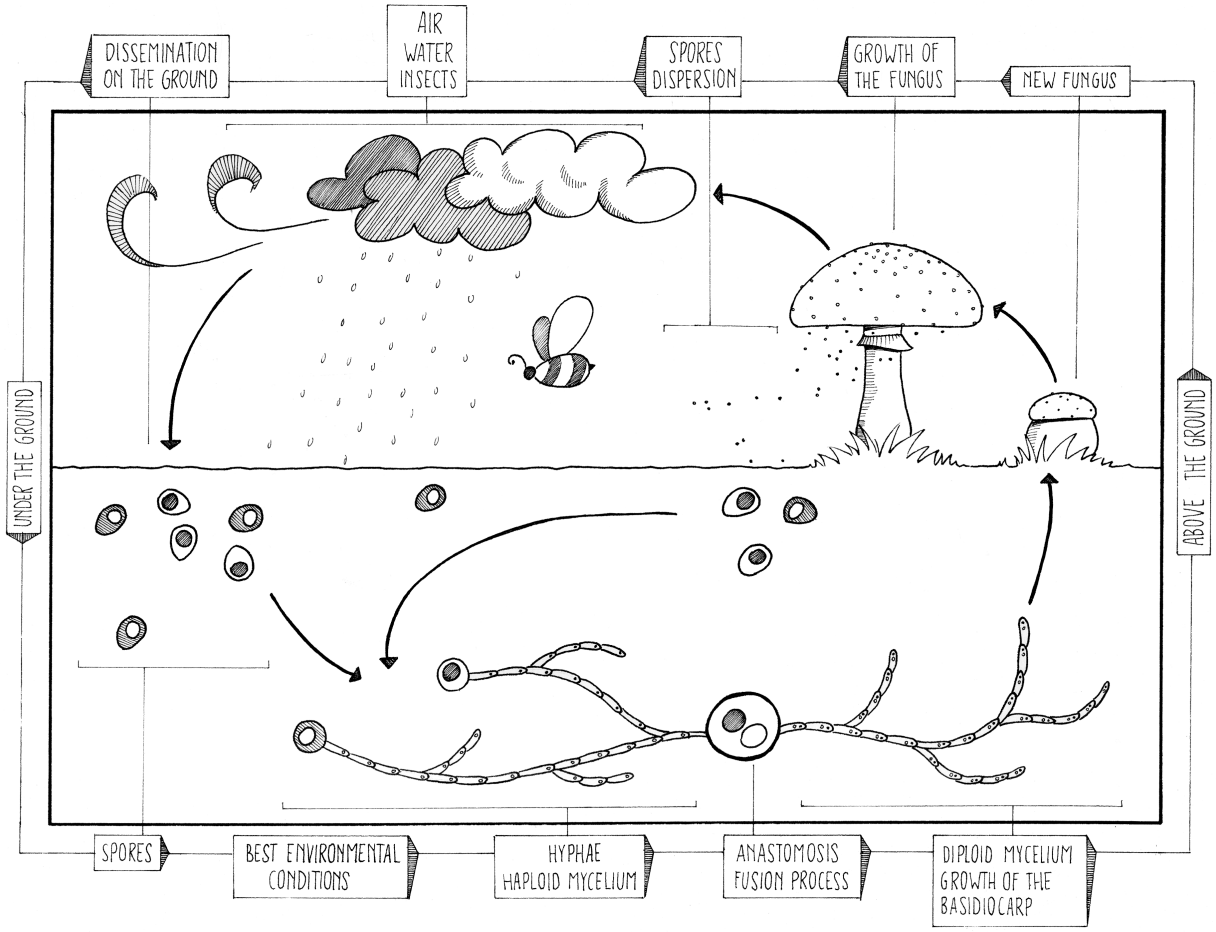

Figure 3. Sexual reproduction cycle in basidiomycetes. Graphic courtesy of Anita Righetto, DensityDesign Research Lab, 2014, Wikimedia Commons. CC BY-SA 4.0.

Some pollutants are more subtle than pesticides and byproducts of combustion. Di(2-ethylhexyl) phthalate (DEHP) is a common additive to increase strength and flexibility in plastic medical devices, namely **polyvinylchloride** (PVC) blood storage bags.[9,12] Because the DEHP is not chemically bonded to PVC, it washes away and ends up in watersheds when the plastics are buried.[9] DEHP has been shown to be harmful to animals and humans, especially in early stages of development.[9,12] In 2012, scientists in India showed that DEHP still bonded to PVC blood bags could be remediated with three types of mycelial fungi, either acting separately, but most effectively when used together.[9] Over 99% of the toxin was remediated, leaving only PVC that could be recycled for future use.[9] The mycoremediation used in this case was very efficient, cost-effective, and eco-friendly.[9]

Bioaugmentation has been studied for several years to combat another common, more obvious pollutant: **trinitrotoluene**, or TNT.[6] In 1999, the fungus *Bjerkandera adusta* was shown to degrade TNT, but the in situ applications had limits.[6] For a fungus to effectively degrade TNT in soil in situ, it must also be able to tolerate indigenous organisms.[1] A 2015 study used three types of fungi to treat soil contaminated with TNT from previous explosive operations.[1] *Phanerochaete velutina* was found to be most effective and thought to have large scale practical use in situ.[1] This fungus degraded 80% of the TNT in only 2.5 months.[1] Mycoremediation has provided yet another example of pollutant treatment that is superior to the current method as recently as November, 2015.[1]

FUNGUS	CHEMICAL	RESULT OF TREATMENT
Phanerochaete chrysosporium	dichlorodiphenyltrichloroethane (DDT)	P. chrysosporium was successful in degrading DDT and other organic pollutants tested by Bumpus et al.[4]
Irpex lacteus	polycyclic aromatic hydrocarbons (PAHs)	Bhatt et al. found mycroremediation to be successful in treating soil contaminated with PAHs. Both PAH fluorine and fluoranthese were removed from the soil.[3]
Mycelial Fungi	Di(2-ethylhexyl) phthalate (DEHP)	Discovered by Pradeep and Benjamin, three types of mycelial fungi when used together, were effective in remediating 99% of the toxin.[9]
Bjerkandera adusta *Phanerochaete velutina*	trinitrotoluene (TNT)	In remediation trials, *Bjerkandera adusta* had limits, but *Phanerochaete velutina* proved to degrade 80% of the TNT in 2.5 months by Anasonye et al.[1]

Figure 4. Results of various studies reviewing bioremediation success.

Paul Stamets has devoted his life to fungus. He currently holds eight patents related to mycelium, ranging from medicinal mushrooms that have antiviral and antibacterial properties, to mycelium as a pesticide.[11] While working with Battelle Labs in 1998, he took part in an experiment that involved treating soil that had been contaminated with diesel and oil.[10] Stamets and his team were given four piles of soil, contaminated at 20,000 parts per million (ppm) petroleum hydrocarbons.[10] One pile was the untreated control, one was treated with enzymes, one with bacteria, and the last with the mycelium of the familiar oyster mushroom.[10] After four weeks, three of the piles were still black and lifeless, while the mycelium treated pile had become overtaken with oyster mushrooms (Figure 5).[10]

Over the next few weeks, the mushrooms produced **spores** and died. In doing so, they attracted insects, which laid eggs that became larvae.[10] This attracted birds that carried seeds and more nutrients.[10] After 9 weeks, the previously contaminated soil had become full of plant and animal life, while the other piles still remained mostly unchanged.[10] The final concentration of petroleum hydrocarbons for the mycelium treated pile was less than 200 ppm.[10] This example shows the remarkable effects of mycoremediation.[10]

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CLIMATE CHANGE

Courtesy of Shever, 2006, FlickrCommons. CC BY 2.0.

4.1 UNCEASING CONCERN FOR THE RAPID RETREAT OF MOUNT KILIMANJARO'S WHITE PEAK

Julie E. Kemerer

The glaciers on Mount Kilimanjaro have shown a considerable decrease in area that has scientists hypothesizing about when — rather than if — the mountains's white peak will completely disappear. With this glacial retreat, just how far-reaching will the consequences be? How much longer will these white peaks be visible?

Figure 1. Mount Kilimanjaro. Photograph by Erik Cleves Kristensen, 2007, FlickrCommons. CC BY 2.0.

Mount Kilimanjaro, a **dormant** volcano in Tanzania on the border of Kenya, has been a topic of interest for scientists for over 100 years.[3] Kilimanjaro is located just 300 km (186 miles) south of the equator which has caused the snow cover on the mountain to be regarded as a peculiarity.[3] Ernest Hemingway, the American novelist, once described the ice fields as being "as wide as all the world, great, high, and unbelievably white in the sun".[5] However, according to scientists, these incredible ice fields are nearing the end. Now, the question is not if the **glaciers** will disappear, but when.

In 1912, the area of snow cover on Mount Kilimanjaro was around 11.40 km^2 (4.40 $miles^2$).[2] In 2011, the area of snow cover decreased to approximately 1.76 km^2 (0.70 $miles^2$).[2] This indicates that in the last century, the total loss in ice cover was around 85%.[2] Furthermore, the amount of ice present in 2007 showed a decrease of 26% when compared to the measurements taken in 2000.[8] There are many factors that contribute to this phenomenon. Scientists have linked global climate change to changes in greenhouse gases as well as land cover change.[5] Multi-scale modeling has shown that there has been significant decrease in montane forests as well as in cloud forests.[6] Research has also indicated an increase in **sublimation**, and a decrease in precipitation/snowfall and air humidity.[4,6,8,10] Moreover, annual precipitation on Mount Kilimanjaro has decreased by 600-1200 millimeters (24-47 inches) over the last 120 years.[3,9] This has led to not only the retreat of the mountain's glaciers, but also to more frequent and intense forest fires.[3,4] In the last 80 years, the mountain has lost nearly a third of its forests, which exacerbates the problem of the disappearing glaciers.[3] With forest reduction, there is less moisture in the atmosphere, which leads to less cloud cover and reduced precipitation.

Increasing **insolation** leads to more evaporation and melting.[5,10] Clearly, both deforestation and the disappearance of the glaciers are detrimental to the Kilimanjaro ecosystem.[3]

There are three remaining ice fields on the plateau and slopes of Kilimanjaro, all of which are shrinking.[2] These ice fields are known as the Northern Ice Field (NIF), Southern Ice Field (SIF), and Furtwangler Glacier (FWG).[2,4,10] From 2000 to 2007 all have experienced significant thinning.[10] One measurement on the FWG showed that the surface lowered by almost 5 meters (16 feet) from 2000 to 2009. This ice field has already split due to such shrinkage. The effects on the SIF are not as extreme, but the ice has continued to diminish. The NIF is expected to shrink enough that it will split in half within the next few years.[10] Numerous aerial photographs clearly outline the changes that the mountain has experienced since 1912 (Figure 2).

An interactive or media element has been excluded from this version of the text. You can view it online here:
https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=74

Figure 2. Kilimanjaro's Disappearing Glaciers. Summit cover in 1) 1938, 2) 1993, and 3) 2000. Courtesy of Mary Meader, 1938, Wikimedia Commons. CC BY-SA 3.0., and NOAA, 2006, Wikimedia Commons. Public Domain.

The precise measurements taken over the years have been possible through the use of numerous technologies. **Global Positioning System** (GPS), **Automatic Weather Stations** (AWS), **aerial photos**, and **ice cores** have been widely used to create maps and models.[4,6,9,10] Stereoscopic aerial photo coverages have been created and then compared to demonstrate ice thinning.[9] Between the years 1962 and 2000, the photos were able to demonstrate an average surface lowering of approximately 17 meters (56 feet) and thinning of about half a meter (1.6 feet) per year.[9] The drilling of ice cores into the glaciers provides a clear record of 11,700 years of **Holocene** climate conditions.[9] The first ice-core based climate history for Africa used a number of ice cores and drilled some of the longest (close to around 50 meters/164 feet deep) in the NIF, which has the largest of the ice bodies.[9] Eventually, these samples showed that there was an annual retreat of roughly 0.9 meters (3 feet) compared to readings taken in the early 2000's.[9] Interestingly, the ice cores showed that the NIF persisted through an intense drought that lasted nearly 300 years, yet the ice field will most likely disappear by the year 2060, indicating that today's conditions must be far worse than any that existed in the past 11 millennia.[2]

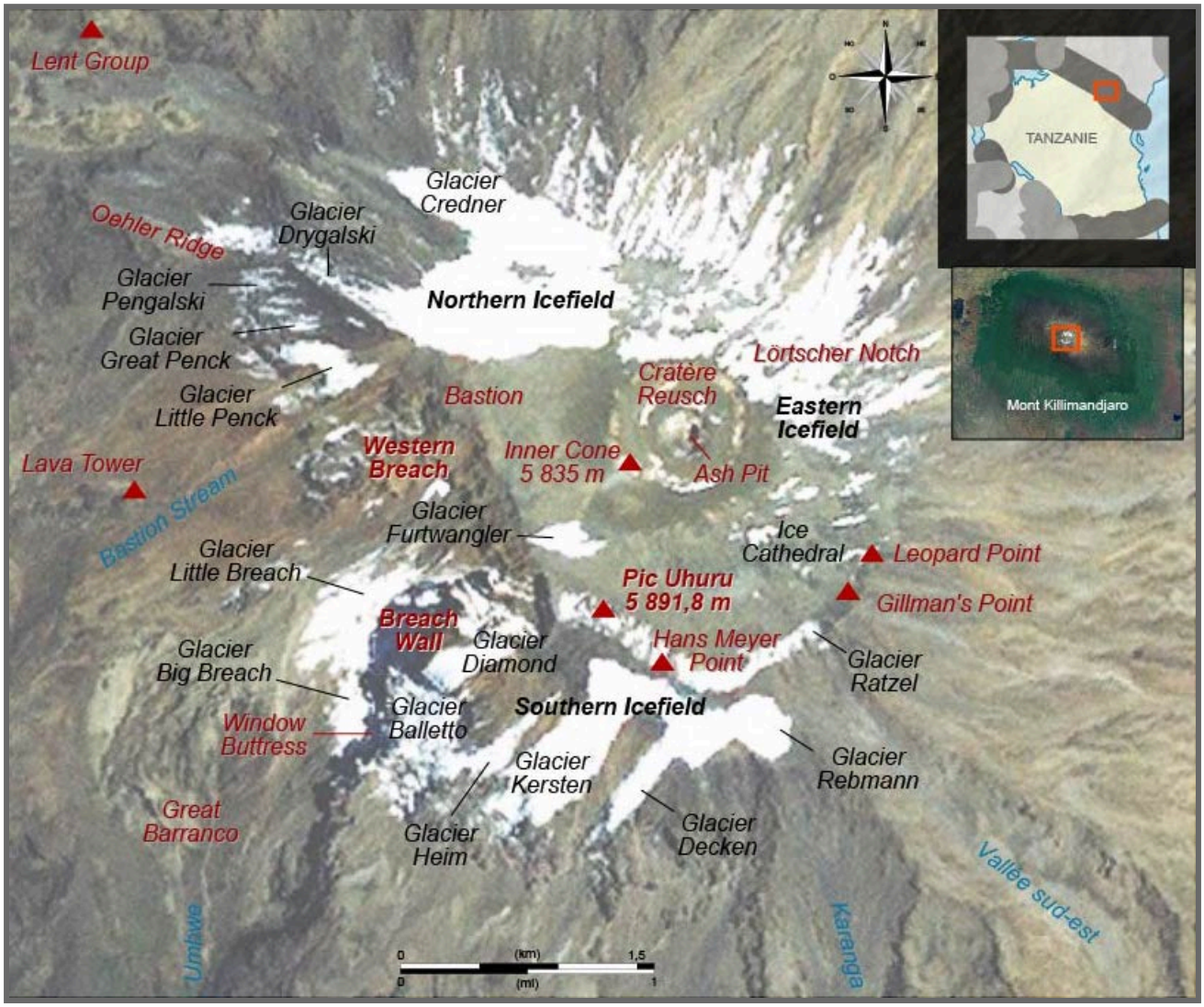

Figure 3. The summit of Mount Kilimanjaro with names of main glaciers, valleys, and peaks. Image by Semhur, 2008. Wikimedia Commons. CC BY-SA 3.0.

Glaciers preserve extremely reliable records of history due to the ability of ice to freeze and keep intact many attributes of the surrounding environment. Such attributes include the air temperature, precipitation, atmospheric chemistry, and volcanic depositions.[11] Additionally, the glaciers preserve human activities, granting anthropologists insight into the past. Thus, with the melting of glaciers, over 11,000 years of history is being erased.[11] The glacial melting also raises concern for drinking water supply, sea level rise, crop irrigation, hydroelectric production, and tourism.[11] A 2001 BBC article highlighted that Kilimanjaro is the primary foreign-currency earner for the Tanzanian government.[1] The article stated that "twenty thousand tourists go there every year because one of the attractions is to see ice at three degrees south of the equator."[1] The melting of the glacier may cause the Tanzanian government to earn less money from a potential reduction in tourism to the region.

The most recent reports of Mount Kilimanjaro's glacial retreat have used linear **extrapolation** for all three zones (NIF, SIF, and FWG) to unfortunately conclude that the ice cover on the western side of the mountain could vanish before 2020 while the remaining ice will disappear closer to 2040.[2,8] At the very latest, the ice will take until 2060 to completely disappear.[2] These predictions only hold true if present-day conditions persist. Scientists are largely in agreement that ice cores must be drilled in a number of locations before the ice melts. More extreme options to prevent ice melt include the use

of tarps to protect against solar radiation.[7] Euan Nisbet, a Zimbabwean greenhouse gas specialist from the University of London, suggested draping the ice cliffs in white polypropylene fabric as a temporary fix.[7] This would keep the ice beneath the fabric cool while research is conducted to find ways to develop reforestation plans. While none of these solutions will be a simple task, they demonstrate the efforts of people all over the world to preserve the historic ice fields of Mount Kilimanjaro.

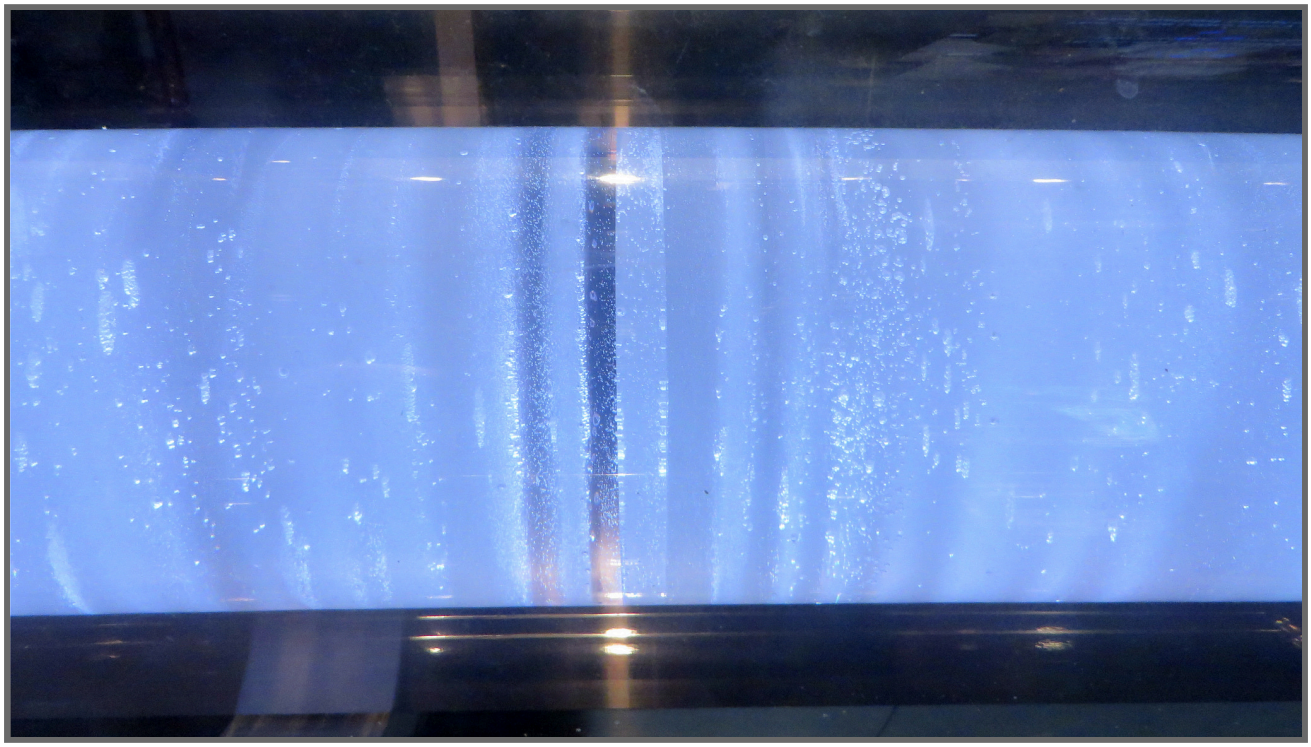

Figure 4. Ice core sample. Photography by Janine and Jim Eden, 2013, FlickCommons. CC BY 2.0.

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4.2 SNOWSHOE HARE STANDS OUT TO PREDATORS AS A RESULT OF CLIMATE CHANGE

Lauren E. Younkin

The snowshoe hare, with its unique ability to change the color of its fur to correspond with the seasons, is excellent at concealment from predators. However, climate change's affect on temperatures has caused the hare's transformation to be out of sync. Will this phenological mismatch cause a decline in hare populations?

Figure 1. A snowshoe hare hides from predators, but its white fur has not fully changed to brown. Photograph by Peg Becks, 2011, FlickrCommons. CC BY 2.0.

The snowshoe hare (*Lepus americanus*) is well-known for its remarkable ability to change the color of

its fur in correspondence with the seasons.[2,3,4,5,7,9,10] With this ability, called **phenotypic plasticity**,[10] the **phenotypes** of the hare are manipulated to its advantage, disguising it from predators like the Canadian lynx (*Lynx canadensis*).[6,8] The snowshoe hare is not the only species with this trait. Several other creatures that live in the Northern Hemisphere share the **molting** capability as well, including the Arctic fox and the collared lemming.[10] Unfortunately, climate change has negatively affected these animals with color-changing coats. As the winters become shorter due to rising temperatures, there is a period of time (currently about a week) in which the snowshoe hare's fur does not match with its surroundings.[3,9,10] This drastically reduces the effectiveness of the hare's fur as a defense mechanism, and makes it more visible to predators (Figure 1). This is called a **phenological mismatch**, and it is a threat to the survival of the species.[4]

This mismatch is dangerous not only for hares, but for other animals living in the ecosystem, primarily the Canadian lynx.[6,8] The snowshoe hare is the main source of prey in the food web of the lynx.[6,8] When the hares are scarce, the lynx will turn to other forest animals for food, such as the red squirrel and other rodents.[6] The hare and the lynx are connected through a predator-prey relationship, and if one population decreases, the other will likely follow.[8] Therefore, as the snowshoe hare's population decreases because it is more visible to potential threats, the lynx population may also decline as its food source dwindles. The Canadian lynx, an already threatened species,[4,5] has had dangerously low population numbers since they started moving farther north as a result of habitat destruction.[8] The additional threat of the phenological mismatch of the snowshoe hare could diminish the lynx's primary food source and further endanger the population.[4,5,8]

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Figure 2. A Snowshoe Hare transitions from an entirely white coat to an entirely brown coat between the seasons of winter and summer. Left photo by D. Gordan E. Robertson 2013, Wikimedia Commons. CC BY-SA 3.0. Right photo by Walter Siegmund, 2013, Wikimedia Commons. CC BY-SA 3.0.

