Environmental ScienceBites

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EDITED BY KYLIENNE A. CLARK, TRAVIS R. SHAUL, AND BRIAN H. LOWER AND EDITED BY KYLIENNE A. CLARK, TRAVIS R. SHAUL, AND BRIAN H. LOWER

SYDNEY R. MORRISON, SYDNEY R. MORRISON, JAYMES T. STCLAIR, JAYMES T. STCLAIR, LEVI J. CRAMER, LEVI J. CRAMER, ALYSSA M. JONES, ALYSSA M. JONES, BRITTANY L. SULAINIS, BRITTANY L. SULAINIS, JEREMIE E. BEAVERSTOCK, JEREMIE E. BEAVERSTOCK, AMANDA L. VARCHO, AMANDA L. VARCHO, KELLY E. PETERSON, KELLY E. PETERSON, CHAYLI T. BUENGER, CHAYLI T. BUENGER, WYATT T. SUSICH, WYATT T. SUSICH, CHRIS EBERSOLE, CHRIS EBERSOLE, BRANDON S. WATOR, BRANDON S. WATOR, JOHN A. ZAGAR, JOHN A. ZAGAR, JACE A. BALL, JACE A. BALL, LEE SEITZ, LEE SEITZ, BENJAMIN W. SCHUMANN, BENJAMIN W. SCHUMANN, MASON F. YE, MASON F. YE, ALYSSA M. ZEARLEY, ALYSSA M. ZEARLEY, CAIN W. CROUSE, CAIN W. CROUSE, ALLYSON E. LOPARO, ALLYSON E. LOPARO, RIKA L. BAILEY, RIKA L. BAILEY, EMILY C. MILLS, EMILY C. MILLS, ANDREW T. WOOD, LYDIA F. BEDNARSKI, LYDIA F. BEDNARSKI, SAMANTHA K.

RUNSER, AND SAMANTHA K. RUNSER

THE OHIO STATE UNIVERSITY
COLUMBUS, OHIO

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.

Contents

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Authors: Sydney R. Morrison, Jaymes T. StClair, Levi J. Cramer, Alyssa M. Jones, Brittany L. Sulainis, Jeremie E. Beaverstock, Amanda L. Varcho, Kelly E, Peterson, Chayli T. Buenger, Wyatt T. Susich, Chris Ebersole, Brandon S. Wator, John A. Zagar, Jace A. Ball, Lee Seitz, Benjamin W. Schumann, Mason F. Ye, Alyssa M. Zearley, Cain W. Crouse, Allyson E. Loparo, Rika L. Bailey, Emily C. Mills, Andrew T. Wood, Lydia F. Bednarski, Samantha K. Runser

Editors: Kylienne A. Clark, Travis R. Shaul, Brian H. Lower

School of Environment and Natural Resources