Studies, like those conducted by Zimova, M., et al. (2014) and Mills, L.S., et al. (2013), have aimed to investigate the phenological mismatch of the snowshoe hare's coat. For over three years, Zimova and Mills placed radio collars on 148 Montana hares, which allowed the researchers to track and monitor the hares' whereabouts.[4,10] Regrettably, due to the short lifespan of snowshoe hares, only seven of the original 148 survived for more than one molting cycle (new hares took the places of the others as they died).[4,10] However, the researchers were able to study these creatures in a time period that "spanned among the shortest and longest snow years in the recent past."[4] This provided them with various backdrops needed to test the new plasticity and mismatch of the hares. The team monitored the snowshoe hares in these different environments during the process of their molts, and calculated the percentages of differentiation between their fur, and the amount of snow covering the ground.

Based on their study, Mills and Zimova concluded that the hares were "mismatched when the contrast between [the] coat color and background was at least 60%".[4] As a result of this study, the researchers were able to determine that the starting point of the molts were generally fixed in the spring and fall, and it took around 40 days for the molting process to be completed.[4] Throughout the varying conditions each year, the researchers also observed that the molts slightly changed from year to year depending on the current environment and snowfall, suggesting that the snowshoe hares were evolving to match their coats with their surroundings.[1,4,10] Unfortunately, scientists do not know what conditions cause this shift in evolution. It may include a number of factors such as the temperature, the

sex of the hare, or the level of snowfall.[1,4,10] The depth of snow is important to the snowshoe hare. The animal got its name because its feet have adapted to be wide, so it can walk across thick snow.[7]

Figure 3. Range map of the Snowshoe Hare. Map by Cephas, 2009, Wikimedia Commons. CC BY-SA 3.0.

Currently, the phenological mismatch concern for the snowshoe hare is not dire. The animals are currently only out of sync for about one week of the year,[3,9,10] and Zimova and Mills found that this increases the rate of death for the hare by approximately seven percent.[3] This is not a significant

increase, but over time, it may diminish the population. The research team has estimated that by the end of the century there will be eight weeks of mismatch, significantly increasing the risk for the snowshoe hare.[3] However, the snowshoe hare experiences relatively quick **evolution** over generations through rapid breeding.[1]

The decrease in snow cover will only worsen as climate change increases. Luckily the snowshoe hare can adapt quickly to environmental changes.[1] This should not be a sole-source solution for the species. Mitigating the effects of climate change will improve the survivability for many species in the northern hemisphere. The continued survival of snowshoe hare should be seen as an opportunity for people to view the costs of climate change on the environment.

Figure 4. Canada Lynx (Lynx canadensis), a Snowshoe Hare predator. Photograph by Keith Williams, 2010, FlickrCommons. CC BY 2.0.

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4.3 CLIMATE CHANGE IMPACTS ON MALARIA TRANSMISSION IN WEST AFRICAN COUNTRIES

Brianna N. VanNoy

There is uncertainty about the impacts of climate change on malaria transmission. Climate change models are created in attempts to predict the future of the disease. Could climate change be a positive phenomenon in the fight against malaria in West African countries?

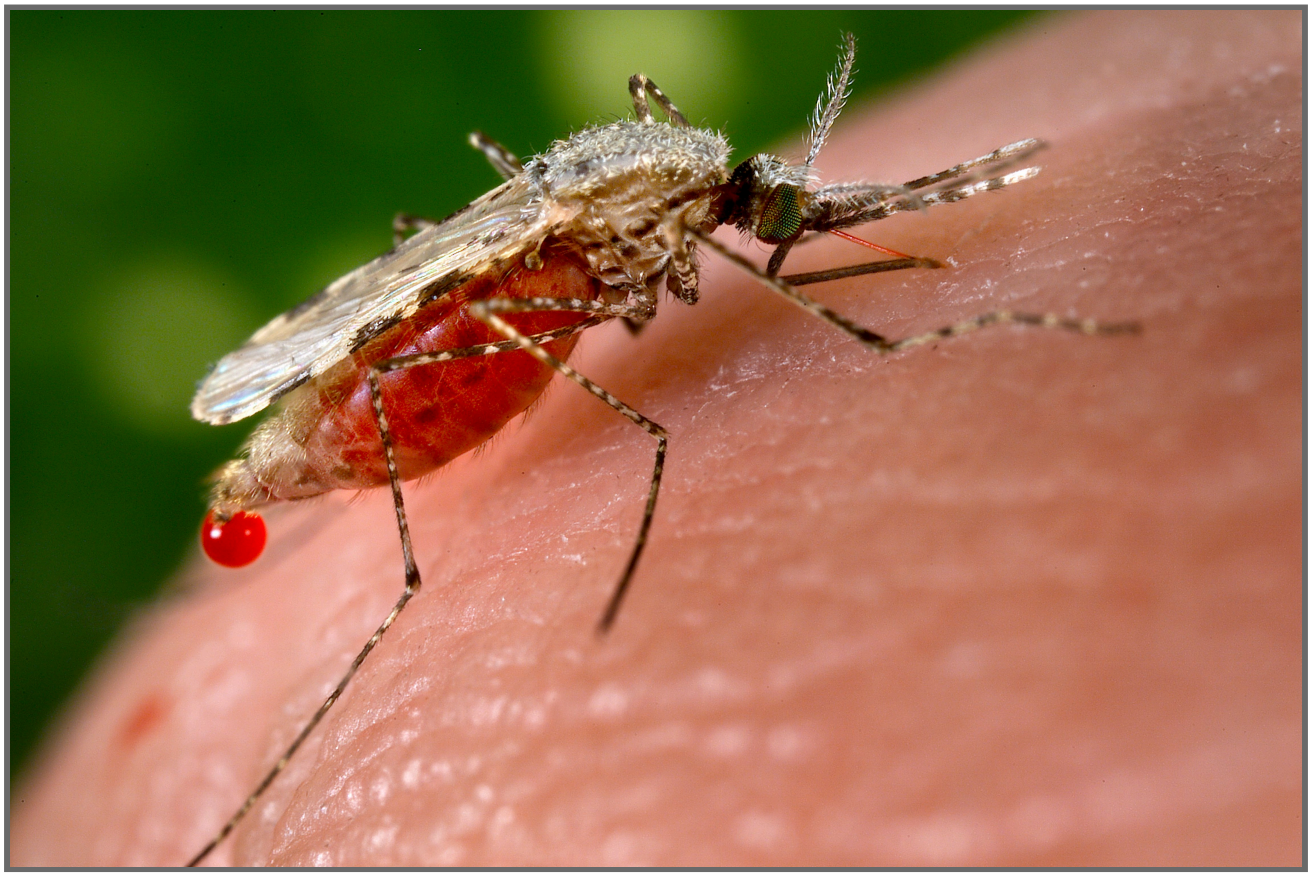

Figure 1. Anopheles stephensi mosquito. Photograph courtesy of William Collins, 2016, Pixnio. Public Domain.

Malaria is a **vector-borne**, parasitic disease transmitted to humans via the bites of infected female

Anopheles mosquitoes.[4,6,11] The severity of malaria is dependent on several factors, including the specific species of the *Plasmodium* parasite.[4,11] *Plasmodium falciparum* is the most **virulent** malaria parasite in Africa, responsible for the most malaria-related deaths worldwide.[4,6,11] Transmission of malaria is dependent upon the survival of mosquito populations, which can be sustained through favorable rainfall, temperature, and humidity patterns.[3,7,11] The longer the lifespan of a mosquito, the better chance the *Plasmodium* parasite has to complete its lifecycle inside the mosquito.[1,11]

Due to favorable environmental conditions, the presence of the most virulent parasite species, and the "strong human-biting habit" of *Anopheles* mosquitoes, Africa suffers from the greatest burden of malaria in the world.[4,6,11] Of the nearly 500,000 people who died from malaria worldwide in 2015, Sub-Saharan Africa suffered 91% of these cases (Figure 2).[4,10,11] While Sub-Saharan Africa carries the greatest burden of disease, West African countries are particularly susceptible to malaria due to extreme poverty and lack of access to care.[11,12] According to the **World Bank**, the average yearly income for an individual in West Africa is only $309, compared to a yearly income of $470 for persons in other Sub-Saharan African countries.[13] In addition to poor **socioeconomic status**, only about 10% percent of the population has access to electricity, and nearly half of the population is illiterate.[13] Global eradication efforts including the use of pesticides, bed nets, and development of anti-malaria medications have controlled the transmission in some areas, but malaria remains pervasive in West and Sub-Saharan Africa (Figure 2).[5,6,12]

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Figure 2. Parasites carried by mosquitoes can transport malaria all over the world. Macrogametocyte from the Plasmodium falciparum parasite that may be ingested by a mosquito spreading the malaria virus. Courtesy of Mae Melvin of the Center for Disease Control, 2973, Wikimedia Commons. Public Domain. The plasmodium parasite has some unique characteristics such as the micronemes, the rhoptry, and the polar rings. Courtesy of Jfbrancj14, 212, Wikimedia Commons. CC BY-SA 3.0. Deaths from malaria in Africa in 2012 have been measured per million persons. Data from the World Health Organization groups them by deciles shown in the last figure here. Courtesy of Chris55, 2016, Wikimedia Commons. CC BY-SA 4.0. and the World Health Organization, 2012.

With **eradication** efforts underway, there is uncertainty about the impacts of climate change on the transmission of malaria in West Africa and other regions. Early research suggested that climate change would result in a "widespread increase in malaria transmission," but recent studies suggest that rather than increase, malaria transmission may shift in its global distribution.[8,13] The disagreement about climate change impacts can be attributed to the limited power of malaria models to properly assess rainfall-dependent processes as well as the difficulty in determining climate change implications in West Africa (Figure 3).[8,13]

Researchers from the Massachusetts Institute of Technology have developed a model to better characterize the relationship between rainfall patterns and mosquito populations.[13] The malaria vectors in Africa typically breed in pools of water formed from rainfall, so researchers sought to better understand the relationship between rainfall and mosquito **proliferation** by monitoring rainfall patterns and other environmental conditions.[7,13] The study utilized the Hydrology, Entomology, and Malaria Transmission Simulator (HYDREMATS) to translate rainfall into water pools, and estimate the impacts of climate change on malaria transmission in West Africa.[13] The simulation characterized the association between rainfall and mosquito abundances by evaluating precipitation, evaporation, infiltration, and topographical features in five representative locations in West Africa. Simulations were conducted using climate data from 1980-1999 to establish baseline climate conditions.[13] These

conditions were coupled with climate change projection data from varying climate change models provided by the **Intergovernmental Panel on Climate Change** (IPCC). Model outputs were measured in vectorial capacity (VC). Results from the simulation predicted a two to six degrees Celsius increase in temperature, and a high range of variability for rainfall from a decline of 400% to an increase of 260%.[13] In arid regions and very wet regions of West Africa, VC is predicted to increase, whereas in transitional zones of West Africa, VC is expected to decrease. Given the variability of rainfall predictions from HYDREMATS, it will be important to closely evaluate rainfall and its role in malaria transmission.[13]

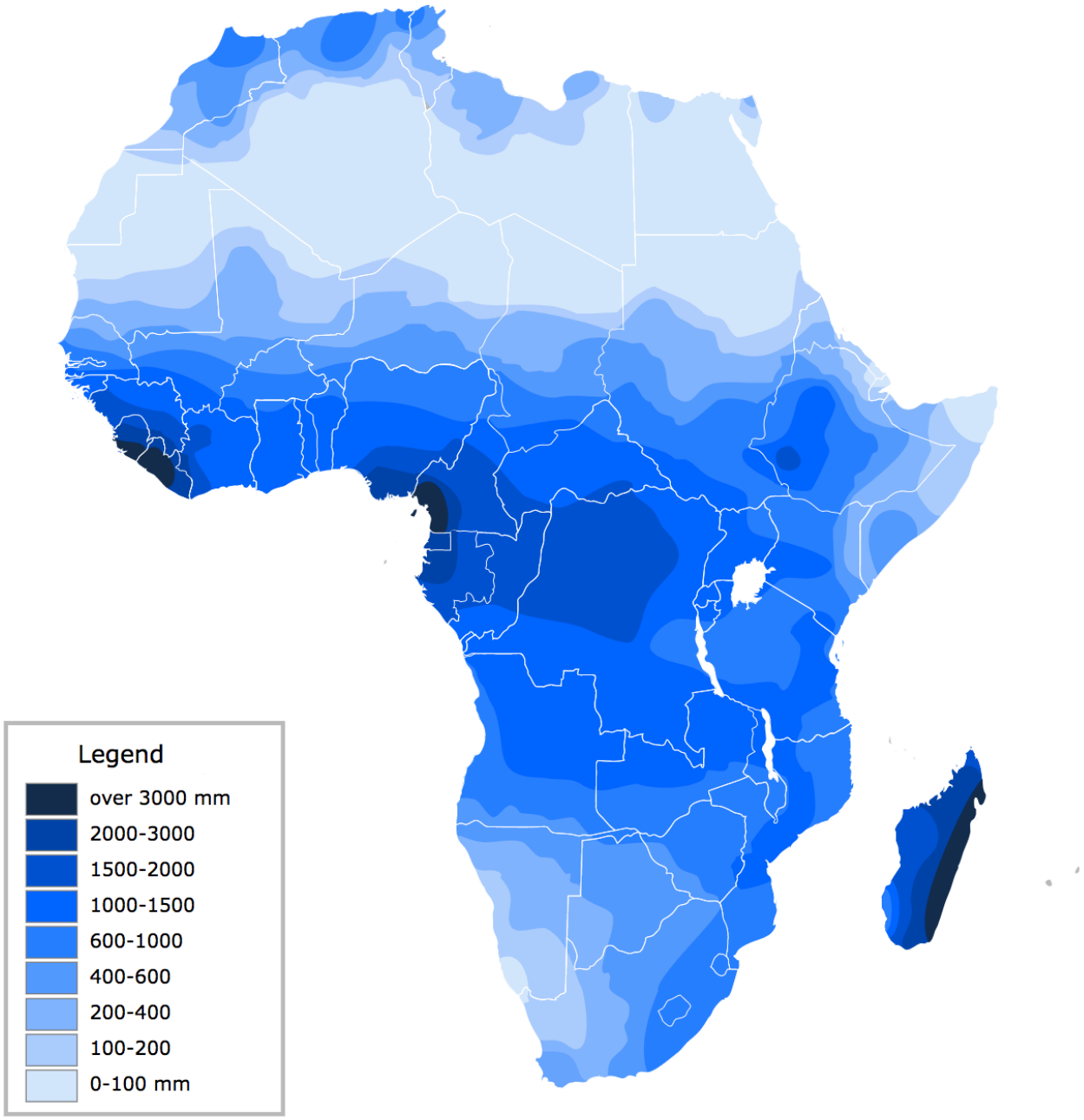

Figure 3. Africa Precipitation Map in millimeters. Courtesy of Delphi234, 2014, Wikimedia Commons. CC BY-SA 4.0.

The IPCC estimates that temperatures in West Africa will increase by nearly 4 degrees Celsius by 2080.[8] Changes in rainfall are slightly more difficult to predict, and the IPCC did not report official

values for precipitation. However, the IPCC predicts that West Africa can expect to see rising sea levels and variability in rainfall patterns.[8] Because mosquito proliferation is partially temperature-dependent, the IPCC suggests that drought (from rising temperatures and variable rainfall) could actually result in a decrease in the *Anopheles* mosquito populations in Africa.[8] Optimum temperatures for the development of the *Plasmodium* parasite in *Anopheles* mosquitoes are between 18 degrees Celsius and 32 degrees Celsius.[1] Below this range, parasite development decreases, and temperatures above this range appear to be unsuitable for mosquito survival.[1] However, Africa is home to the most virulent *Plasmodium* parasite species and the most persistent *Anopheles* mosquitoes, which can result in swift adaptations to new ecological niches including swamps or springs.[8] Moreover, a recent study suggests that fluctuating temperatures may not have a large effect on developmental rates of certain *Anopheles* mosquito species. Furthermore, extreme weather events and irregular rainfall patterns could provide opportunities for mosquito proliferation at unexpected times.[7]

Although there is uncertainty about the impacts of climate change on malaria transmission in West Africa, it is important to note that malaria is already highly endemic in the region. Thus, climate change will not be the sole factor to consider when developing strategies to combat malaria. According to a study published in 2011 that evaluated the opposing effects of climate change on malaria transmission when coupled with socioeconomic development, malaria risk will exhibit relatively no change in areas of West and Sub-Saharan Africa by 2050.[2] The model was created using spatial patterns, and researchers note that in regions where the **gross domestic product** (GDP) is less than $20,000, climate change could have a larger impact on malaria transmission.[2] These modeling results are expected considering that malaria is often exacerbated by poverty.[4,11,12] This study suggests that although climate change may not have a substantial impact on malaria transmission in West Africa, climate change coupled with socioeconomic burden may provide an additional hurdle for malaria eradication efforts.[2]

Figure 4. Mosquito Larva. Courtesy of Harry Weinburgh, Free Stock Photos. Public Domain.

The West African burden of malaria and the factors that influence transmission are multi-faceted and convoluted in nature. As the global implications of climate change become more apparent, experts expect that poor nations will unfortunately have a greater share of the hardship.[9] However, given the uncertainty of climate change impacts on malaria transmission, there is some hope that warming temperatures in West Africa may not exacerbate malaria transmission, but may rather play a role in slowing the rate of transmission.[8] Yet, with the coupling of extreme poverty, lack of public health infrastructure, limited data, and the strength of *Anopheles* mosquitoes as vectors, these claims are impractical given the current state in West Africa. Development of better climatic models, as well as financial and educational strategies to alleviate confounding factors of malaria transmission, are necessary to lessen the burden of malaria in West African countries and create healthier futures for the next generation.

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4.4 CLIMATE CHANGE EFFECTS MIGRATION PATTERNS OF ADELIE PENGUINS

Melissa L. Dick

Adélie Penguins are being forced to migrate thousands of miles in Antarctica due to climate change. Human activities are causing an effect in even these uninhabited zones. Will the increasing temperatures associated with climate change have a negative impact on the species or will these penguins continue to thrive in the Ross Sea?

Figure 1. Adelie Penguin at Shingle Cove in the South Orkneys of Antarctica. Photograph by Liam Quinn, 2011, FlickrCommons. CC BY-SA 2.0.

The Adélie Penguin population has significantly increased in the last 50 years, but many researchers believe that this current trend may not correlate to a positive future for the species. Adélie Penguins are one of the few animals that have adapted to live in the extreme environments of Antarctica, however they are highly sensitive to the effects of **climate change**. Adélie Penguins were discovered in 1840 by the French explorer Jules Dumont d'Urville.[3] Adélie Penguin colonies have been known to exist primarily around the Antarctic Peninsula, an 1,287 km (800 mile) long peninsula on the northern edge of the continent.[3,7] For many years, the Antarctic Peninsula provided perfect living conditions for Adélie Penguins due to the large amount of sea ice that formed in this area.[7,9,8,12,13]

Adélie Penguins are known for their ability to dive into deeper water than most predators in the surrounding oceans. Their main food source, krill, lives under the sea ice and are easy for the penguins

to reach due to their deep diving ability.[13] Without sea ice, Adélie Penguins must swim further and longer to find food, have no place to rest, and krill become easily accessible to other predators in Antarctica, which causes a food shortage for Adélie Penguins.[7,8]

In the last 50 years, the Antarctic Peninsula's yearly mean temperature has increased by over 2℃, making it one of the most rapidly warming regions in the Southern Hemisphere and the world.[1,7,8,9] The region has also experienced a rise in the mean winter temperature, as well as, the surface ocean.[8] This annual temperature increase has caused melting of sea ice, which has diminished the Adélie population on the peninsula by almost 90% in the past three decades.[9] The penguin populations rely on this sea ice, an approximately 70% ice cover is ideal for the species.[4] The increase in temperature and the resulting decrease in sea ice has caused the species to migrate from areas surrounding the Antarctic Peninsula to colder areas of Antarctica surrounding the Ross Sea.[7,8]

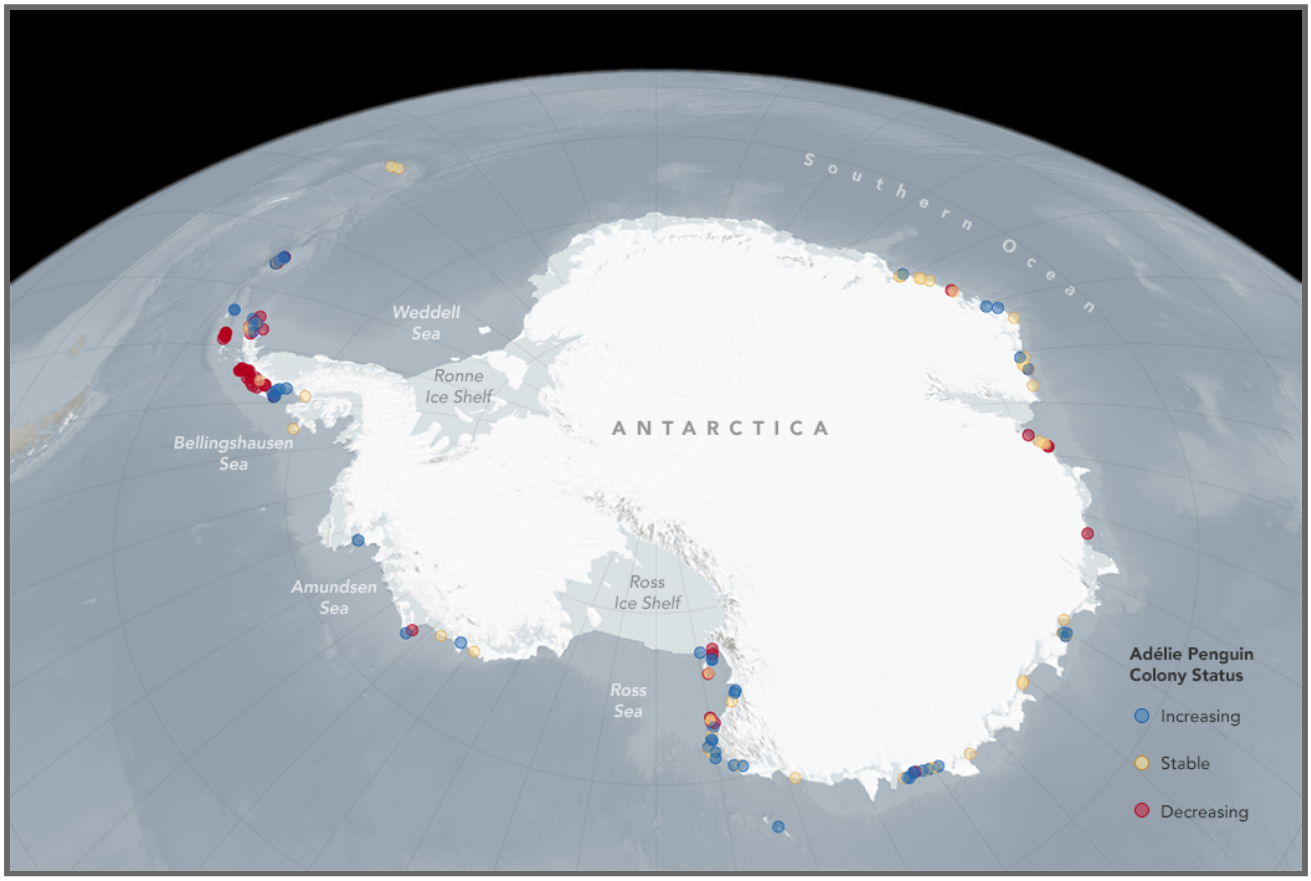

Figure 2. Breeding locations can typically be seen across the entire Antartic continent for the Adelie penguin. However, the Adelie Penguin's breeding areas will be altered due to climate change. This graphic shows how these movements may occur with time and what areas may be most vulnerable to the shifting regions climate trends. Courtesy of NASA's Earth Observatory, 2017. Public Domain.

Unlike the Antarctic Peninsula, the Ross Sea is a part of Antarctica that has not yet seen a decrease in sea ice in recent decades.[1,9] This area has not been as affected by climate change so its temperatures remain cold enough to maintain a large amount of sea ice.[9,11] Surprisingly, there has been an overall upward trend in sea ice in areas around the Ross Sea, thus making it a perfect new location for Adélie Penguin populations to settle.[9,11]

Thousands of Adélie Penguins have been forced to migrate to areas surrounding the Ross Sea to survive.[7,8] Penguins that inhabit these areas have endured extensive migrations, averaging 12,760 km (7,929 miles).[4] This migration results in a change of habitat for these penguins and has led to an

increase of their population.[5,7,9] According to ecologist Heather Lynch at Stony Brook University in Stony Brook, New York, the Adélie Penguin population now has 3.79 million breeding pairs, which is about 1.4 million more pairs than 20 years ago.[5]

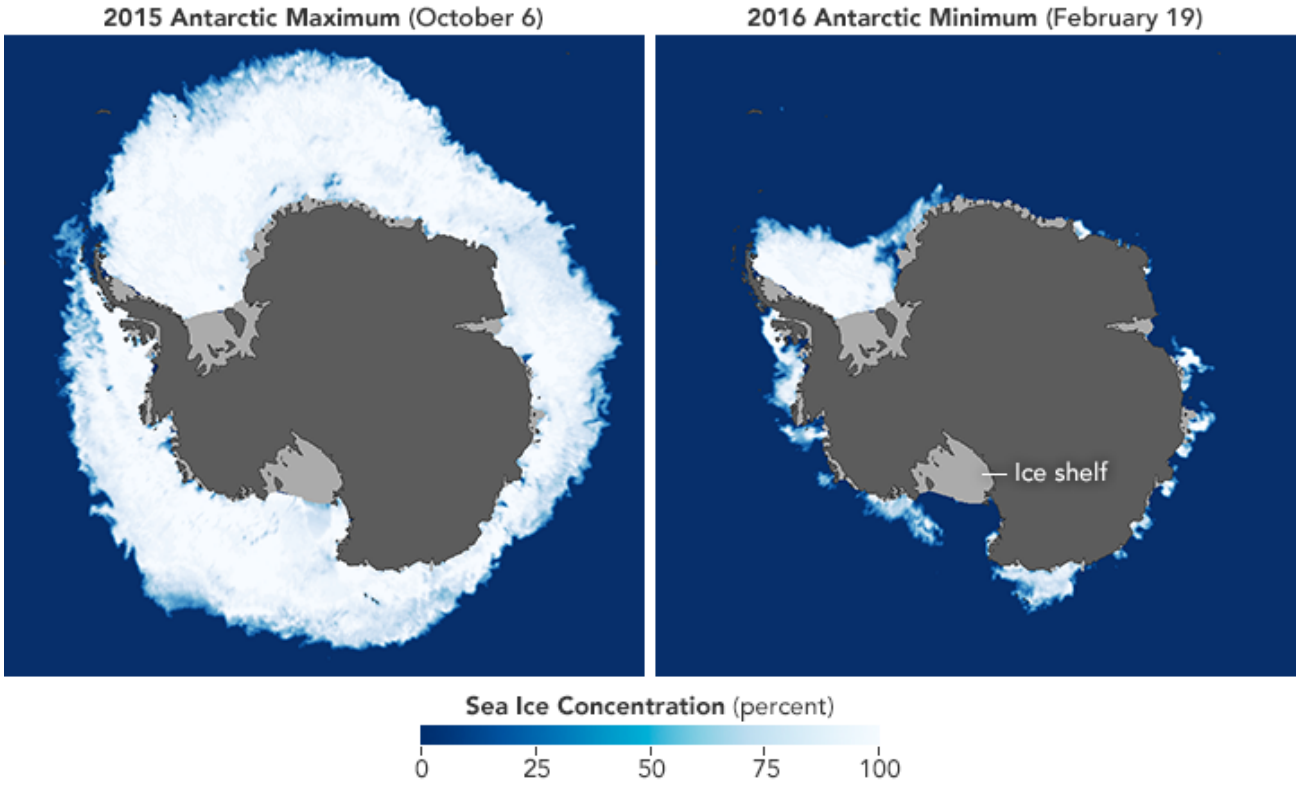

Figure 3. Seasonal Sea Ice Concentrations. Courtesy of Joshua Stevens, NASA, 2011. Public Domain.

Now that Adélie Penguins are thriving in areas around the Ross Sea, scientists consider if climate change will start to have a negative impact on the species in these areas. **Climate models** are used to better to gauge future changes in penguin habitats.[2] One of the most recent and accurate climate models was created by Dr. David Ainley, a Senior Ecological Associate at H.T. Harvey & Associates in San Jose, California.[2] The model was named the **Ensemble model**, and is used to help compare current conditions in the Ross Sea to conditions projected for when the Earth's average **tropospheric** temperature reaches 2°C above preindustrial levels (around 1860).[2] This model uses averages of several different models to determine when this will occur.[2]

The Ensemble model predicts that the Ross Sea's overall temperature will increase in the future.[2] The model indicates that the 2°C threshold will be reached between the years 2025-2052.[2] The Ensemble model also predicts a steady decrease in sea ice in the area (Figure 4).[2] Once the 2°C threshold is reached, there will be a decrease in the expanse and thickness of sea ice in the Ross Sea.[2] Fortunately, the Ross Sea mean annual temperature is currently about 10°C colder than the coast of East Antarctica, so it is projected to take hundreds of years until the Ross Sea area experiences habitat changes similar to the Antarctica Peninsula due to climate change.[2]

An interactive or media element has been excluded from this version of the text. You can view it online here:
https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=80

Figure 4. Although the upward trend in population, documented by several different researchers in last two decades,

appears promising, it is believed that the temperatures across Antarctica will continue to rise and melt sea ice in every part of the continent.[9] These habitat changes will lead to the eventual decline in penguin populations. The Ross Sea is projected to be the last place on Earth where sea ice will persist.[9] As of 2012, Adélie Penguins have been considered a near threatened species.[5] Due to the change in climate occurring in Antarctica, researchers such as Dr. Ainley believe that in the foreseeable future, the Adélie Penguin population will go from a near threatened species, to a status of more concern, such as vulnerable or endangered.[7]

It is up to humans to reduce actions that are causing climate change to aid in the survival of the Adélie Penguins. Human activities contribute to climate change by causing changes in the Earth's atmosphere in the amounts of greenhouse gases, aerosols, and cloudiness.[6,10] The largest known contribution of greenhouse gas is from the burning of **fossil fuels**, which releases carbon dioxide into the atmosphere.[6]The impact of climate change is global, even affecting Antarctica, which is mostly uninhabited by humans.[10]These effects are best observed by ozone depletion in Antarctica over the last few decades. Research conducted by NASA (1979-2003) and by the Royal Netherlands Meteorological Institute (2004-Present),demonstrate the **ozone hole** has grown from 1979-2003 (Figure 5).[10] The growth of the ozone hole suggests that climate change will continue to have a major effect on Antarctica until the development of fossil fuel alternatives.[6]Whether through government regulations or contributions made by individual people, it is up to humans to combat climate change so that Adélie Penguins continue to thrive in the Ross Sea.

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4.5 RED SEA CORAL REEDS SURVIVE AMIDST CLIMATE CHANGE

Hannah J. Kraus

While coral reefs throughout the world have been unable to survive for years due to continuous climate change, coral reefs in the Red Sea seem to be an exception. What enables certain species of coral reefs to live and thrive in the naturally warm waters of the Red Sea? Can these discoveries be applied to all coral reefs as climate change alters natural ecosystems?

Figure 1. Thriving underwater coral reef. Courtesy of joakant, 2009, Pixabay. Public Domain.

Coral reefs throughout the world have experienced the detrimental impacts of climate change.[2,3,5,6,7,9,10] As Earth continues to warm, it was thought that coral reefs around the world would eventually disappear.[10] However, scientists recently discovered large populations of coral reefs thriving in the deep waters of the Red Sea, which is a continuation of the Indian Ocean between Asia and Africa (Figure 2).[1,2,6,7,8] Coral reefs in the Red Sea are surviving in upwards of 20°C waters, temperatures that were previously thought by scientists to be too warm for coral reefs to survive.[7,8] These coral species are already adapted to the naturally warm waters of the Red Sea, and are therefore not disturbed by the recent rise in global temperatures, which is causing mass bleaching events.[1,2,3,6] Scientists previously thought coral reefs only resided in water temperatures below 12°C, but the recent discovery of flourishing coral reefs in the Red Sea, one of the warmest bodies of water on Earth, refutes this notion.[7] This new finding has provided scientists with hope that coral reefs will endure future climate change and continue to prosper on Earth.

Climate change hinders crucial processes that occur for coral reefs to survive and flourish.[2,5,9] Increasing air temperatures on Earth subsequently cause water temperatures to rise, creating an unlivable environment for many coral reefs.[2] Damage to the reefs typically occurs when water temperatures surpass the region's average summer air temperature by 0.5-1.5°C (0.9-2.7 °F).[2] Specifically, these high water temperatures cause the process of bleaching to occur.[2,4,5,7,9,20] Bleaching weakens the **symbiotic** relationship between the coral and the Symbiodinium dinoflagellates, algae that lives in the coral's tissues and provides energy to coral reefs.[2,4,5,6] The reduction of energy transmitted to coral reefs decreases **calcification** rates, a process vital for the construction and existence of coral reefs.[2,7] If destruction of coral reefs is occurring quicker than construction, coral reefs will eventually cease to exist. However, the discovery of coral reefs residing in the inherently warm Red Sea may give researchers hope for the future. By studying the characteristics of coral reefs in the Red Sea, scientists can determine how they are surviving in warmer water, and this may led to a breakthrough that can save other coral reefs around the world.

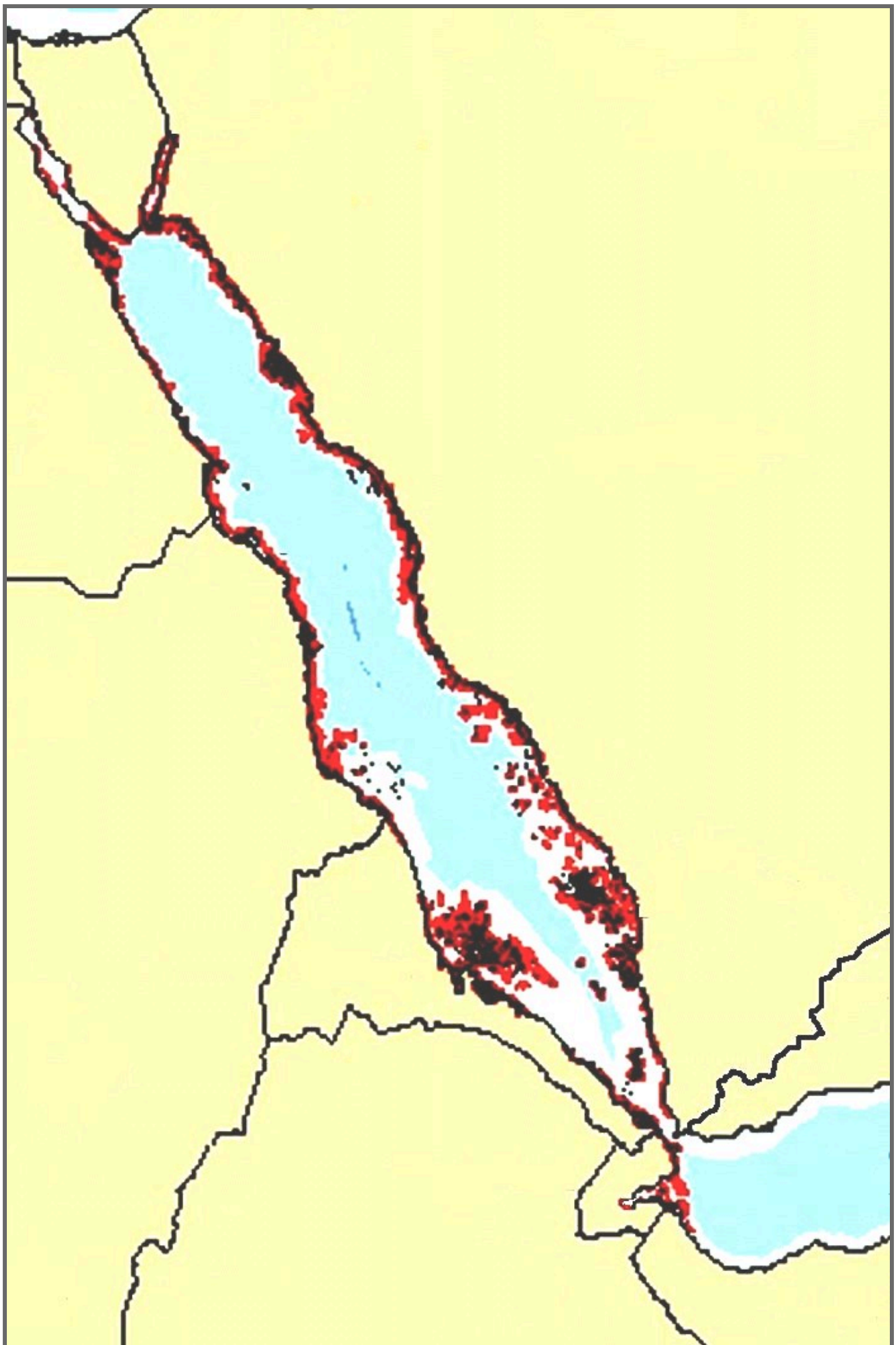

Figure 2. Coral Reefs located near the Red Sea. Courtesy of Lubiesque, 2013, Wikimedia Commons. CC BY-SA 3.0.

Scientists are examining the unique characteristics acquired by coral reefs in the Red Sea to determine what differentiates them for other coral reefs around the world.[1,2,3,5,6,7] A study conducted in 2013 examined three species of coral found in the Red Sea: *Eguchipsammia fistula*, *Dendrophyllia sp*, and an undetermined species of *Caryophyllidae* coral.[7] Researchers discovered that all three of these coral species had low rates of **metabolic** activity.[7] Additionally, *Eguchipsammia fistula* and the *Caryophyllidae* species had low calcification rates and *Eguchipsammia fistula* and *Dendrophyllia sp*. had low rates of respiration.[7] Because of naturally warm temperatures, the Red Sea has a low concentration of dissolved oxygen.[7,8]

Scientists believe that the species of coral living in the Red Sea adapted to the lack of oxygen by decreasing their metabolic rates.[7] Since these coral reefs are accustomed to the lower levels of oxygen in the water, they are not as affected by climate change as reefs in colder bodies of water.[7] The low calcification and respiration rates indicate the coral has adapted to the warmer temperatures of the Red Sea.[7] These corals compensate for the lack of oxygen and other nutrients in the warm water by decreasing their needed rates of calcification and respiration to survive.[7]

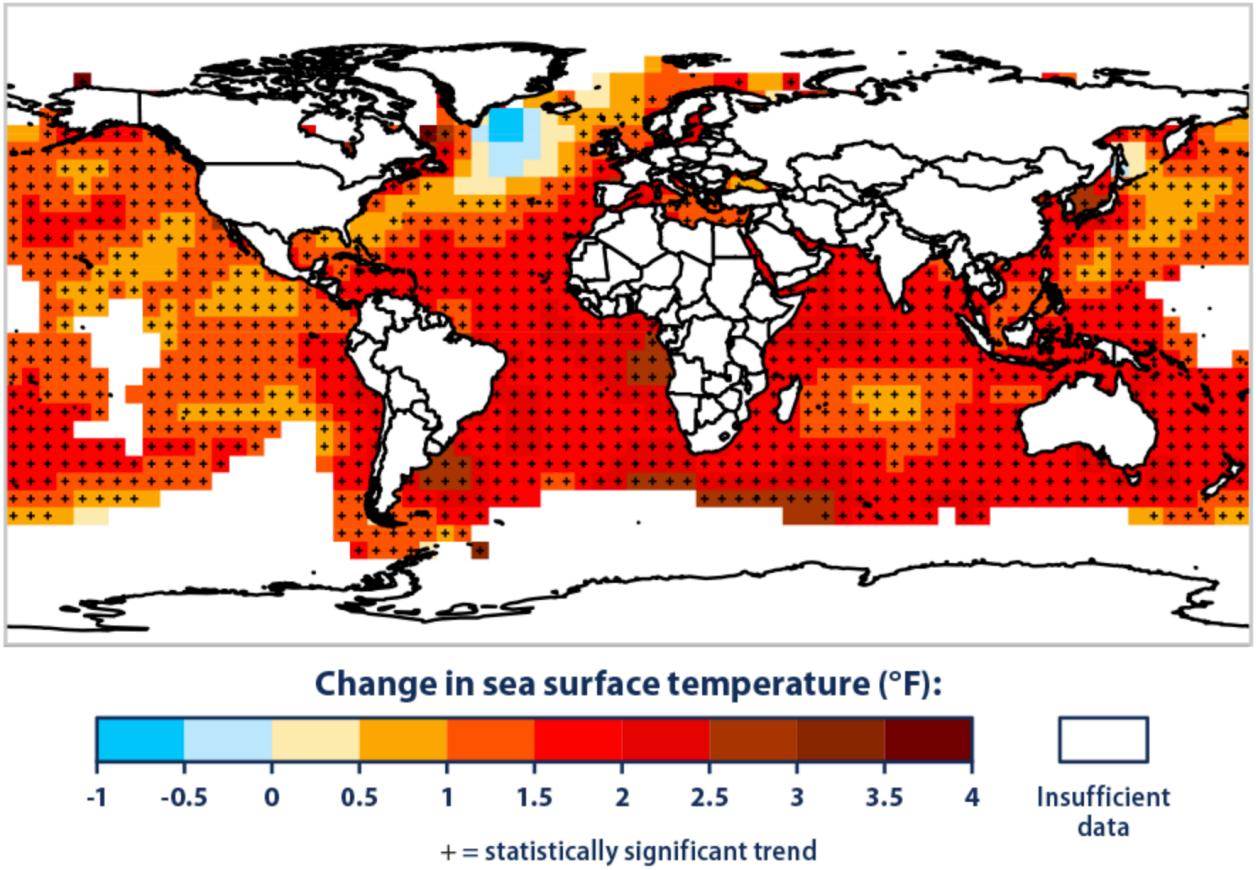

Figure 3. Change in Sea Surface Temperature, 1901-2015. Courtesy of U.S. EPA, data from IPCC and NOAA, 2016. Public Domain.

In a more recent study, the coral species *Pocillopora verrucosa* was observed in six different reefs throughout both the northern and southern regions of the Red Sea.[9] The researchers' goal was to understand the necessary biological processes used by the coral in warmer temperatures. An **in situ study** was conducted where pieces from each of the six coral reefs were taken, placed in incubators, and then measured in both the winter and summer.[9] Researchers focused on genetic aspects, calcification

and respiration rates, and photosynthesis rates of each coral species.[9] The results displayed high **acclimatization** to the water temperatures that nearly exceeded 31°C, but very little genetic adaptation.[9] This discovery indicates that the differences between coral reefs in the Red Sea and coral reefs elsewhere were phenotypic rather than **genotypic**.[9] Additionally, calcification rates were highest in temperatures ranging between 28°C-29°C (82-84 °F), temperatures formerly believed to be too warm for coral reefs.[9] This finding demonstrates that the *Pocillopora verrucosa* did not necessarily need to adapt to the water conditions of the Red Sea, but needed to make changes in its processes, implying this species has high plasticity.[9] Contrary to the Roder et al. study, the analysis of the *Pocillopora verrucosa* indicates that coral reefs in the Red Sea have not previously adapted to warmer temperatures, but rather formed the ability to maintain essential processes by changing how they survive.[9] While there are no definite answers, studies targeting different species of corals living in the Red Sea offer researchers a glimpse as to how these corals are surviving and continuously changing with their environment.

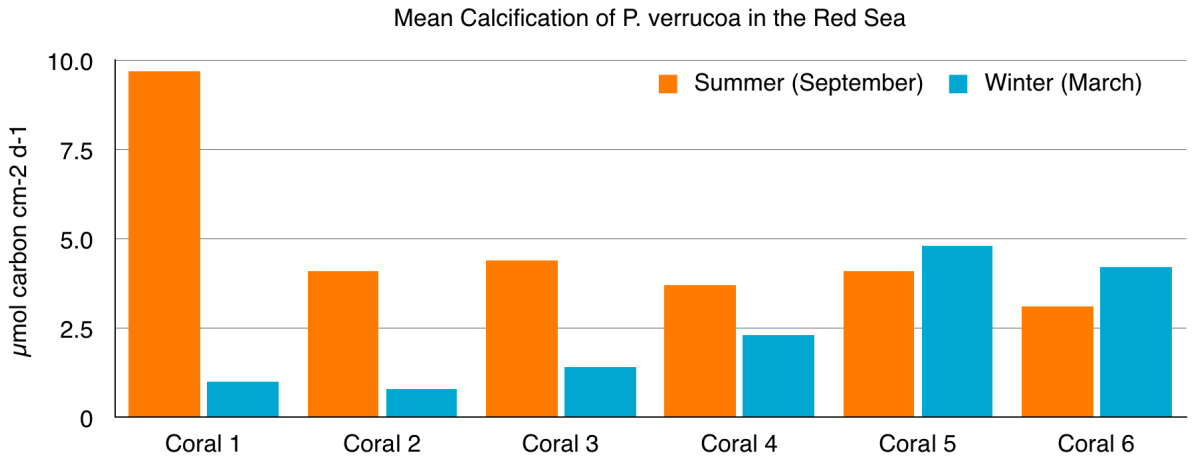

Figure 4. Sawall et al. performed an analysis of covariance on the data collected from the P. verrucoa coral tests in both the summer and winter months. Results concluded that the effect of the season, the effect of the latitude, and the interaction between these variables were all statistically significant. Data from Sawall et al., 2015.[9]

The discovery of coral reefs in the Red Sea contradicts the belief that corals cannot survive in temperatures above a certain threshold.[1,2,3,7,8,9] Even with relatively few studies conducted, researchers now have an idea of what separates the unique corals of the Red Sea from corals living in colder temperatures.[2,3,7] The corals in the Red Sea are accustomed to above-average temperatures, and are not affected by the detrimental impacts of climate change.[1,2,3,7] Although climate change is one of the most harmful factors to coral reefs today, Red Sea corals may provide possible solutions to combat the demise of coral reefs worldwide.

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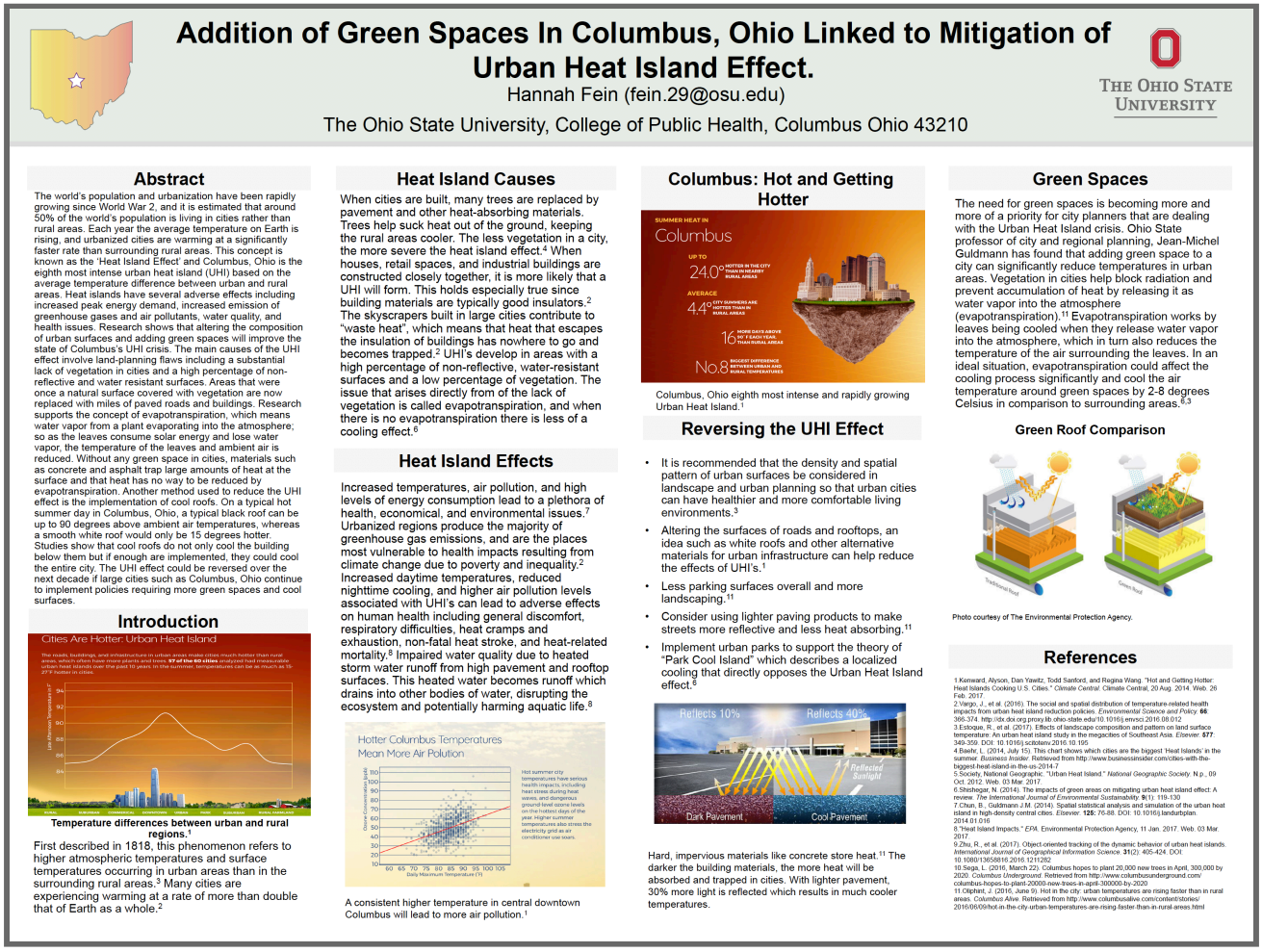
4.6 ADDITION OF GREEN SPACES IN COLUMBUS, OHIO LINKED TO MITIGATION OF URBAN HEAT ISLAND EFFECT



Addition of Green Spaces In Columbus, Ohio Linked to Mitigation of Urban Heat Island Effect.

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THE OHIO STATE UNIVERSITY

Abstract

The world's population and urbanization have been rapidly growing since World War 2, and it is estimated that around 50% of the world's population is living in cities rather than rural areas. Each year the average temperature on Earth is rising, and urbanized cities are warming at a significantly faster rate than surrounding rural areas. This concept is known as the 'Heat Island Effect' and Columbus, Ohio is the eighth most intense urban heat island (UHI) based on the average temperature difference between urban and rural areas. Heat islands have several adverse effects including increased peak energy demand, increased emission of greenhouse gases and air pollutants, water quality, and health issues. Research shows that altering the composition of urban surfaces and adding green spaces will improve the state of Columbus's UHI crisis. The main causes of the UHI effect involve land-planning flaws including a substantial lack of vegetation in cities and a high percentage of non-reflective and water resistant surfaces. Areas that were once a natural surface covered with vegetation are now replaced with miles of paved roads and buildings. Research supports the concept of evapotranspiration, which means water vapor from a plant evaporating into the atmosphere; so as the leaves consume solar energy and lose water vapor, the temperature of the leaves and ambient air is reduced. Without any green space in cities, materials such as concrete and asphalt trap large amounts of heat at the surface and that heat has no way to be reduced by evapotranspiration. Another method used to reduce the UHI effect is the implementation of cool roofs. On a typical hot summer day in Columbus, Ohio, a typical black roof can be up to 90 degrees above ambient air temperatures, whereas a smooth white roof would only be 15 degrees hotter. Studies show that cool roofs do not only cool the building below them but if enough are implemented, they could cool the entire city. The UHI effect could be reversed over the next decade if large cities such as Columbus, Ohio continue to implement policies requiring more green spaces and cool surfaces.

Introduction

Temperature differences between urban and rural regions.[1]

First described in 1818, this phenomenon refers to higher atmospheric temperatures and surface temperatures occurring in urban areas than in the surrounding rural areas.[3] Many cities are experiencing warming at a rate of more than double that of Earth as a whole.[2]

Heat Island Causes

When cities are built, many trees are replaced by pavement and other heat-absorbing materials. Trees help suck heat out of the ground, keeping the rural areas cooler. The less vegetation in a city, the more severe the heat island effect.[4] When houses, retail spaces, and industrial buildings are constructed closely together, it is more likely that a UHI will form. This holds especially true since building materials are typically good insulators.[2] The skyscrapers built in large cities contribute to "waste heat", which means that heat that escapes the insulation of buildings has nowhere to go and becomes trapped.[2] UHI's develop in areas with a high percentage of non-reflective, water-resistant surfaces and a low percentage of vegetation. The issue that arises directly from of the lack of vegetation is called evapotranspiration, and when there is no evapotranspiration there is less of a cooling effect.[6]

Heat Island Effects

Increased temperatures, air pollution, and high levels of energy consumption lead to a plethora of health, economical, and environmental issues.[7] Urbanized regions produce the majority of greenhouse gas emissions, and are the places most vulnerable to health impacts resulting from climate change due to poverty and inequality.[2] Increased daytime temperatures, reduced nighttime cooling, and higher air pollution levels associated with UHI's can lead to adverse effects on human health including general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality.[8] Impaired water quality due to heated storm water runoff from high pavement and rooftop surfaces. This heated water becomes runoff which drains into other bodies of water, disrupting the ecosystem and potentially harming aquatic life.[8]

A consistent higher temperature in central downtown Columbus will lead to more air pollution.[1]

Columbus: Hot and Getting Hotter

Columbus, Ohio eighth most intense and rapidly growing Urban Heat Island.[1]

Reversing the UHI Effect

- It is recommended that the density and spatial pattern of urban surfaces be considered in landscape and urban planning so that urban cities can have healthier and more comfortable living environments.[3]
- Altering the surfaces of roads and rooftops, an idea such as white roofs and other alternative materials for urban infrastructure can help reduce the effects of UHI's.[1]
- Less parking surfaces overall and more landscaping.[11]
- Consider using lighter paving products to make streets more reflective and less heat absorbing.[11]
- Implement urban parks to support the theory of "Park Cool Island" which describes a localized cooling that directly opposes the Urban Heat Island effect.[6]

Hard, impervious materials like concrete store heat.[11] The darker the building materials, the more heat will be absorbed and trapped in cities. With lighter pavement, 30% more light is reflected which results in much cooler temperatures.

Green Spaces

The need for green spaces is becoming more and more of a priority for city planners that are dealing with the Urban Heat Island crisis. Ohio State professor of city and regional planning, Jean-Michel Guldmann has found that adding green space to a city can significantly reduce temperatures in urban areas. Vegetation in cities help block radiation and prevent accumulation of heat by releasing it as water vapor into the atmosphere (evapotranspiration).[11] Evapotranspiration works by leaves being cooled when they release water vapor into the atmosphere, which in turn also reduces the temperature of the air surrounding the leaves. In an ideal situation, evapotranspiration could affect the cooling process significantly and cool the air temperature around green spaces by 2-8 degrees Celsius in comparison to surrounding areas.[6,3]

Green Roof Comparison

Photo courtesy of The Environmental Protection Agency.

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Poster by student author Hannah Fein.

Climate change affects a variety of ecosystems and species, as seen in the previous sections. When temperatures

begin to rise, we see phenomena including glacier retreat, increasing disease risks, and altered migration patterns. Another affect, the urban heat island, is described in this student created poster.

Read the entire transcript of the poster below to learn more about the urban heat island effect in Columbus, Ohio.

Abstract:

The world's population and urbanization have been rapidly growing since World War 2, and it is estimated that around 50% of the world's population is living in cities rather than rural areas. Each year the average temperature on Earth is rising, and urbanized cities are warming at a significantly faster rate than surrounding rural areas. This concept is known as the 'Heat Island Effect' and Columbus, Ohio is the eighth most intense urban heat island (UHI) based on the average temperature difference between urban and rural areas. Heat islands have several adverse effects including increase peak energy demand, increased emission of greenhouse gases and air pollutants, water quality and health issues. Research shows that altering the composition of urban spaces and adding green spaces will improve the state of Columbus' UHI crises. The main causes of the UHI effect involve land-planning flaws including a substantial lack of vegetation in cities and a high percentage of non-reflective and water resistant surfaces. Areas that were once a natural surface covered with vegetation are now replaced with miles of paved roads and buildings. Research supports the concept of evapotranspiration, which means water vapor from a plant evapotranspiration, which means water vapor from a plant evaporating into the atmosphere; so as the leaves consume solar energy and lose water vapor the temperature of the leaves and ambient air is reduced. Without any green space in cities, materials such as concrete and asphalt trap large amounts of heat at the surface and that heat has no way to be reduced by evapotranspiration. Another method used to reduce the UHI effect is the implementation of cool roofs. On a typical hot summer day in Columbus, Ohio a typical black roof can be up to 90 degrees above ambient air temperatures, whereas a smooth white roof would only be 15 degrees hotter. Studies show that cool roofs do not only cool the building below them but if enough were implemented, they could cool the entire city. The UHI effect could be reversed over the next decade if large cities such as Columbus, Ohio continue to implement policies requiring more green spaces and cool surfaces.

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Heat Island Effects:

Increased temperatures, air pollution, and high levels of energy consumption lead to a plethora of health, economical, and environmental issues.[7] Urbanized regions produce the majority of greenhouse

gas emissions, and are the places most vulnerable to health impacts resulting from climate change due to poverty and inequality.[2] Increased daytime temperatures, reduced nighttime cooling, and higher air pollution levels associated with UHI's can lead to adverse effects on human health including general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality.[8] Impaired water quality due to heated storm water runoff from high pavement and rooftop surfaces. This heated water becomes runoff which drains into other bodies of water, disrupting the ecosystem and potentially harming aquatic life.[8] Figure 2: graph of hotter Columbus temperatures mean more air pollution showing the ozone concentration vs. the daily maximum temperature. A consistent higher temperate in central downtown will lead to more air pollution.[1]

Columbus: Hot and Getting Hotter:

Columbus is the eighth more intense and rapidly growing Urban Heat Island.[1] Up to 24 degrees hotter in the city than in nearby rural areas. On average 4.4 degrees city summers are hotter than rural areas. 26 more days above 90 degrees F each year than rural areas. Number 8 biggest difference between urban and rural temperatures.

Reversing the UHI Effect:

- It is recommended that the density and spatial pattern of urban surfaces be considered in landscape and urban planning so that urban cities can have healthier and more comfortable living environments.[3]
- Altering the surfaces off roads and rooftops, an idea such as white roofs and alternative materials for urban infrastructure can help reduce the effects of UHI's.[1]
- Less parking surfaces overall and more landscaping.[11]
- Consider Ising lighter paving products tp make street more reflective and less heat absorbing.[11]
- Implement urban parks to support the theory of "Park Cool Island" which describes a localized cooling that directly opposes the Urban Heat Island effect.[6]

Figure showing a dark pavement reflecting 10% of sunlight and a cool pavement reflecting 40% of sunlight. Hard impervious materials like concrete store heat.[11] The darker the building materials, the more heat will be absorbed and trapped in cities. With lighter pavement, 30% more light is reflected which results in much cooler temperatures.

Green Spaces:

The need for green spaces is becoming more and more of a priority for city planners that are dealing with the Urban Heat Island crisis. Ohio State professor of city and regional planning, Jean-Michel Guldmann has found that adding green space to a city can significantly reduce temperatures in urban areas. Vegetation in cities help block radiation and prevent accumulation of heat by releasing it as water vapor into the atmosphere (evapotranspiration).[11] Evapotranspiration works by leaves being cooled when they release water vapor into the atmosphere, which in turn also reduces the temperate of the air surrounding the leaves. In an ideal situation, evapotranspiration could affect the cooling process significantly and cool the air temperate around the green spaces by 2-8 degrees Celsius in comparison to surrounding areas.[3,6] Figure showing a green roof comparison with a traditional roof and a green roof courtesy of the Environmental Protection Agency.

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SUSTAINABILITY

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5.1 JAPAN'S ENVIRONMENTAL CHALLENGES AND ENERGY FUTURE

Christopher T. Hauer

Can Japan continue to thrive as an import-focused nation and what are the prospects like for nuclear power in the country? What alternatives have the Japanese government and its citizens proposed? What are the geopolitical implications of Japan's energy future?

Figure 1. Fukushima Nuclear Power Plant. Courtesy of Kawamoto Takuo, 1999, Wikimedia Commons. CC BY 2.0.

Japan has emerged from the tumult of the mid-20th century as one of the world's leading economic and cultural powerhouses. Japan does not currently have access to any significant fossil fuel source, so they must import most of their oil from other countries.[2,3] Japan's crude oil imports have recently decreased,[4] but this does not necessarily signal a shift away from imports, rather, the country's declining population size and overall lower energy consumption appear to serve as better explanations for this phenomenon.[2,4] **Nuclear power** has been considered an alternative solution to relying on energy imports, but there is significant concern over the safety of this option after the 2011 **Fukushima Daiichi nuclear disaster**.[2,3] The Japanese government faces the difficult task of reconciling public opinion towards nuclear energy with the reality of being a country that relies heavily on imports.[2,3,9] Research into alternative methods of energy production has increased, as has the significance of environmental policy implementation in Japan.

The Fukushima Daiichi nuclear disaster has understandably swayed public perception away from the use nuclear power.[2,3] The Fukushima disaster was caused by a magnitude 9.0 earthquake, and subsequent tsunami off the coast of Honshu Island.[2] This led to the full meltdown of three **nuclear reactors**, the loss of 17.3% of Japan's total electricity capacity, and around 20,000 dead or missing.[2] Nuclear power in Japan must be considered in the context of a country attempting to break away from its dependency on other nations for its energy. Immense import expenditures also hurt its economy.[3] Statistically, nuclear power is safer than other means of electricity generation,[3] and it may be in Japan's best interests to continue investing in nuclear power. Despite currently having only two operational reactors, the Japanese government indicates that it will shift focus away from nuclear power and concentrate on coal and **liquid natural gas** (LNG).[1,2,9] Scaling back nuclear power without fully abandoning it and focusing on domestic energy production seems to be a healthy and likely compromise.

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https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=87

Figure 2. Diagram of the Fukushima Nuclear Power Plant accidents. The Fukushima Nuclear Power Plant disaster occurred as a result of a magnitude 9.0 earthquake. This resulted in the full meltdown of three nuclear reactors. Click on each icon near the reactor numbers to read the damages sustained to each reactor.

Methane hydrate reserves located around the **Nankai Trough** present a unique opportunity for Japan to foster commercial interest in a legitimate domestic energy source.[10] These reserves were first extracted in 2013 underneath the Nankai Trough seabed, and Japan has already invested hundreds of millions of dollars into studying these reserves.[10] The relationship between methane, a greenhouse gas, and anthropogenic climate change is worth investigating in this context. Gas hydrate reserves contain comparatively less carbon than fossil fuels such as coal, which is important when considering humanity's desire to lower carbon emissions.[10] The progression from high-carbon to low-carbon sources of energy favors the combustible ice reserves located in the Nankai Trough because methane is a hydrocarbon with the lowest carbon intensity.[7] Research shows that even one-thousandth of the world's supply of methane hydrate would satisfy the global energy demand for one year.[1] The total gas reserves off the coast of Japan are equivalent to 40-63 times the nation's natural gas consumption in 2012.[1] There are risks, however, in that gas hydrates located underwater produce immense pressure when released, which could cause damage to the underwater environment. Specifically, the Nankai Trough is susceptible to earthquakes, due to its location near the intersection of the Philippine and Eurasian Sea Plates.[6] The main goal of Japanese research and development of the methane hydrate

program is to achieve commercial production by 2018, while continuing to evaluate the environmental impact and potential risks of such a venture.[10]

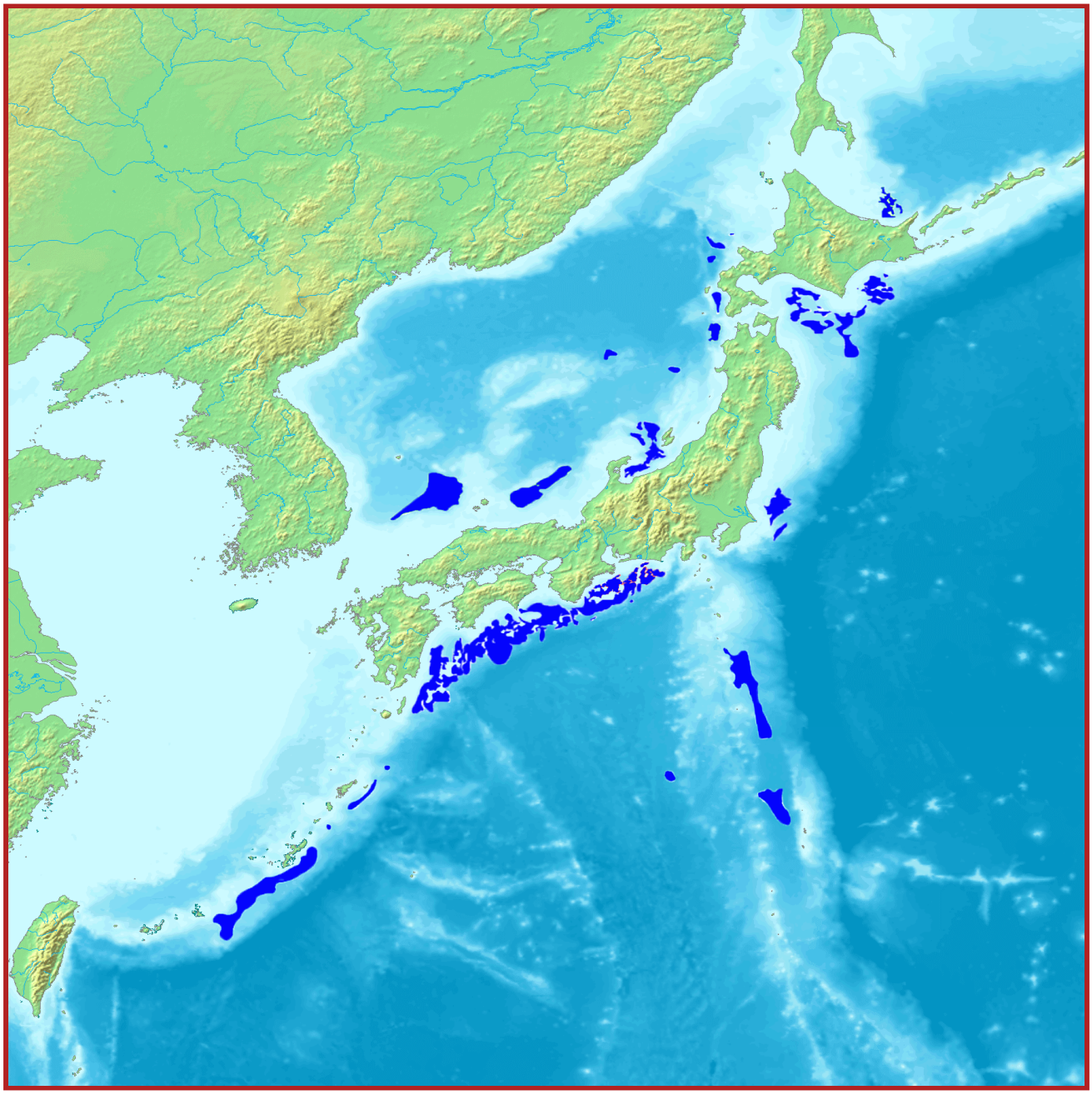

Figure 3. Methane hydrate located around Japan's islands. Courtesy of Jakounezumi, 2016, Wikimedia Commons. CC BY 3.0.

Japan has historically had a complicated history with environmental policy, both domestically and internationally. In adherence with the **Kyoto Protocol**, Japan has implemented national policies that have placed a greater focus on combating climate change, but their greenhouse gas emissions continue to be an issue.[8] Prefectural local governments have become increasingly active in instituting policies that address environmental issues.[8] While subnational governments in Japan are becoming more attentive to climate change, it has not translated to success in stimulating non-governmental organizations and individual citizens into making concerted efforts to decrease their emissions.[8] Environmental and energy policies in Japan will require synergy between all levels of government and

society, and will necessitate both government subsidies and civilian investment to achieve tangible results.[8] The Japanese government has historically stepped in to address domestic health issues and promote environmentally conscious solutions with mixed results. The Act on the Promotion of Effective Utilization of Resources was amended in 2001 in an effort to reduce waste produced by electronic equipment such as personal computers and LCD screens.[11] The domestic disposal rate was reduced, but Japan began exporting more electronic waste to other developing countries.[11]

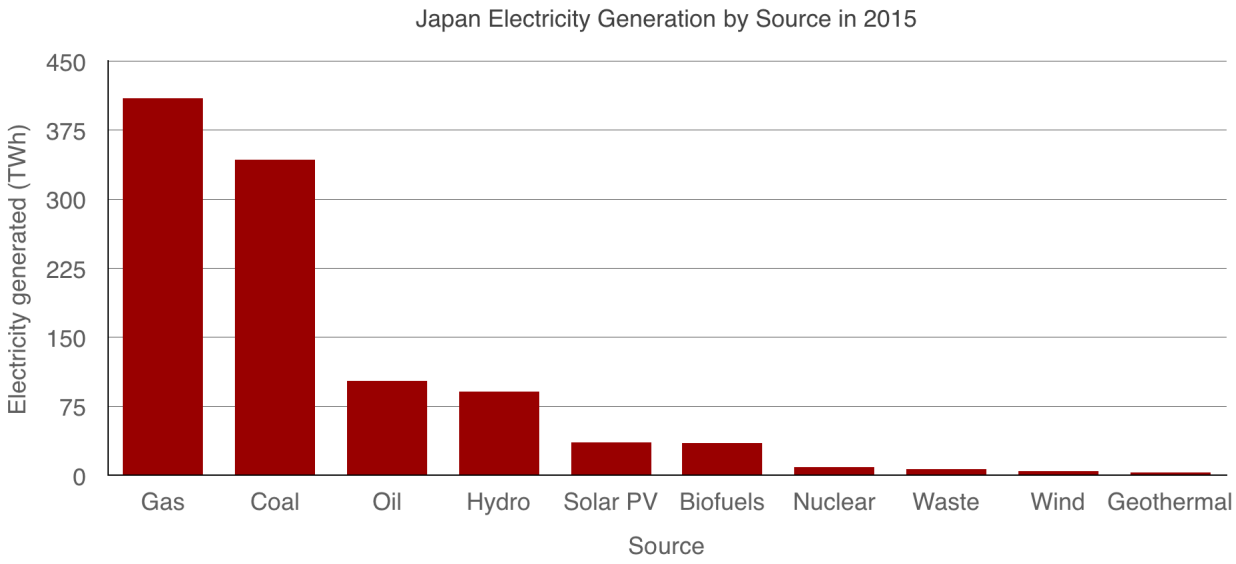

Figure 4. Japan Electricity Generation by Source in 2015. Data from the International Energy Agency, 2015. Public Domain.

Japan is effective at addressing problems, but they have not had the same success when it comes to preventing problems. The proportion of lung cancer in Japan has slowly been increasing since 1993, but deaths caused by lung cancer have decreased since 1996.[5] This is a trend with other types of cancer in the country, where there is a noticeable increase in incidence and decrease in mortality.[5] Although the decrease in mortality is laudable and can be attributed to improved detection and treatment, the increase in incidence can be attributed to a failure to properly address risk factors that lead to cancer.[5] The Japanese government instituted the Basic Plan to Promote Cancer Control Programs in 2007, but it has not had a statistically significant impact on the decrease in incidence rates.[5] The same can be said of their approach to environmental policy, which is why it will be important for the country to take more preventative steps so that they are as prepared as possible for any future challenges.

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5.2 DECIDING TO RECYCLE: A PSYCHOLOGICAL PERSPECTIVE

Rebecca L. Sallade

What encourages individuals to recycle? Are their actions influenced by their beliefs or other actions? Intrinsic and extrinsic motivators work together to lead to pro-environmental behavior in the United States.

Figure 1. Aluminum soda can on a wooden dock. Courtesy of Skitterphoto, 2015, Pixabay. Public Domain.

In recent years, the global community has attempted to boost the motivation to recycle in various ways. The United States has tried to encourage pro-environmental behavior, but the results have not been radically significant. However, it is important to understand what influences pro-environmental behavior so that more communities can utilize these tactics to achieve better results. Both intrinsic and

extrinsic factors need to be considered, and various theories are available to promote environmental health (Figure 3).

In the **Theory of Planned Behavior**, values, beliefs, and other intrinsic values all contribute to whether or not an individual decides to participate in pro-environmental behavior.[4,5] Deep beliefs and values often result in behavior, and studying what individuals value can give an insight about their environmental mindset.[6] The Theory of Planned Behavior helps predict what intentions will turn into actions, and the degree of control a person has over what intentions turn into actions.[4,5] This theory is more effective when an individual's environment and emotions are taken into account.[2] Decision making stems from the ability to understand one's beliefs; the greater the clarity, the more likely an individual is to carry out the action.[2] Understanding emotional intelligence can help determine how an individual adapts to their environment, and this can lead to the identification of what emotions were triggered by intrinsic motives.[2] According to the theory, different interpretations can arise from the same situation, thus, researching the context can help clarify the cognitive process.[6]

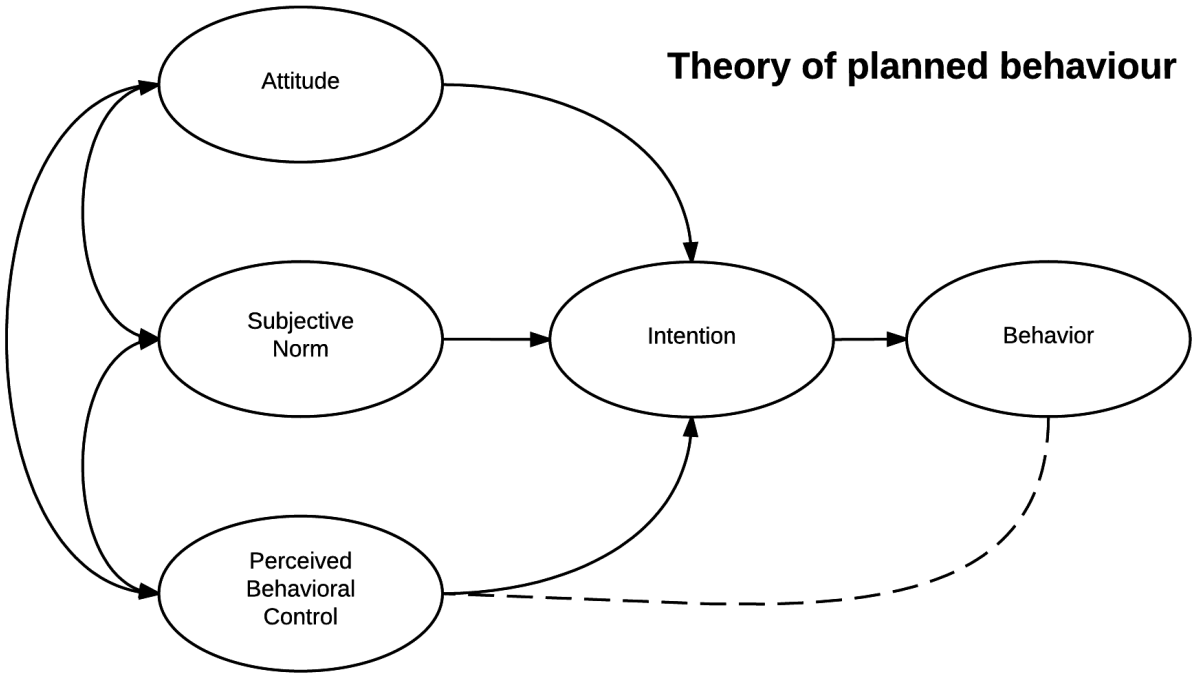

Figure 2. The Theory of Planned Behavior links beliefs to behaviors. Courtesy of Robert Orzanna, 2015, Wikimedia Commons. CC BY-SA 4.0.

In comparison, the **self-determination theory** can also be utilized to help predict the likelihood of pro-environmental actions.[6] This theory describes motivated behavior as part of a continuum that ranges from autonomous to controlled actions.[6] This continuum consists of intrinsic, integrated, identified, introjected, and extrinsic constructs.[6] Another intrinsic motivator is the **warm-glow effect**, which consists of personal satisfaction and altruistic motives that benefit the well-being of others.[1] Individuals "feel good" for partaking in pro-environmental behaviors and continue to repeat the activities regardless of extrinsic rewards.[1]

However, extrinsic motivators are just as important to the decision making process.[3] Common extrinsic motives include monetary and social rewards, such as tax breaks and a good reputation.[1,3] On many occasions, individuals are not likely to recycle because of the time cost, the lack of monetary

reward, and possible charges associated with recycling.[1] It is understandable that less people are likely to recycle when given this situation.[1,4] Individuals are more likely to recycle in the workplace rather than their households due to the direct "visible" cost from home bills.[5] Consumerism causes excess waste while nothing is being done to reduce the disposables.[4] Social norms may also play a large part in this process, as individuals attempt to conform to ideal perceptions and thus their behaviors are altered.[1] **Conformity** is a very relevant extrinsic motivator, and different organizations in the United States are attempting to spread pro-environmental behavior throughout the culture.[1] In many communities, the majority of the population has adapted an anthropogenic, or human-based perspective, and have little to no concern about the wellbeing of their environment.[2] Social norms contribute to the percentage of the United States population that chooses to engage in pro-environmental behavior.[4] Norms can predict actions and are also said to be the antecedents of certain attitudes.[1,4] Attitudes, subjective norms, moral norms, and perceived behavioral controls generate environmental intentions, which in turn can result in actions, such as recycling.[4] Other factors that contribute to the process include an environmental worldview and surrounding social influence.[6] An individual's worldview contributes to behavioral demonstration while social norms influence behavioral intention.[1,6] Both factors are necessary for optimal pro-environmental behaviors.[1,6] In most cases, the peer effect seems to be the most effective factor.[1] The effect contributes to the **kerbside scheme**, which solidifies norms, provides the means for a behavior, and can sometimes give a warm-glow effect.[1] The scheme provides norm awareness, and most of the people in a society will try to conform.[1] Displaying **pro-social behavior** is important to "fit in", and recycling (or the lack of recycling) can be a result of this phenomenon.[3]

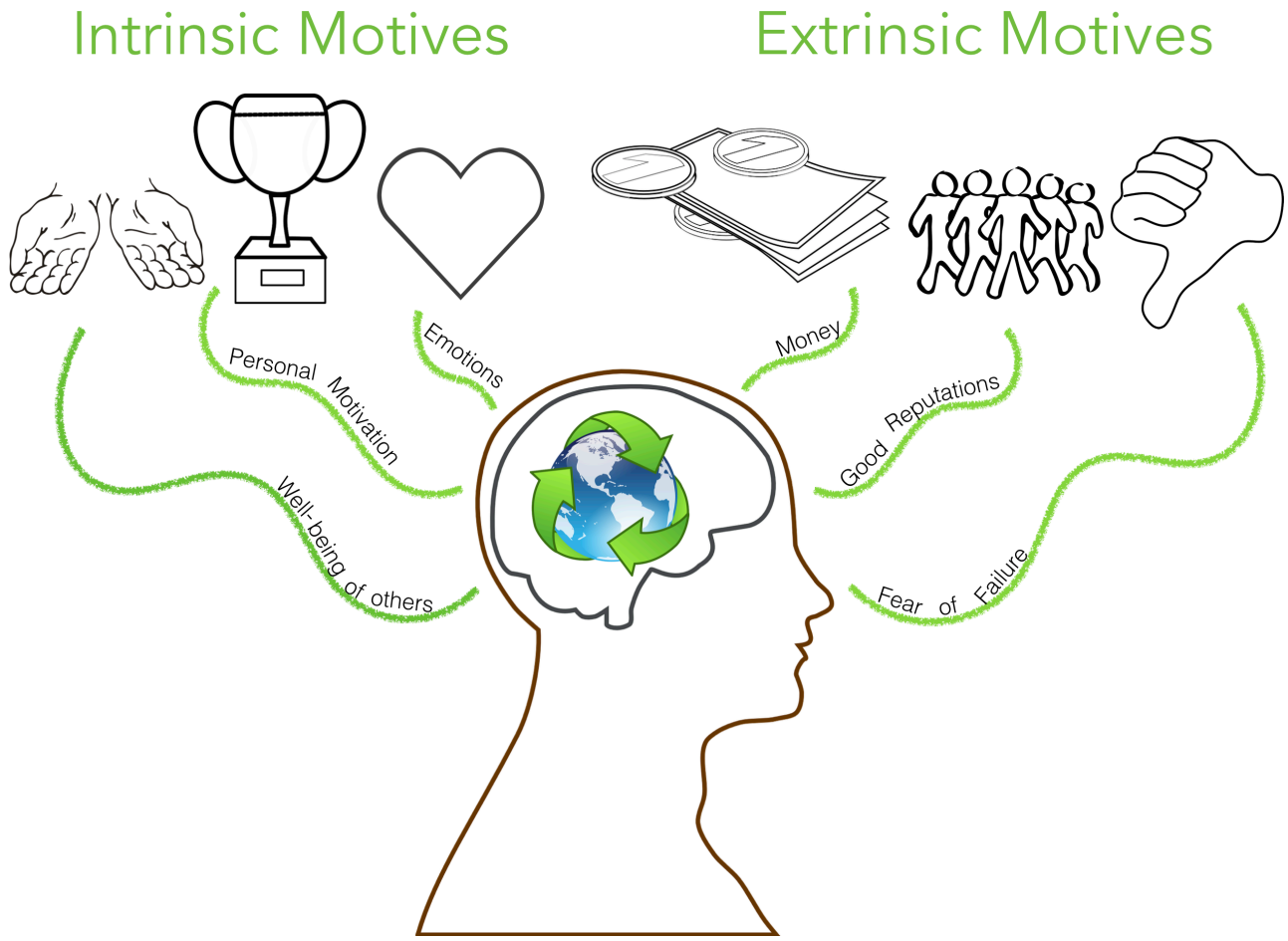

Figure 3. Both intrinsic motives, like emotional well-being, and extrinsic motives, like financial well-being, influence the behavior of individuals and groups. It is important to consider as many of these motives as possible when seeking to explain human behavior. Figure created by Ella M. Weaver with graphics collected from Pixabay, Public Domain. (References below)

Over the years, the United States has implemented various programs and awareness campaigns to try to make recycling a pro-social behavior, but the results have not been as significant as the country originally hoped. The average American still produces 1,600 pounds of trash annually, and although environmentally-friendly programs have attempted to encourage recycling to control this, the amount of trash produced is still an issue.[7] Various programs have made it their mission to encourage recycling, however not enough campaigns have made an effort to reduce the initial amount of waste.[3] Consumers are more likely to buy what is convenient, so education about what to buy and how to dispose of it is crucial.[8] Changing human behavior is the first step; educating people could help them reconsider their actions, and pro-environmental efforts may become more common.[5] Morris (2011) emphasizes how recycling can be made worthwhile through monetary reward programs, family-oriented goals, and conveniences like homemade fertilizer.[7] Morris (2011) also provides solutions for recycling electronic waste, which utilize monetary rewards and are crucial because the buildup of electronic waste is potentially the most harmful.[7] Electronic waste makes up 70% of the toxic material in landfills.[7]

Through the promotion and adoption of pro-environmental behaviors such as recycling, individuals can reduce the consumption and waste of natural resources and energy.[4,7] However, a great percentage of the United States population does not view environmental problems as moral concerns, and because of this fewer actions are taken to promote environmental health. To improve this, morals, norms,

and intrinsic motivators must be utilized to make social changes. Abbott (2013) also argues that the focus of awareness should be on the voluntary nature of pro-environmental behaviors instead of mandatory aspects.[1] However, the different control levels of motivation are likely to yield only temporary results.[6,8] The **temporal construal theory** articulates how competing motivations can change over time, thus short-term goals are likely to interfere with long-term plans.[8] Because of this, acting on "here and now" goals are said to be more effective.[8] Understanding the relationship between short and long-term goals is a paramount to developing effective policies. It is important to realize that automatic evaluations, or impulses, can drive actions of individuals.[8] This can be depicted through recycling campaigns, Earth Day, and other pro-environmental movements. The effects are likely to last for a short amount of time, yet society will get a warm-glow effect from the behaviors that they undertake.[1,3] **Goal priming** is also a motivator, and Tate's (2014) study emphasizes that using goal priming led to more environmentally-friendly goals.[8] Examples such as available recycling bins, green packaging, posters, and other subliminal priming paradigms have been successful in many studies.[8] An increased cognitive accessibility of pro-environmental behavior has led to more effective behaviors.[8]

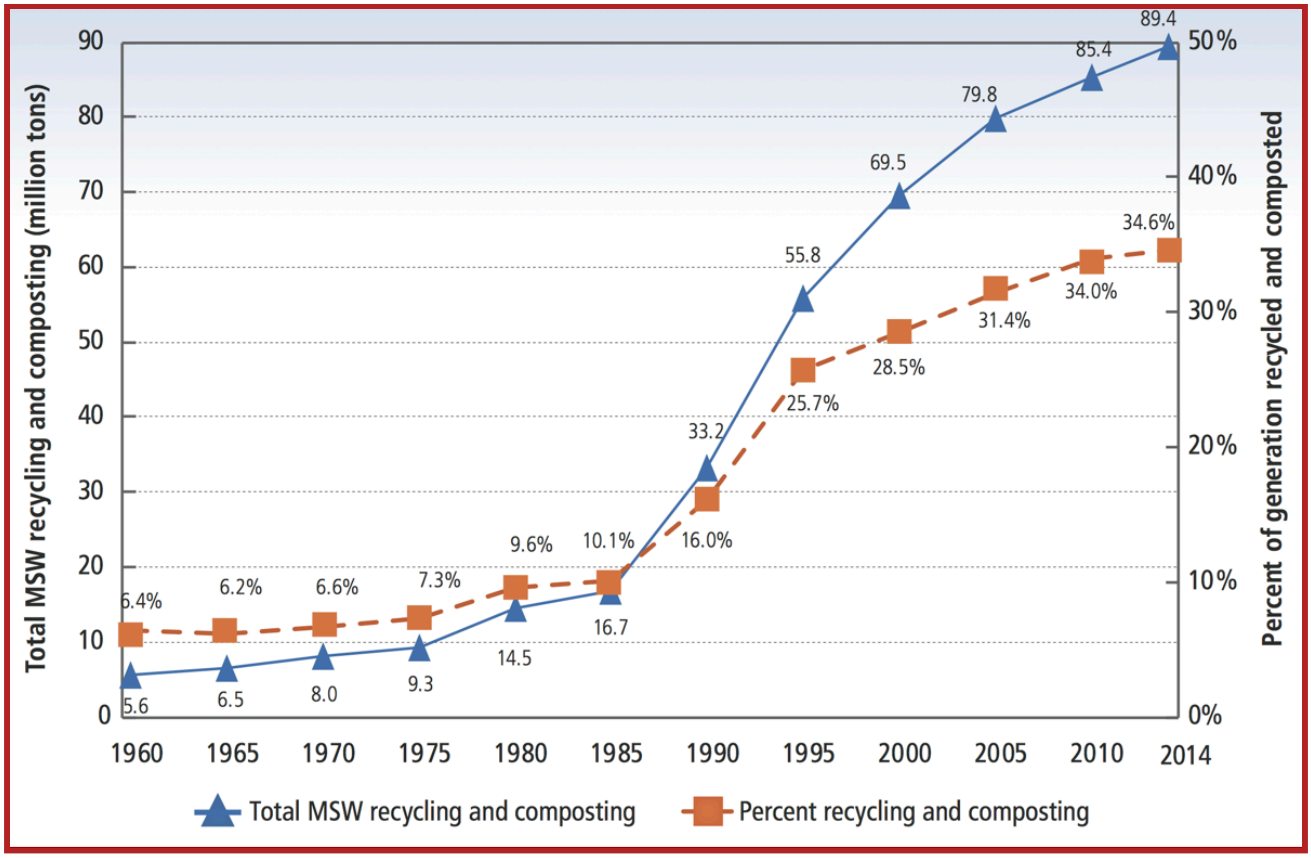

Figure 4. Municipal Solid Waste (MSW) Recycling Rates, 1960 to 2014. Courtesy of the U.S. EPA, 2016. Public Domain.

Deciding whether or not to recycle is a psychological, sociological, and environmental decision. Both intrinsic and extrinsic factors play a role in the cognitive process, and understanding how solutions influence an individual's behavior can improve their success rates for the future. Policymakers at all levels of government in the United States should consider these factors when implementing pro-environmental policies.

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5.3 THE EFFECT OF SOLAR PHOTOVOLTAIC PANELS ON RESIDENTIAL SALE PRICE

Michael S. Schaal

The installation of a solar photovoltaic system often takes many years to achieve a full return on investment. Can homeowners with photovoltaic systems benefit from selling their home at a premium compared to non-solar homes? What does the future hold for this energy source?

Figure 1. This roof showcases two types of solar photovoltaic systems: one standard solar panel (left) that sits on top of the roof, and the other mimicking the roof tiles (right). Courtesy of John Hritz, 2007, FlickrCommons. CC BY 2.0.

The solar energy industry has seen unprecedented growth in the United States (U.S.) in recent years.[7,9,10] Since 2008, total **solar photovoltaic** (PV) installations in the U.S. increased from 1.2 gigawatts (GW) to an estimated 30 GW.[10] This represents a 17-fold increase in cumulative PV installations which includes utility, residential, and non-residential applications.[10] Residential solar applications have been a significant portion of this growth.[8] In 2015, residential PV installations accounted for 41% of total installations in the U.S. (utility-scale PV systems accounted for 42% with the remainder being non-residential).[8]

As the residential solar market has seen rapid growth in recent years, costs have come down significantly.[7] From 2010 to 2014, the cost of a typical solar panel system has declined by approximately 50%.[9] Despite this, the cost of a residential PV system remains substantial. There are many factors that determine the cost effectiveness of installing solar panels.[9] These include the initial cost of installation, a particular home's **solar availability**, federal and state incentives, projected electricity use, and home sales price.[9] Some of these factors can be calculated or estimated with some degree of certainty.[9] The home sales price, however, is one factor for which there has been limited knowledge. Until recently, there had not been extensive research on this topic, therefore, this factor has been difficult to gauge in analyzing the cost effectiveness of a residential home photovoltaic system. This is an important issue because homeowners may not be able to count on getting a good return on investment through lower electricity bills. This could occur if an individual buys a newly-built solar home or installs panels on an existing home, and then has to move out of that home in a short period of time.

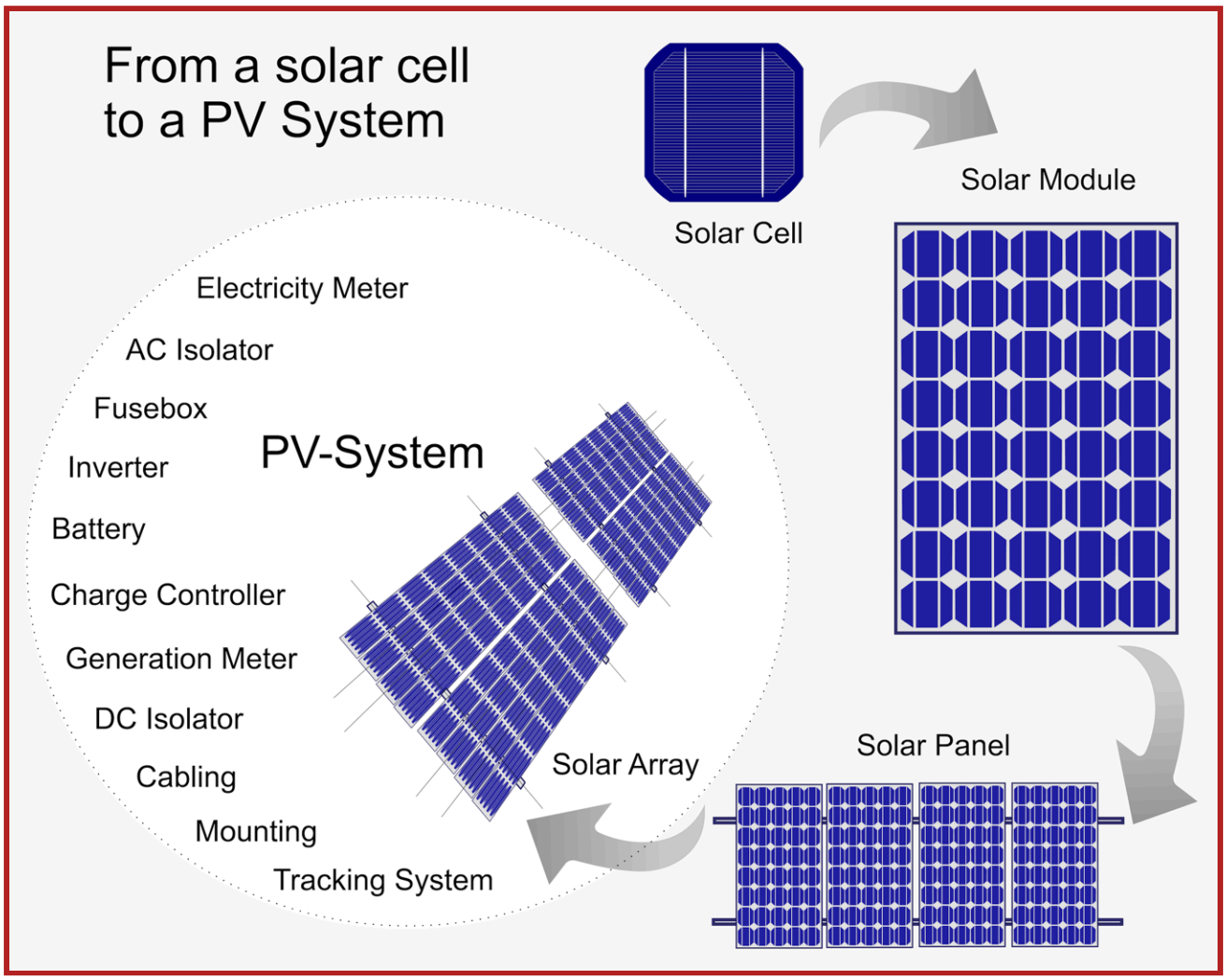

Figure 2. Diagram of common components of photovoltaic systems. Courtest of Rfassbind, 2014, Wikimedia Commons. Public Domain.

Prior to 2009, research was somewhat lacking on whether installing a residential PV system would lead to an increase in home sales price.[3] Without this data, potential buyers and sellers in the solar home marketplace had to look to other existing research to help predict whether installing a PV system would lead to a higher market value.[3] Previous studies had shown that lower energy bills were correlated with a premium on residential sales price.[2,5,6] The lower energy bills in these studies were typically the result of home improvement energy efficiency measures.[2] Potential homebuyers were willing to pay more for a home with built-in utility cost savings. Many in the solar industry reasoned that, since lower energy bills correlated with home price premiums, installing a residential PV system should also translate into a higher home selling price.[1] One study published in 2010, evaluated 279 single family homes in the San Diego, CA metropolitan area that had PV installations.[1] These residential properties were compared to similar homes without PV.[1] The results showed that those homes with solar panels sold at a 3.3% premium compared to non-PV homes.[1] For the average home in this study, the premium was equivalent to an added value of $16,235.[1] The mean PV system size for the solar homes in the study was 3.18 **kilowatts** (kW), yielding a $5.1 premium per installed watt.[1]

The average total cost of PV installations for homes in the San Diego study was $26,700.[1] However, when federal and state rebates and incentives were included, the effective cost dropped to $15,712.[1] Comparing this effective cost to the average added value of $16,235, this study provided evidence

that, on average, homeowners could expect to fully recover the cost of installing a solar PV system.[1] Furthermore, any electricity cost savings would be additional gains in the overall return on investment.[1] While this research supported the notion that installing a residential PV system can add value to a home in the form of a higher selling price, the study had a relatively small sample size and was conducted in a limited geographic setting.[1] Could these results be duplicated in other parts of the country? In 2015, researchers at the Lawrence Berkeley National Laboratory (NBNL) conducted an analysis of approximately 4,000 solar PV homes and approximately 19,000 non-PV homes sold in eight states from 2002-2013 (California, Connecticut, Florida, Massachusetts, Maryland, North Carolina, New York, and Pennsylvania).[4] This research was able to evaluate multiple geographic locations, with the vast majority of the PV homes located in California.[4]

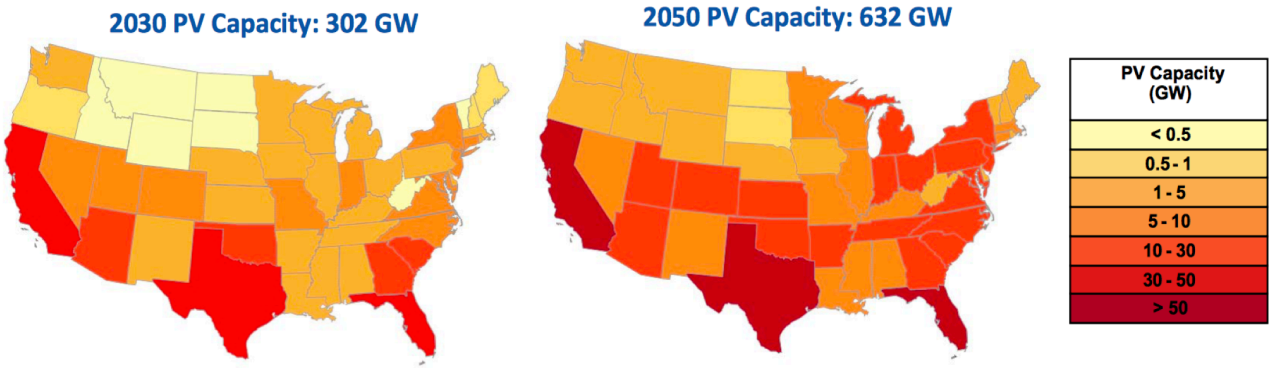

Figure 3. The Department of Energy introduced the SunShot program in order to make solar energy implementation more affordable. The initiative aims to reduce the cost of solar technologies by 75% by 2020. While studies initially focused on select states, research is quickly spreading throughout the US as photovoltaic systems become competitive in a broader set of markets. Courtesy of the U.S. Department of Energy, 2012. Public Domain.

The results of this multi-state study revealed that the average PV home sold for a premium of $4.18/watt which nearly equals the average net cost of installation of $4.14.[4] For an average sized 3.6kW PV system, this equates to an approximate $15,000 premium.[4] For the California PV homes alone, the premium was $4.21/watt.[4] For all other states, the premium averaged $3.11/watt.[4] The cost of PV installation was also lower in the non-California homes at $3.09/watt which is almost identical to the premium per watt for those homes.[4] Of note, the $3.11/watt premium for the non-California homes was deemed statistically significant, however, the 95% confidence interval was $2.33/watt.[4] This indicates that the small sample size did not allow for a precise estimate.[4] Therefore, the premium was not considered statistically different from the premium for the California homes.[4] The multi-state study also compared premiums for new vs. existing PV homes.[4] New PV homes were found to have a premium of $3.58 compared to $4.51 for existing homes.[4] Both values were statistically significant by themselves but the difference between the two was not statistically significant.[4] So, the study was not able to discern a difference in premiums between new and existing homes.[4] Nonetheless, the premiums did correlate fairly closely to the net costs for each home type.[4] The net cost of a PV system for new homes was $3.85, while the net cost for existing homes was $4.29.[4]

The age of the PV system and its effect on premiums was also explored, showing that premiums decline as systems age.[4] There was a noticeable drop in premiums from the newest to the oldest group of PV systems.[4] The newest group had a mean age of 1.6 years and a premium of $5.90, while the oldest group had a mean age of system 7.8 years and a premium of $2.60.[4] Finally, the multi-state study looked at the effect of PV system size on premiums and was evaluated by calculating an incremental dollar per watt premium.[4] It was found that each additional kilowatt of PV system size adds monetary worth to a home but at a decreasing dollar per watt value.[4]

Figure 4. The time required to install a solar photovoltaic system depends on the size of the project itself. However, most projects can be completed within 1-2 days, making solar installation a relatively quick process. Depending on the specifics of the PV system that is installed in an individual's home, a sizable return may be seen. Courtesy of skeeze, 2016, Pixabay. Public Domain.

In the last several years, there has been a tremendous amount of knowledge gained regarding solar panels and their effect on home values. Overall, homeowners should be able to see a sizable return on their solar investment depending on the specifics of their PV system. If one owns a solar home and resides there for many years prior to selling, the premium might be somewhat reduced due to the age of the PV system, but the homeowner likely would have had substantial savings from multiple years of reduced electricity bills. However, if one installs solar panels and then decides to move after only a few years, then there would have been less time to accumulate electricity bill savings. Fortunately, the **sale price premium** would likely equate to the investment cost since the PV system would be relatively new. In either scenario, the homeowner will likely see a decent return on investment. The current research supports this notion and can help individuals make informed decisions in the residential marketplace.

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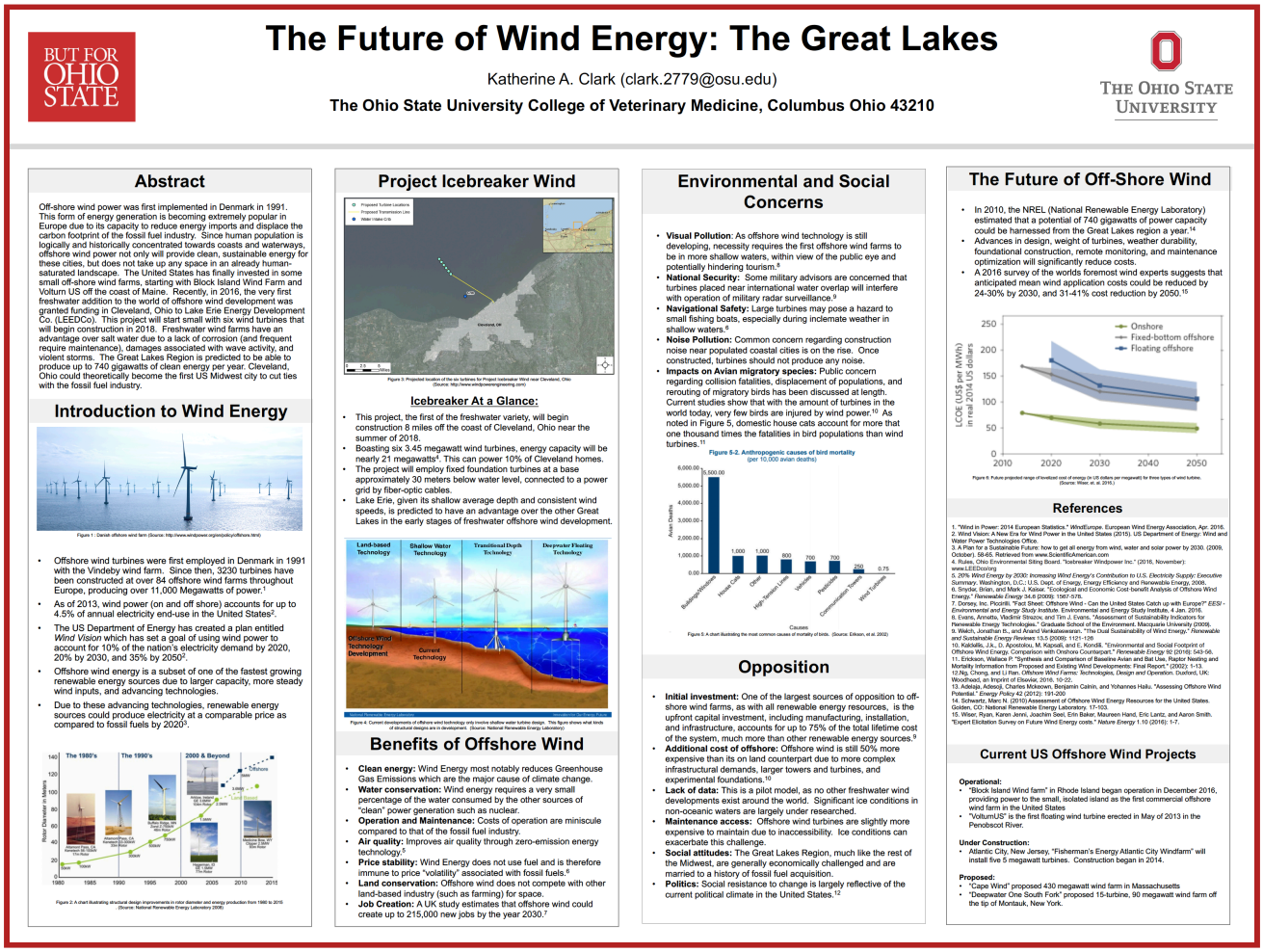
5.4 THE FUTURE OF WIND ENERGY: THE GREAT LAKES



The Future of Wind Energy: The Great Lakes

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Abstract

Off-shore wind power was first implemented in Denmark in 1991. This form of energy generation is becoming extremely popular in Europe due to its capacity to reduce energy imports and displace the carbon footprint of the fossil fuel industry. Since human population is logically and historically concentrated towards coasts and waterways, offshore wind power not only will provide clean, sustainable energy for these cities, but does not take up any space in an already human-saturated landscape. The United States has finally invested in some small off-shore wind farms, starting with Block Island Wind Farm and Volturn US off the coast of Maine. Recently, in 2016, the very first freshwater addition to the world of offshore wind development was granted funding in Cleveland, Ohio to Lake Erie Energy Development Co. (LEEDCo). This project will start small with six wind turbines that will begin construction in 2018. Freshwater wind farms have an advantage over salt water due to a lack of corrosion (and frequent require maintenance), damages associated with wave activity, and violent storms. The Great Lakes Region is predicted to be able to produce up to 740 gigawatts of clean energy per year. Cleveland, Ohio could theoretically become the first US Midwest city to cut ties with the fossil fuel industry.

Introduction to Wind Energy

Figure 1 : Danish offshore wind farm (Source: http://www.windpower.org/en/policy/offshore.html)

- Offshore wind turbines were first employed in Denmark in 1991 with the Vindeby wind farm. Since then, 3230 turbines have been constructed at over 84 offshore wind farms throughout Europe, producing over 11,000 Megawatts of power.[1]
- As of 2013, wind power (on and off shore) accounts for up to 4.5% of annual electricity end-use in the United States[2].
- The US Department of Energy has created a plan entitled *Wind Vision* which has set a goal of using wind power to account for 10% of the nation's electricity demand by 2020, 20% by 2030, and 35% by 2050[2].
- Offshore wind energy is a subset of one of the fastest growing renewable energy sources due to larger capacity, more steady wind inputs, and advancing technologies.
- Due to these advancing technologies, renewable energy sources could produce electricity at a comparable price as compared to fossil fuels by 2020[3].

Figure 2: A chart illustrating structural design improvements in rotor diameter and energy production from 1980 to 2015 (Source: National Renewable Energy Laboratory (2009))

Project Icebreaker Wind

Figure 3: Projected location of the six turbines for Project Icebreaker Wind near Cleveland, Ohio (Source: http://www.windpoweringamerica.com)

Icebreaker At a Glance:

- This project, the first of the freshwater variety, will begin construction 8 miles off the coast of Cleveland, Ohio near the summer of 2018.
- Boasting six 3.45 megawatt wind turbines, energy capacity will be nearly 21 megawatts[4]. This can power 10% of Cleveland homes.
- The project will employ fixed foundation turbines at a base approximately 30 meters below water level, connected to a power grid by fiber-optic cables.
- Lake Erie, given its shallow average depth and consistent wind speeds, is predicted to have an advantage over the other Great Lakes in the early stages of freshwater offshore wind development.

Figure 4: Current developments of offshore wind technology only involve shallow water turbine design. This figure shows what kinds of structural designs are in development. (Source: National Renewable Energy Laboratory)

Benefits of Offshore Wind

- **Clean energy:** Wind Energy most notably reduces Greenhouse Gas Emissions which are the major cause of climate change.
- **Water conservation:** Wind energy requires a very small percentage of the water consumed by the other sources of "clean" power generation such as nuclear.
- **Operation and Maintenance:** Costs of operation are miniscule compared to that of the fossil fuel industry.
- **Air quality:** Improves air quality through zero-emission energy technology[5].
- **Price stability:** Wind Energy does not use fuel and is therefore immune to price "volatility" associated with fossil fuels.[6]
- **Land conservation:** Offshore wind does not compete with other land-based industry (such as farming) for space.
- **Job Creation:** A UK study estimates that offshore wind could create up to 215,000 new jobs by the year 2030.[7]

Environmental and Social Concerns

- **Visual Pollution**: As offshore wind technology is still developing, necessity requires the first offshore wind farms to be in more shallow waters, within view of the public eye and potentially hindering tourism.[8]
- **National Security:** Some military advisors are concerned that turbines placed near international water overlap will interfere with operation of military radar surveillance.[9]
- **Navigational Safety:** Large turbines may pose a hazard to small fishing boats, especially during inclemate weather in shallow waters.[8]
- **Noise Pollution:** Common concern regarding construction noise near populated coastal cities is on the rise. Once constructed, turbines should not produce any noise.
- **Impacts on Avian migratory species:** Public concern regarding collision fatalities, displacement of populations, and rerouting of migratory birds has been discussed at length. Current studies show that with the amount of turbines in the world today, very few birds are injured by wind power.[10] As noted in Figure 5, domestic house cats account for more that one thousand times the fatalities in bird populations than wind turbines.[11]

Figure 5-2. Anthropogenic causes of bird mortality (per 10,000 avian deaths)

Figure 5: A chart illustrating the most common causes of mortality of birds. (Source: Erikson, et al. 2002)

Opposition

- **Initial investment:** One of the largest sources of opposition to off-shore wind farms, as with all renewable energy resources, is the upfront capital investment, including manufacturing, installation, and infrastructure, accounts for up to 75% of the total lifetime cost of the system, much more than other renewable energy sources.[9]
- **Additional cost of offshore:** Offshore wind is still 50% more expensive than its on land counterpart due to more complex infrastructural demands, larger towers and turbines, and experimental foundations.[10]
- **Lack of data:** This is a pilot model, as no other freshwater wind developments exist around the world. Significant ice conditions in non-oceanic waters are largely under researched.
- **Maintenance access:** Offshore wind turbines are slightly more expensive to maintain due to inaccessibility. Ice conditions can exacerbate this challenge.
- **Social attitudes:** The Great Lakes Region, much like the rest of the Midwest, are generally economically challenged and are married to a history of fossil fuel acquisition.
- **Politics:** Social resistance to change is largely reflective of the current political climate in the United States.[12]

The Future of Off-Shore Wind

- In 2010, the NREL (National Renewable Energy Laboratory) estimated that a potential of 740 gigawatts of power capacity could be harnessed from the Great Lakes region a year.[14]
- Advances in design, weight of turbines, weather durability, foundational construction, remote monitoring, and maintenance optimization will significantly reduce costs.
- A 2016 survey of the worlds foremost wind experts suggests that anticipated mean wind application costs could be reduced by 24-30% by 2030, and 31-41% cost reduction by 2050.[15]

Figure 6: Future projected range of levelized cost of energy (in US dollars per megawatt) for three types of wind turbine. (Source: Wiser, et. al. 2016.)

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Current US Offshore Wind Projects

Operational:
- "Block Island Wind farm" in Rhode Island began operation in December 2016, providing power to the small, isolated island as the first commercial offshore wind farm in the United States
- "VolturnUS" is the first floating wind turbine erected in May of 2013 in the Penobscot River.

Under Construction:
- Atlantic City, New Jersey, "Fisherman's Energy Atlantic City Windfarm" will install five 5 megawatt turbines. Construction began in 2014.

Proposed:
- "Cape Wind" proposed 430 megawatt wind farm in Massachusetts
- "Deepwater One South Fork" proposed 15-turbine, 90 megawatt wind farm off the tip of Montauk, New York.

Poster by student author Katherine A. Clark.

As seen in the last section, the use of renewable energy is on the rise. Here a student explores another source of alternative energy, offshore wind power.

Read the entire transcript of the poster below to learn more about the use of wind turbines in offshore locations.

Abstract:

Off-shore wind power was first implemented in Denmark in 1991. This form of energy generation is becoming extremely popular in Europe due to its capacity to reduce energy imports and displace

the carbon footprint of the fossil fuel industry. Since human population is logically and historically concentrated towards coasts and waterways, offshore wind power all not only provide clean, sustainable energy for these cities, but does not take up any space in an already human-saturated landscape. The United States has finally invested in some small off-shore wind farms, starting with Block Island Wind Farm and Volturn US off the coast of Maine. Recently in 2016, the very first freshwater addition to the world of offshore wind development was granted funding in Cleveland, Ohio to Lake Erie Energy DevelopmentCo. (LEEDCo). This project will start small with six wind turbines that will begin construction in 2018. Freshwater wind farms have an advantage over salt water due to a lack of corrosion (and frequent require maintenance), damages associated with wave activity, and violent storms. The Great Lakes Region is predicted to be able to produce up to 740 gigawatts of clean energy per year. Cleveland, Ohio could theoretically become the first US Midwest city to cut ties with the fossil fuel industry.

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Figure 1: Danish offshore wind farm with many rows of wind turbines rising out of the water. Offshore wind turbines were first employed in Denmark in 1991 with the Vindeby wind farm. Since then, 3230 turbines have been constructed at over 84 offshore wind farms throughout Europe, producing over 11,000 Megawatts of power.[1] As of 2013, wind power (on and off shore) accounts for up to 4.5% of annual electricity end-use in the United States.[2] The US Department of Energy has created a plan entitled Wind Vision which has set a goal of using wind power to account for 10% of the nation's electricity demand by 2020, 20% by 2030, and 35% by 2050.[2] Offshore wind energy ir a subset of one of the fastest growing renewable energy sources due to larger capacity, more steady wind inputs, and advancing technologies. Due to these advancing technologies, renewable energy sources could produce electricity at a comparable price as compared to fossil fuels by 2020.[3] Figure 2: A chart illustrating structural design improvements in rotor diameter and energy production from 1980 to 2015.

Project Icebreaker Wind:

Figure 3: Projected location of the six turbines for Project Icebreaker Wind near Cleveland, Ohio via a satellite map. Icebreaker at a Glance: This project, the first of the freshwater variety, will begin construction 8 miles off the coast of Cleveland, Ohio near the summer of 2018. Boasting six 3.45 megawatt wind turbines, energy capacity will be nearly 21 megawatts.[4] This can power 10% of Cleveland homes. The project will employ fixed foundation turbines at a base approximately 30 meters below water level, connected to a power grid by fiber-optic cables. Lake Erie, given its shallow average depth and consistent wind speeds, is predicted to have an advantage over the other Great Lakes in the early stages of freshwater offshore wind development. Figure 4: Current development of offshore wind technology only involves shallow water turbine design. This shows what kinds of structural designs are in developments from the National Renewable Energy Laboratory.

Benefits of Offshore Wind:

- Clean Energy: Wind Energy most notably reduces Greenhouse Gas Emissions which are the major cause of climate change.
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- Operation and Maintenance: Costs of operation are minuscule compared to that of the fossil fuel industry. Air quality: Improves air quality through zero-emission energy technology.[5]
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- Land conservation: Offshore wind does not compete with other land based industry (such as farming) for space.
- Job Creation: A UK study estimates that offshore wind could create up to 215,000 new jobs by the year 2030.[7]

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- Impacts on Avian migratory species: Public concern regarding collision fatalities, displacement of populations, and rerouting of migratory birds has been discussed at length. Current studies show that with the amount of turbines in the world today, very few birds are injured by wind power.[10] As noted in Figure 5, domestic house cats account for more than one thousand times the fatalities in bird populations than wind turbines.[11] Figure 5. A bar graph illustrating the most common causes of mortality in birds (Erikson, et al. 2002) with buildings/windows being the largest contributor, followed by house cats.

Opposition:

- Initial investment: One of the largest sources of opposition to offshore wind farms, as with all renewable energy resources, is the upfront capital investment, including manufacturing, installation, and infrastructure, accounts for up to 75% of the total lifetime cost of the system, much more than other renewable energy sources.[9]
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5.5 MITIGATING CLIMATE CHANGE AND INCREASED FOOD SECURITY THROUGH AQUAPONICS SYSTEMS TECHNOLOGY

Sabrina C. Mazyck

Aquaponics is a hybrid food technology system that helps mitigate climate change through the combination of fish tanks and crops. As an alternative to both traditional agriculture and fish farming, might this technology be able to help feed urban populations? Does it have the potential to increase food security?

Figure 1. This example of an aquaponics system from Milwaukee, utilizes tilapia and perch to assist in the growth of plants in trays and pots. Pumps draw up water from the fish habitat, which is then fed through plants to remove any chemicals and fish waste. After the water is cleaned, it moves freely back into the tank.
Courtesy of Ryan Griffis, 2008, FlickrCommons. CC BY-NC-SA 2.0.

The world is facing a number of serious problems. Population rise, climate change, soil degradation, water scarcity, and food security are arguably among the most important.[2] Utilizing a new technology known as **aquaponics** could mitigate many of these issues.[2] Clearing land for crops, artificial fertilizers, insecticides, herbicides, and larger livestock herds account for almost one quarter of anthropogenic, greenhouse gas (GHG) emissions.[4] **Sustainable agriculture** is not a new phenomenon.[7] It is the production of food, fiber, or other plant or animal products using farming techniques that protect the environment, public health, human communities, and animal welfare.[7] This technique produces crops and raises animals without relying on toxic chemical pesticides, synthetic fertilizers, genetically modified seeds, or practices that degrade soil, water, or other natural resources. More specifically, aquaponics is a hybrid food technology system that has the potential to remove the negative environmental impact of current farming techniques. The name "aquaponics" derives from mixture of two words; aqua from aquaculture, which is the farming of aquatic organisms, and ponics from hydroponics, which uses water instead of soil to grow plants. It combines conventional aquaculture, or tank rearing of aquatic animals, with hydroponics, the growing of crops in nutrient-rich water.[2,5,6] This system is a valuable alternative to both traditional agriculture, fishing, and fish farming. Its advantages include water conservation, sustainability, and the eliminated need for soil.

An interactive or media element has been excluded from this version of the text. You can view it online here:
https://ohiostate.pressbooks.pub/sciencebitesvolume2/?p=95

Figure 2. Variety of aquaponic systems.

System 1: This aquaponics system, located in a greenhouse, utilizes catfish and earthworms for plant production. Courtesy of Ryan Somma, 2008, Wikimedia Commons. CC BY-SA 2.0.

System 2: This aquaponics system is set up in a freshwater pond. Photograph by Saifullahrony, 2010, Wikimedia Commons. CC BY-SA 3.0.

System 3: Aquaponics systems can also be used residentially, like this backyard setup. Photograph by Vasch~nlwiki, 2013, Wikimedia Commons. CC BY-SA 4.0.

System 4: A vertical design is utilized in this aquaponic system at the Bangladesh Agricultural University. Photograph by BackyardAquaponics, 2011, Wikimedia Commons. Public Domain.

In an aquaponics system, fish and vegetables co-exist in a delicate, symbiotic cycle.[5] Systems can be as small as a household aquarium with a tray of plants covering the top.[1,6] Larger systems are often multilevel, recirculating aquaculture systems that incorporate the production of plants without soil.[5,6] Recirculating systems are designed to raise large quantities of fish in relatively small volumes of water by treating the water to remove toxic waste products and then reusing it.[5,6] In the process of reusing the water many times, non-toxic nutrients and **organic matter** accumulate.[1,3,6] This waste water can then be channeled to support the production of secondary crops, providing further economic benefit to the primary fish production system.[6] Dissolved metabolic by-products are recovered as nutrients by the plants, which allows for rapid growth, reduced discharge to the environment, and extended water use.[1,6] Aquaponics can operate in more **arid** climates due to cost efficiencies gained by minimal water exchanges.[6] This has the potential to save costs to people utilizing this system in places where space to grow food is generally unavailable.[2,3] Urban areas which have large populations, require a great amount of food, and have limited space for production, will benefit immensely from aquaponics.[2,3] Globally, this is important since only eleven percent of the Earth's surface is ice-free land that produces food easily. Having a plant crop that receives most of its required nutrients at no additional cost improves a system's profit potential.[3,6] Fish feed, through ingestion and excretion, or decomposition, supplies a steady source of nutrients to plants, and thereby eliminates the need to remove, replace, or adjust nutrient solutions. Aquaponics systems achieve savings by requiring less water quality monitoring, less physical land, and the sharing of equipment such as pumps and heaters.[6] The operational cost savings for commercial use would also be evident through elimination of insect and weed control.

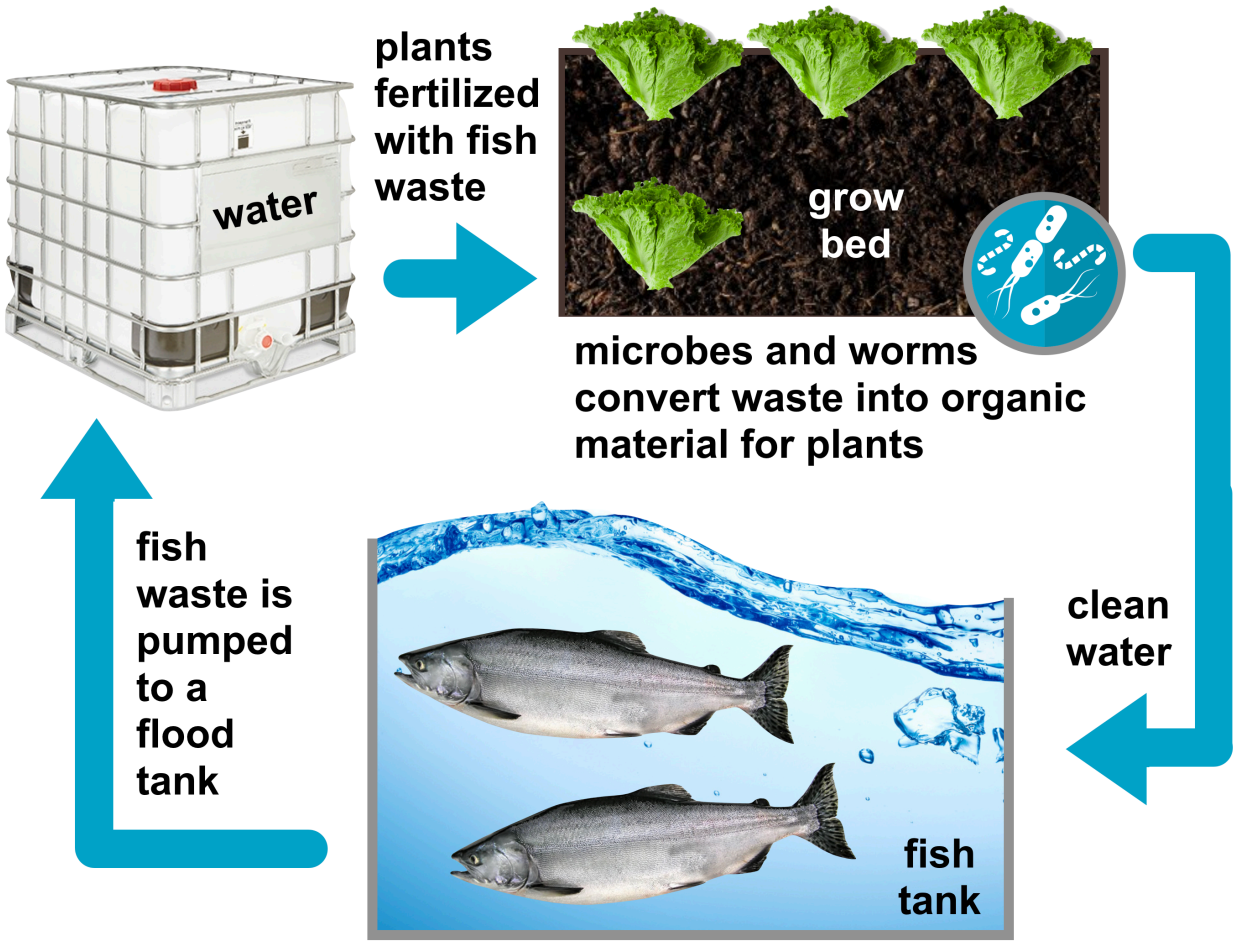

Figure 3. While each aquaponics system is unique in size and complexity, most utilize the same standard nutrient and water flow, shown here. Graphic created by Brian H. Lower. (References below)

Pesticides should not be used to control insects on aquaponic plant crops, as these pose a threat to fish.[2,3,6,8] Also, antibiotics for treating fish parasites and diseases do not need to be used because vegetables have the ability to absorb them.[2,6] This is appealing as the plants are grown without the use of **genetically modified organisms** (GMOs) or harmful chemicals that are present in many of the commonly consumed foods.[8] The practice of adding salt to treat fish diseases or reduce nitrite toxicity is also detrimental to plant crops. Rising consumer demand for more organic products can be met with this technique.[8] Non-chemical methods of pest management are the better option for the health of the human population as well as the environment.[6] These include biological controls like resistant cultivars, predators, pathogens, antagonistic organisms, physical barriers, traps, and manipulation of the physical environment.[6] There are more opportunities to use biological control methods in enclosed greenhouse environments than in exterior installations, like traditional farms, making aquaponics ideal for usage of these methods.[6] Examples of non-chemical control includes parasitic wasps and ladybugs, which can be used to control white flies and aphids.[6]

In its current form, the agricultural and land use sector is an important contributor to climate change.[4] However, agriculture contributing to climate change is a two-fold problem that has become a cyclical process as the human population increases. The worldwide agricultural sector sees itself affected by climate change.[4] In the very near future, this may create challenges for the sufficient provision of food for the growing global population.[4] Thus, there is a need for adaptive action, and

agriculture should be an integral part of any global strategy for climate change mitigation.[4] Agriculture is dependent on a wide range of **ecosystem processes** that support productivity including maintenance of soil quality and regulation of water quality and quantity. In developing countries, or places that are frequently and heavily affected by climate change issues, the use of aquaponics delivers a source of food that is unaffected by climate change. Agriculture vulnerability to climatic change is strongly dependent on the responses taken by humans to moderate the effects of climate change. Utilizing aquaponics systems could mitigate climate change and significantly add to increased food security to the benefit of people worldwide.

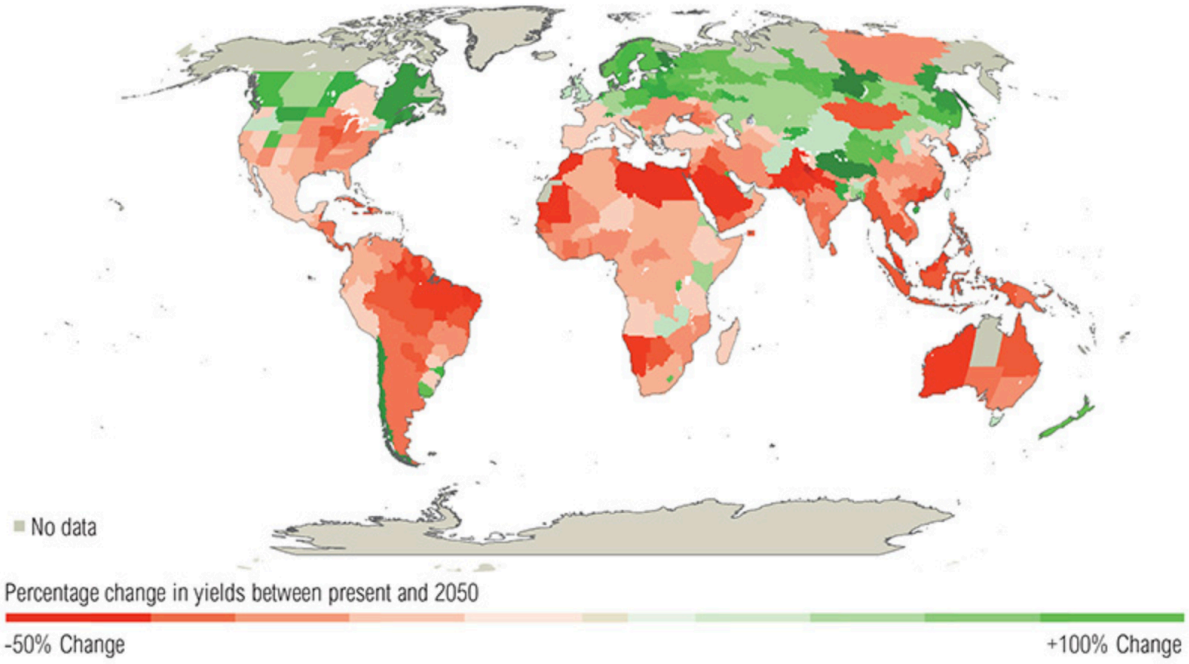

Figure 4. Climate change negatively affects crop yields, specifically in parts of the world like sub-Saharan Africa. The map shows the effects of a 3 degree Celsius increase on crop yields due to climate change.
Courtesy of Janet Ranganathan, World Bank, 2013. Public Domain.

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5.6 SOIL EROSION IN ICELAND: RECLAIMING A FRAGILE ENVIRONMENT

Leslie M. Beauchamp

Centuries of human activity in a fragile volcanic environment is eroding soils and vegetation in Iceland. Various programs have been introduced to better regulate industries such as farming. Could something like afforestation reverse erosion effects as well as assist in lowering CO2 emissions?

Figure 1. Soil erosion in Iceland. Courtest of Manfred Morgner, 2005, Wikimedia Commons. CC BY-SA 3.0.

The island nation of Iceland is characterized by high volcanic activity, cold winters, and cool summers due to the climate moderating effects of the Atlantic Gulf Stream.[2,3] The landscape can be defined as sparsely vegetated, or having less than 50% of land surface covered by vegetation.[1,11,13] There is also virtually no tree cover, though that is a historical change.[1] Before human settlement, nearly 65% of the country was covered in vegetation.[1] Since settlers arrived with livestock, about 50% of that vegetative cover has been lost due to harsh climates, volcanic activity, and wind, paired with human activity and livestock **overgrazing**.[1,11] The exposure of the soils and consequent erosion has caused a disruption in the distribution of soil organic carbon as well as a loss of biodiversity.[6,9,11,12]

Iceland has a population of approximately 280,000, with the first settlers having arrived with their livestock approximately 1,100 years ago.[1,2] With the introduction of herbivorous animals, the evolution of Iceland's vegetation was altered, and the fragile volcanic soils quickly began to erode.[1,10] These highly erodible **Andosols**, which are typical of the Icelandic Highlands, can be characterized by a large proportion of coarse-grained solid material, high porosity, low levels of organic matter, low cohesion, and the dispersal of many layers of **tephra** caused by frequent volcanic eruptions.[3,4,8,9,10]

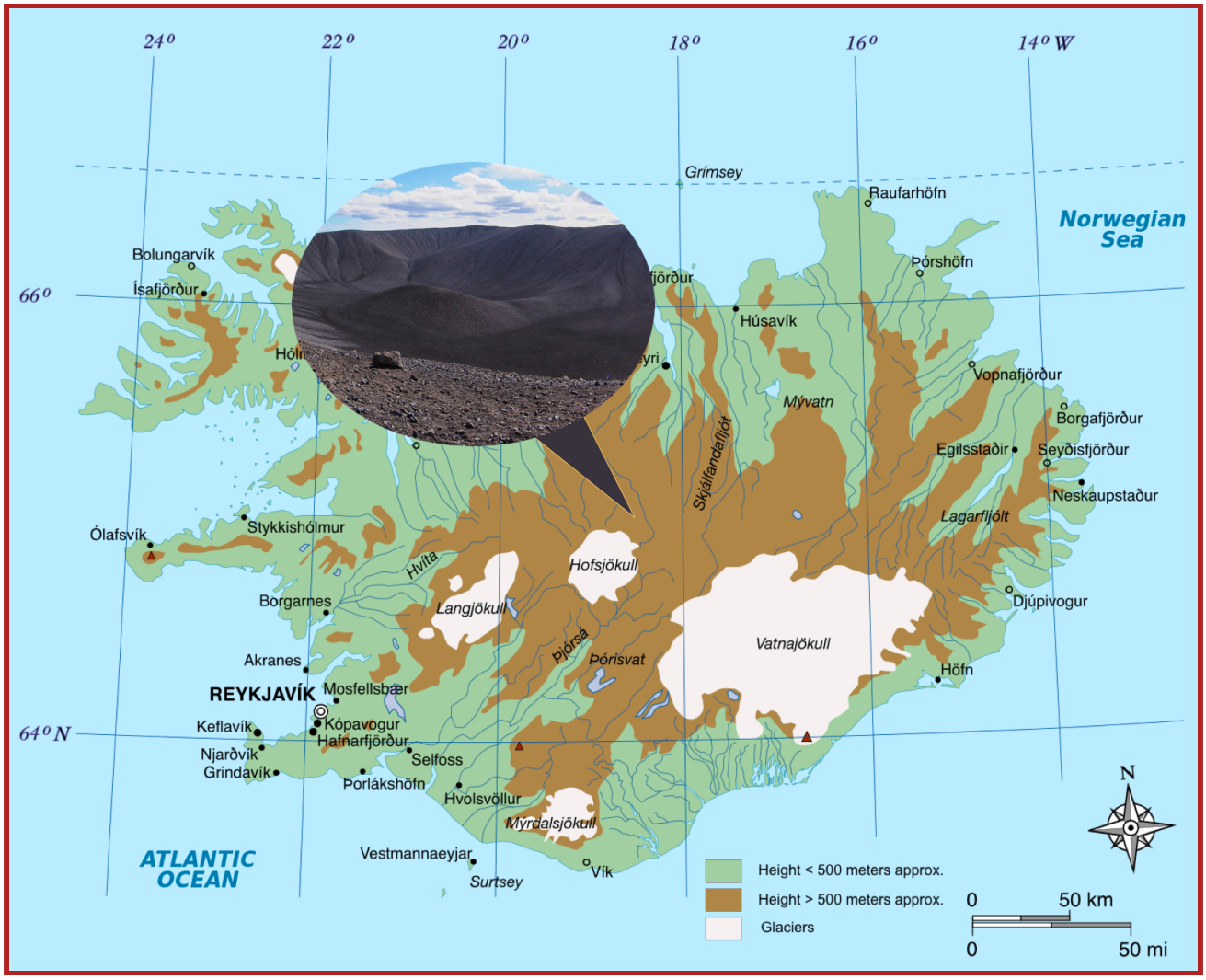

Figure 2. Map of the highlands of Iceland highlighting tephra present in these regions. Courtesy of Pethrus, 2010, Wikimedia Commons. CC BY-SA 3.0. and Chen Hand, 2015, Panoramio. CC BY 3.0.

Scientists used **tephrochronological dating** to determine the types of vegetation that were present

on these lands before settlement, finding that the majority of areas now prone to desertification had been dominated by birch woodlands.[1,7,8,12] The most dramatic decline in vegetation, and resulting soil erosion, was found to coincide much more directly with dates of human settlement than with climate change, with deforestation peaking in the 18th to 20th centuries.[1,7,8,11] This information indicates that the rapid destruction of Icelandic soils has been primarily induced by anthropogenic factors. While overgrazing by sheep and horses is a more obvious contributor to this, common cultivation practices such as planting crops in rows can lead to excess runoff, furthering the progression of erosion.[5]

The effects of early land degradation caused by human activities can be seen in a variety of different areas. These effects include farmers being forced to relocate or abandon their farms due to shifting sand dunes, erosion of stream banks impacting aquatic species through habitat depletion, and a reduction in biodiversity leading to a decrease in natural **carbon sequestration**.[6,8,10] In a study on the effects of soil erosion on soil organic carbon, it was found that atmospheric carbon (CO_2) released over approximately 1000 years of soil disturbance is equivalent to that of up to 320 years of current anthropogenic emissions.[9] A study conducted in 2000 found that due to recent **afforestation** efforts, Iceland's C-sequestration totaled 4.7% up from 2.9% just five years earlier.[11] In an interview with host Scott Simon on National Public Radio in 2007, Soil Scientist Dr. Olafur Arnalds and Assistant Director of the Icelandic Soil Conservation Service Dr. Andres Arnalds, discussed how afforestation is a necessary process for sequestering excess CO_2 that has **volatilized** into the atmosphere following the erosion of carbon-rich soils.[12] The researchers believe that Iceland has the potential to become a zero-emission country under proper management.[12] Other scientists agree that the creation of **forest plantations** in soils with inadequate carbon levels could help reduce national greenhouse gas levels, assisting in overall goals to diminish factors contributing to climate change.[11]

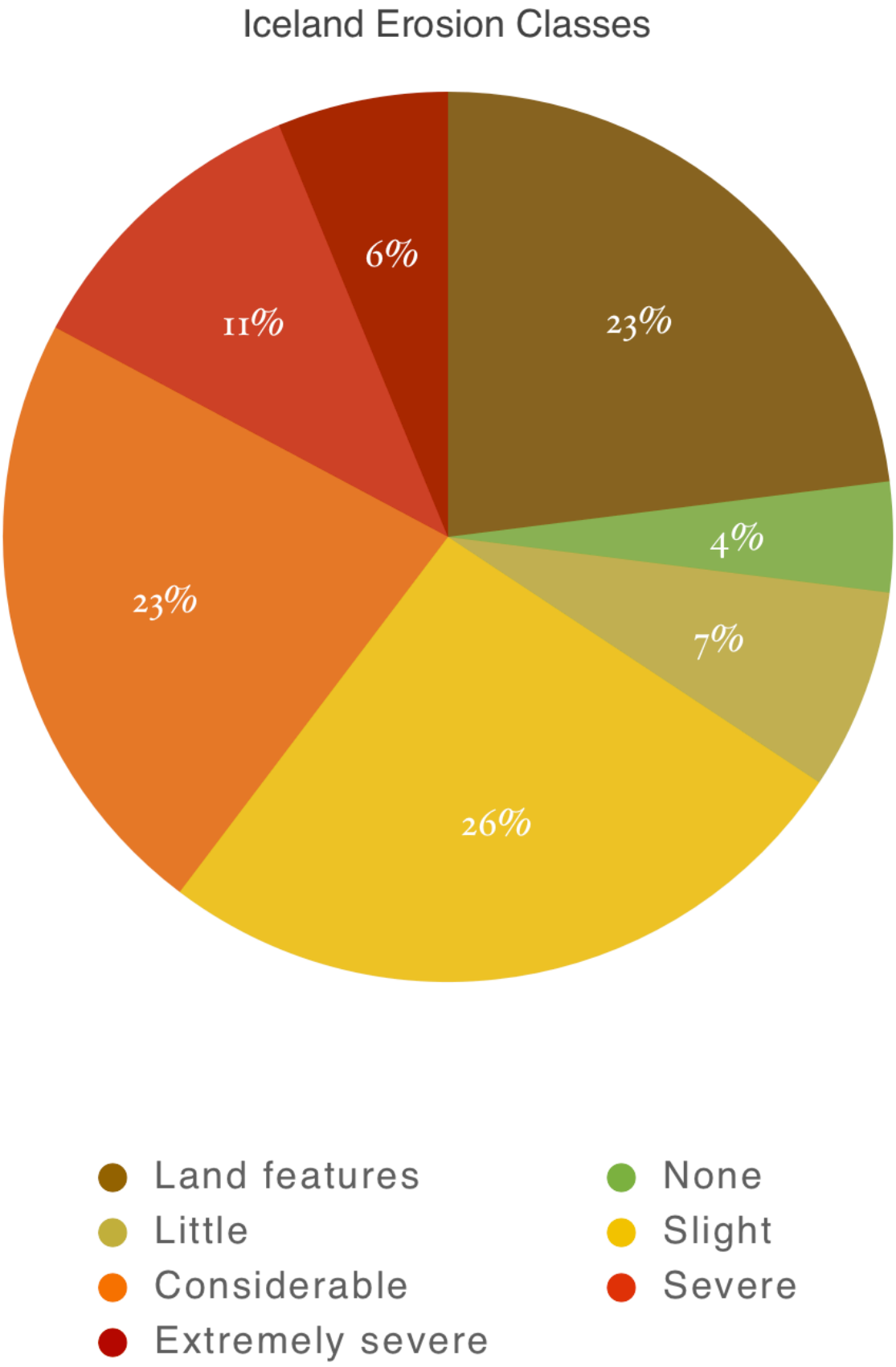
Iceland Erosion Classes
6%
23%
11%
4%
23%
7%
26%
Land features
None
Little
Slight
Considerable
Severe
Extremely severe

Figure 3. Iceland Erosion Classes. Data obtained from Arnalds, O. et al., Soil Conservation Service, 2001.

So, why have the effects of land degradation not been a prevalent issue in other heavily grazed and farmed areas such as the Great Plains in the United States? This has to do with various geologic and climatic conditions in Iceland that are specific to this fragile ecosystem, some of which put the island nation in the ill-fated position of continuing on this degenerative path. Iceland is rampant with volcanic activity, with an eruption occurring at a historic rate of 20 per century.[1] These eruptions, such as the destructive **Eyjafjallajökull eruption** in 2010, can cause large-scale dust storms that bury vegetation in **Aeolian** deposits.[4] A loss of vegetation leaves top layers of soil without a steady root system, and thus is easily disrupted by wind erosion.[4,10] Volcanic activity that occurs beneath Iceland's large glaciers can also have profound effects on soil stability due to water erosion from severe flooding.[1,3,4] These numerous specific environmental factors acting together in a systematic manner makes it difficult for land managers, governing bodies, and scientists to derive long-term solutions.

The Icelandic Soil Conservation Service was established in 1907 in response to the extent of land degradation issues.[2] Various programs have been introduced in recent years to better regulate sustainable farming and grazing activities.[2] In 2000, the government and sheep farmers came to a subsidy agreement provided that certain criteria was met by the farmers, such as no grazing in areas defined as highly erodible.[2,5]

Figure 4. Sheep grazing in Iceland contributes to the country's soil erosion. Courtesy of shaharkehat, 2016, Pixabay. Public Domain.

Social scientists have asserted that human practices that compromise land quality should be put into a more **synergistic** context while seeking government regulation.[6] In 2005, G. Gisladottir explained that there is a greater likelihood of government involvement and funding for conservation efforts if the underlying issues are described and understood to be an issue of poverty alleviation and food security.[6] The suggestion that environmental issues are directly correlated with socioeconomic factors is a critical idea in the endeavor to determine a permanent resolution.[5] This is a natural reaction considering

that many recent environmental and climate change-related problems have been attributed to human action.

Afforestation remains a very promising method of reversing damage done by erosion. Research to discover more effective, long-lasting solutions towards Iceland's largest environmental issue are ongoing, as well as initiatives to regulate harmful practices. The ability to connect every factor, both natural and social, while seeking answers for such a complex natural phenomenon will be crucial to gain a broad and complete understanding and take the first steps to restore this unique, fragile, and beautiful environment.

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CLOSING

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Appendix Image
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GLOSSARY

ACCLIMATIZATION
the process of an organism adjusting to changes in the environment

ADAPT
the ability to fit in and live within one's surroundings

AEOLIAN
deposited by wind

AERIAL PHOTO
a photograph taken from an aircraft or other flying object

AFFORESTATION
the planting of new forested area

AKAIKE MODEL WEIGHT
measures the relative quality of a statistical model based on both the complexity and goodness of fit

ANDOSOLS
soils containing volcanic material and formed in volcanic areas with tephra

ANTHROPOGENIC
caused by or originating by human activity

ANURAN
scientific name for all frog species

APEX PREDATOR
a predator that is at the top of the food chain and is not preyed upon by any other species in the environment

AQUAPONICS
any system that combines conventional aquaculture (raising aquatic animals such as snails, fish, crayfish or prawns in tanks) with hydroponics (cultivating plants in water) in a symbiotic environment

ARBOREAL
adapted for living in trees

ARID
barren land lacking rainfall

ARTHRITIS
soreness and irritation of joints usually due to activity

AUTOMATIC WEATHER STATION (AWS)
a stationary automated system that records and monitors weather conditions using a data logger, sensors, and a rechargeable battery, often in unfavorable conditions

BIOACCULMULATION
refers to the build-up of toxins or other chemicals in an organism; usually the result of an organism absorbing more of a toxin at a rate faster than that substance is excreted

BIOAUGMENTATION
the method of adding foreign living organisms to a contaminated system to break down compounds

BIODEGRADE
to be decomposed by bacteria or other living organisms

BIODIVERSITY
the variety of life in a defined area of on Earth

BIOLOGICAL CONTROL
a method of controlling unwanted organisms using other living organisms that are usually natural enemies

BIOMAGNIFICATION
refers to the increasing concentration of a substance in the tissues of organisms at successively higher levels in the food chain

BIOMASS
available total weight of biological material in an area of system

BIOREMEDIATION
the method of cleaning contamination using living organisms

BIOTA
the plant and animal life of a certain region, habitat, or time period

BLACK MARKET
an illegal network where trade in scarce and/or illegal goods is common. Drugs, firearms, humans, and animals are all traded on the black market

BOTTLENECK EFFECT
a hibernating-like statue used by cold blooded species to handle extreme temperatures

BRUMATION
a hibernating-like statue used by cold blooded species to handle extreme temperatures

CALCIFICATION
the process through which coral reefs produce calcium carbonate, which is necessary for their construction

CALVIN CYCLE
the cycle of reactions that occurs in the second phase of photosynthesis and does not require the presence of light. It involves the fixation of carbon dioxide and its reduction to carbohydrate and the dissociation of water, using chemical energy stored in ATP.

CANINE DISTEMPER
a highly contagious viral disease that affects a wide assortment of animals and causes symptoms in multiple areas of the body

CARBON SEQUESTRATION
capturing carbon dioxide, CO2, to remove it from the atmosphere

CHROMATOGRAPHY
the separation of a mixture by passing it in solution or suspension or as a vapor through a medium in which the components move at different rates

CLIMATE CHANGE
a change in the pattern of the world's climate, mostly due to the increase in carbon dioxide levels in the atmosphere due to the use of fossil fuels

CLIMATE MODEL
mathematical and scientific system that is used to predict future behavior of the climate

COLD BLOODED
an animal whose body temperature varies with the temperature of their environment

COMPACTION
using available land within city limits as opposed to expanding

CONCENTRATED ANIMAL FEEDING OPERATIONS (CAFO)
an industrialized livestock operation

CONFORMITY
the extent to which an individual complies with group norms or expectations

CONNECTIVITY
the amount which the landscape allows for animal movement from one habitat to another

CONSERVATION
effort by countries, organizations, and individuals to prevent the excessive or wasteful use of a resource

CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES) an international agreement between governments that aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival

CORAL BLEACHING
the loss of intracellular endosymbionts (Symbiodinium, also known as zooxanthellae) through either expulsion or loss of algal pigmentation

COST-BENEFIT ANALYSIS
an economic concept in which a decision is made after assessing the cost and the benefit of all options

CURRENT
a body of water or air moving in a definite direction

CYANIDE
a salt or ester of hydrocyanic acid, containing the anion CN- or the group — CN. The salts are generally toxic

DEHORNING
to remove the horn from an animal, such as a rhinoceros, elephant, or cow

DELETERIOUS
causing harm or damage. In the case of genes, these can lead to malformations and often result in the death of the individual, whether before or after birth

DICHLORODIPHENYLTRICHLOROETHANE (DDT)
an environmentally harmful yet effective pesticide

DIURNAL
a species that is active during the day

DORMANT
temporarily inactive; resting

ECHINODERM
a marine invertebrate of the phylum Echinodermata, such as a starfish, sea urchin, or sea cucumber

ECONOMIC IMPACT ASSESSMENT
a scientific assessment that calculates the direct, indirect, and induced costs and benefits of a project or phenomenon

ECOSYSTEM
a community of living organisms and abiotic components linked in the environment

ECOSYSTEM PROCESSES
chemical, biological, and physical actions or events that connect organisms to their environment

ECTOTHERMIC

a 'cold-blooded' organism. A term which often refers to animals which cannot regulate their own body temperature. Note that cold-blooded denotes the organism may be 'cold' to the touch, where that is not always the case.

EL NINO

an irregularly occurring and complex series of climatic changes affecting the equatorial Pacific region and beyond every few years, characterized by the appearance of unusually warm, nutrient-poor water off northern Peru and Ecuador, typically in late December

ENDANGERED

a conservation status for threatened, wild populations that can show a species are risk of extinction

ENDEMIC

a native species restricted to a certain location

ENDOCRINE DISRUPTOR

chemicals, such as PCBs, that if ingested in certain amounts can interfere with the hormone cycles of mammals

ENDOSYMBIOTIC

a symbiosis in which one of the symbiotic organisms lives inside the other

ENSEMBLE MODEL

a climate model produced by Dr. Ainley to predict future temperature/sea ice conditions in Antarctica. It is used to help compare current conditions in the Ross Sea to conditions projected for when the Earth's average tropospheric temperature reaches 2°C above preindustrial levels.

ENVIRONMENTAL DEGREDATION

the deterioration of the environment through depletion of resources, such as air, water, and soil, and/or through the destruction of ecosystems and the extinction of wildlife

ERADICATION

to completely destroy or remove

EVOLUTION

the alteration of heritable traits over generations of biological populations giving rise to diversity

EXTANT

still in existence

EXTIRPATED

to become extinct locally, but still have an extant population elsewhere

EXTRAPOLATION

an estimation of an unknown value by extending beyond a known sequence of values

EYJAFJALLAJOKULL ERUPTION

a volcano in southern Iceland that erupts relatively frequently

FECAL PELLET

rounded pellets excreted by an organism

FEN

a marshy or frequently flooded area of land, often having a neutral or alkaline/basic pH

FERMENT

a form of anaerobic respiration

FORAGE

plants or plant matter typically best utilized by ruminants (i.e. pasture, corn silage)

FORB

a herbaceous, flowering plant that is distinct from grasses

FOREST DEGRADATION
reduction of forest quality usually resulting from the removal of forest cover

FOREST PLANTATION
not a naturally occurring forest; planted by humans for a specific purpose

FOSSIL FUELS
fuels formed by natural processes over an extended period over time, such as anaerobic decomposition of buried dead organisms

FUKUSHIMA DAIICHI NUCLEAR DISASTER
an energy accident that occurred in 2011 as a result of a 9.0 magnitude earthquake in Japan. The resulting damage led to three nuclear meltdowns and release of radioactive material into the air.

GENETICALLY MODIFIED ORGANISMS (GMOs)
an organism in which the use of genetic engineering tools have been used to edit the organism's genetic makeup

GENOTYPE
the genetic makeup of an organism

GLACIER
a large, persistent body of ice that takes many years to form from compacted snow. These bodies of ice form where accumulation has exceeded melting and sublimation. Their melting can be indicative of climate change

GLOBAL POSITIONING SYSTEM (GPS)
a system that utilizes satellites to provide location and time information in all weather conditions

GOAL PRIMING
unconscious activation, leads to desired behaviors

GRAVID
pregnant with eggs or young

GREENHOUSE GAS
a gas that traps the sun's heat in Earth's atmosphere, with the most prominent being the following: H2O, CO2, CH4, N2O, O3, CFCs

GREENSPACE
piece of land partially or totally covered by grass, trees, and other vegetation

GROSS DOMESTIC PRODUCT (GDP)
a periodic measurement of total monetary value in relation to all final goods and services produced

GYRE
any large system of rotating ocean currents caused by the Coriolis affect, where horizontal and vertical friction determines circulation patterns

HABITAT
the environment and surroundings of an organism

HARVESTING
systematic hunting of problematic species

HEPATIC STRESS
medical problems of the liver when affecting the hepatic artery, which conveys oxygenated blood to the liver

HERBICIDE
a chemical substance that is toxic to plants

HERBIVORE
an animal that only eats and gets its energy solely from consuming plants

HIBERNACULA
a location which an animal hibernates

HOLOCENE
the present epoch of geologic time which began about 10,000 years ago. It is the second of the two epochs in the Quaternary period. It is associated with the current "warm period."

HUMAN DEVELOPMENT INDEX
a statistic representing the level of income, education, and life-expectancy of citizens in a nation

HUMAN-COYOTE CONFLICTS
the potentially unsafe interactions between humans and coyotes, including attacks

ICE CORE
a long cylinder of ice that is typically removed from an ice sheet. They are formed over time through snow build-up and are obtained by drilling into a glacier.

IN SITU STUDY
a study that takes place on site or in a field setting

INDICATOR SPECIES
any biological species that defines a trait or characteristic of the environment; behaviors of these organisms reflect the health and activity of their environment

INFINITESIMAL
incredibly, almost impossibly small

INJURIOUS SPECIES
a species listed by the government as a threat to the indigenous ecosystem

INSOLATION
the solar radiation that reaches a given area. It is measured by the amount of solar energy received per square centimeter per minute

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)
intergovernmental panel of the United Nations designed to provide the world with unbiased data on climate change and its impacts both economic and political

INTERNATIONAL CONVENTION FOR THE PREVENTION OF POLLUTION FROM SHIPS (MARPOL)
an international marine environmental convention development to minimize pollution in the oceans and seas, such as dumping, oil, and air

INVASIVE SPECIES
any species of plant, animal, or microbe that has a tendency to spread or displace desirable species and has the potential to cause harm to the environment, human health, or the economy

JAMBIYA
an Arabian knife with a curved blade, in which often the handle is made of ivory/tusk

KERBSIDE SCHEME
makes norms, makes means, gives warm-glow, creates norm awareness

KILOWATT (kW)
a unit of electrical power, equivalent to 1000 watts or 1000 joules/second

KYOTO PROTOCOL
international treaty with the goal to reduce greenhouse has emissions

LACEY ACT of 1900
a United States conservation law that prohibits trade in wildlife, fish, and plant species that have been obtained illegally /span>

LEACH
draining away from soil, as in rainwater

LETHAL
deadly; sufficient to cause death;

LIQUID NATURAL GAS (LNG)
a natural gas that has been converted to liquid for for ease of storage or transport

MESOCARNIVORE
carnivorous animal with a diet consisting of 50-70% meat or flesh of another animal

METABOLISM
chemical transformations that occur within organisms that serve to sustain life

METHANE (CH_4)
a chemical compound considered to be a greenhouse gas that is produced by cattle due to enteric fermentation

METHANE HYDRATE
methane gas trapped within ice-like crystals found underwater

METHANOGENESIS
the process of the formation of methane by methanogens

METHANOGENS
microorganisms that produce methane as a metabolic byproduct in absence of free oxygen

MICROBIAL POPULATION
microorganisms within the gut of ruminants that break down feed that cannot otherwise be digested

MICROPLASTIC
small plastic particles that are less than 1 mm (0.039 in)

MIDWAY ATOLL
a 2.4 square mile atoll in the Pacific Ocean that contains the Midway Atoll National Wildlife Refuge created to preserve species of the area

MITIGATE
lessen or make less severe

MOLT
when animals lose their fur, skin, or feathers so that new ones will grow back in their place

MULTICOLLINEARITY
a statistical occurrence where two predictor variables are highly correlated that results in inaccurate model predictions

MYCELIUM
the vegetative heart of fungus; small, root-like tubular structures

MYCOREMEDIATION
bioremediation with mycelium as the medium

NANKAI TROUGH
location of vast gas hydrate reserves off the east coast of Japan

NATIONAL ACADEMY OF SCIENCES
an organization in the United States that is nonprofit and consists of some of the countries greatest scientists who offer their advice to the nation on scientific topics

NATIVE
originating in a certain area

NEONATES
a newborn

NOCTURNAL
done, occurring, or active at night

NON-NATIVE SPECIES
any species of plant, animal, or microbe that occurs outside of its native range due to human introduction, accidental, or otherwise

NUCLEAR POWER
the use of nuclear fission to generate electricity

NUCLEAR REACTOR
used at nuclear power plants in order to generate electricity by containing controlled nuclear chain reactions

NULL HYPOTHESIS
often denoted H0, it is the hypothesis the researcher wishes to disprove, reject, or nullify, and it often is stated as there being no relationship between variables

OMNIVORE
an organism that consumes both other organisms and plants /span>

OPTICAL FIBER
a thin glass fiber through which light can be transmitted /span>

ORGANIC MATTER
natural material composted of remains of plants, animals, and other environmental waste products

OUTBREAK
the sudden or violent start of something unwelcome

OVERFISHING
to deplete or exhaust a stock of fish by excessive fishing

OVERGRAZING
long-term exposure of vegetation to extensive grazing without a proper recovery period

OZONE HOLE
a region where the ozone layer is thinning due to pollutants in the atmosphere

PATCH OCCUPANCY
the proportion of a specific area or habitat unit occupied by a species

PERSISTENT POLLUTANT
compounds that bioaccumulate and therefore do not properly degrade in the environment through common chemical or biological processes

PESTICIDE
a substance used for destroying insects or other organisms harmful to cultivated plants and animals

PHENOLOGICAL MISMATCH
timing between seasonal activities and activities of a species are not in sync with one another

PHENOTYPE
the observable traits of living things

PHENOTYPIC PLASTICITY
an organism's ability to change its phenotype as a result of a change in its environment

POACHING
an illegal practice of trespassing to hunt or steal game without the owner's permission

POCKET PARK
small parks available for public use

POIKILOTHERMIC
an organism which has a variable body-temperature, often coinciding with external conditions

POINT COUNT METHOD
process by which a birder documents all birds that are seen or heard from a location during a specific time period

POLYCHLORINATED BIPHENYLS (PCBs)
a synthetic organic chemical compound of chlorine attached to biphenyl. Is known to cause cancer, affect the immune system, reproductive system, nervous system, and endocrine system

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)
an organic pollutant; often a byproduct of fossil fuel combustion

POLYETHYLENE
a tough, light, flexible synthetic resin made by polymerizing ethylene, often used for plastic bags, food containers, and other packaging

POLYMERASE CHAIN REACTION (PCR)
the use of technology to view a single or few copies of DNA pieces by copying the fragments and reproducing them

POLYPROPYLENE
a synthetic resin that is a polymer of propylene, used for ropes, fabrics, and molded objects

POLYVINYLCHLORIDE (PVC)
a common plastic with many applications

POPULATION
the number of a specific species living in a given vicinity

POTASSIUM NITRATE
A white crystalline salt, occurring naturally and produced synthetically, used in fertilizer, as a meat preservative, and as a constituent of gunpowder

PREDATOR
an organism that preys on other organisms

PRESCRIBED GOAT GRAZING
a method of plant control used to inhibit or encourage growth of specific plants by controlling the timing, intensity, duration, and area of goat grazing behavior

PRO-SOCIAL BEHAVIOR
actions or beliefs that go along with the present social norms, accepted by society

PROBABILITY VALUE
a function of observed sample results in statistical analysis that is used for determining whether a hypothesis is to be rejected or fails to be rejected – if probability falls below the predetermined value, the null hypothesis is rejected

PROLIFERATION
rapid growth or spread

PROPIONATE
a volatile fatty acid that does not require methanogenesis to be broken down and utilized

RANGELAND
an expanse of land whose native vegetation is suitable for grazing and browsing animals and can be comprised of grasses, forbs, or shrubs

RED LIST
a list that details threatened species

REPATRIATION
returning an organism to its place of origin (historical habitat/range)

RESIDENTIAL DENSITY
measure of how intensely an area is filled with development or population

ROAD STRIP CORRIDORS
strips of greenspace along roads and highways in urban areas

RUMEN
the first of the four compartments that make up the stomach in ruminant animals, it's purpose is to act as the main site of microbial fermentation

SALE PRICE PREMIUM
the additional price one would pay for a residential home with a solar photovoltaic system compared to a similar home without PV

SCALABLE
the ability of a system or product to handle growth and changes in size without compromising integrity

SECONDARY PLANT COMPOUNDS
non-essential complex compounds made by plants

SELF-DETERMINATION THEORY
motivated behavior is characterized as lying along a continuum of intentional regulation ranging from autonomous to controlled

SHIVERING THERMOGENESIS
increased metabolism of the skeletal muscles in an animal due to shivering

SOCIOECONOMIC STATUS
the social standing or class of an individual or group, measured in relation to income, occupation, and education

SOLAR AVAILABILITY
a measure of how much solar radiation that will reach a particular area. For rooftop solar panels, this can be affected by latitude, cloudiness, shading from nearby trees or other objects

SOLAR PHOTOVOLTAIC
a technology that converts solar radiation into direct current electricity

SPECIES RICHNESS
number of different species found in an ecosystem

SPORES
part of the fungi life cycle as a unit of reproduction that may be adapted for dispersal. This may often be in unfavorable conditions or over long periods of time.

STARCH
a carbohydrate made up of glucose connected by α-glycosidic linkages which can be broken down by enzymes in the gut rather than necessitating a microbial population

STATISTICAL SIGNIFICANCE
increased metabolism of the skeletal muscles in an animal due to shivering

STIGMA
a public view that something is unusual, disgraceful, or undesirable

SUBLIMATION
the transition of a substance from the solid phase to the gas phase, thus bypassing the liquid phase. It occurs at temperatures and pressures below a substance's triple point

SUPPLY-AND-DEMAND
An economic concept in which the trade of a goods or services is analyzed by reviewing factors such as what is the current supply of the item, what is the current demand for the item, and what is the price set

by those two factors. If supply is low, and demand is high, price will also be high. If supply is high, and demand is held constant, the price will decrease.

SUSTAINABLE AGRICULTURE
the act of farming based on an understanding of ecosystem services, the study of relationships between organisms and their environment

SYMBIOTIC
an interdependent relationship between two organisms in which both organisms benefit

SYNERGISTIC
acting as a system or collection of ideas or events

SYNTHETIC
a substance made by chemical synthesis, especially to imitate a natural product

TEMPORAL CONSTRUAL THEORY
competing motivations evolve and change over time with short-term goals often acting to undermine long-term goals

TEMPORAL PATTERNS
of or relating to time

TEPHRA
deposited volcanic material produced by eruptions

TEPHROCHRONOLOGICAL DATING
the use of deposited volcanic material for chronological dating of geological or environmental events

TERRESTRIAL
of or relating to the Earth

THEORY OF PLANNED BEHAVIOR
a function of a willingness to perform a behavior, and the degree of control that one perceives they have over the behavior

THERMOREGULATION
the regulation of body temperature

THREATENED
a categorization by the International Union for Conservation of Nature reserved for animals likely to become endangered

TOP DOWN PRESSURE
when the top predator in an ecosystem puts large struggles for survival on lower species of the food chain

TRANSLOCATION
transporting problematic animals to another location

TRINITROTOLUENE (TNT)
a common pollutant used as an explosive in mining and construction

TROPOSPHERE
the lowest part of the earth's atmosphere. This is the part of the atmosphere where weather changes occur.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC, AND CULTURAL ORGANIZATION (UNESCO)
an agency of the United Nations responsible for instituting and administering programs for cooperative, coordinated action by member states in education, science and the arts

URBAN FOREST
densely wooded area in a city

URBAN PLANNING
the process of development of a city, with respect to protection of local environment, public welfare, and city structure design

URBAN SPRAWL
also referred to as suburbanization, the expansion of a city outward from its center into further out residential communities

URBANIZATION
urban growth; movement of humans to cities

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)
an agency of the federal government with the goal of protecting the environment and public health through regulations

VECTOR-BORNE
transmission of a pathogen from the bite of an infected arthropod species such ticks or mosquitos

VIRULENT
characterized by the ability of an agent of infection to produce disease; can also be a measure of the severity of the disease it causes

VIVIPAROUS
an organism which gives birth to live young

VOLATILIZE
to disperse as vapor into the atmosphere

WARM-GLOW EFFECT
personal satisfaction from activity independent of impact; private benefit

WORLD BANK
a global organization working to alleviate poverty by implementing sustainable strategies

ZOOXANTHELLAE
a yellowish-brown symbiotic dinoflagellate present in large numbers in the cytoplasm of many marine invertebrates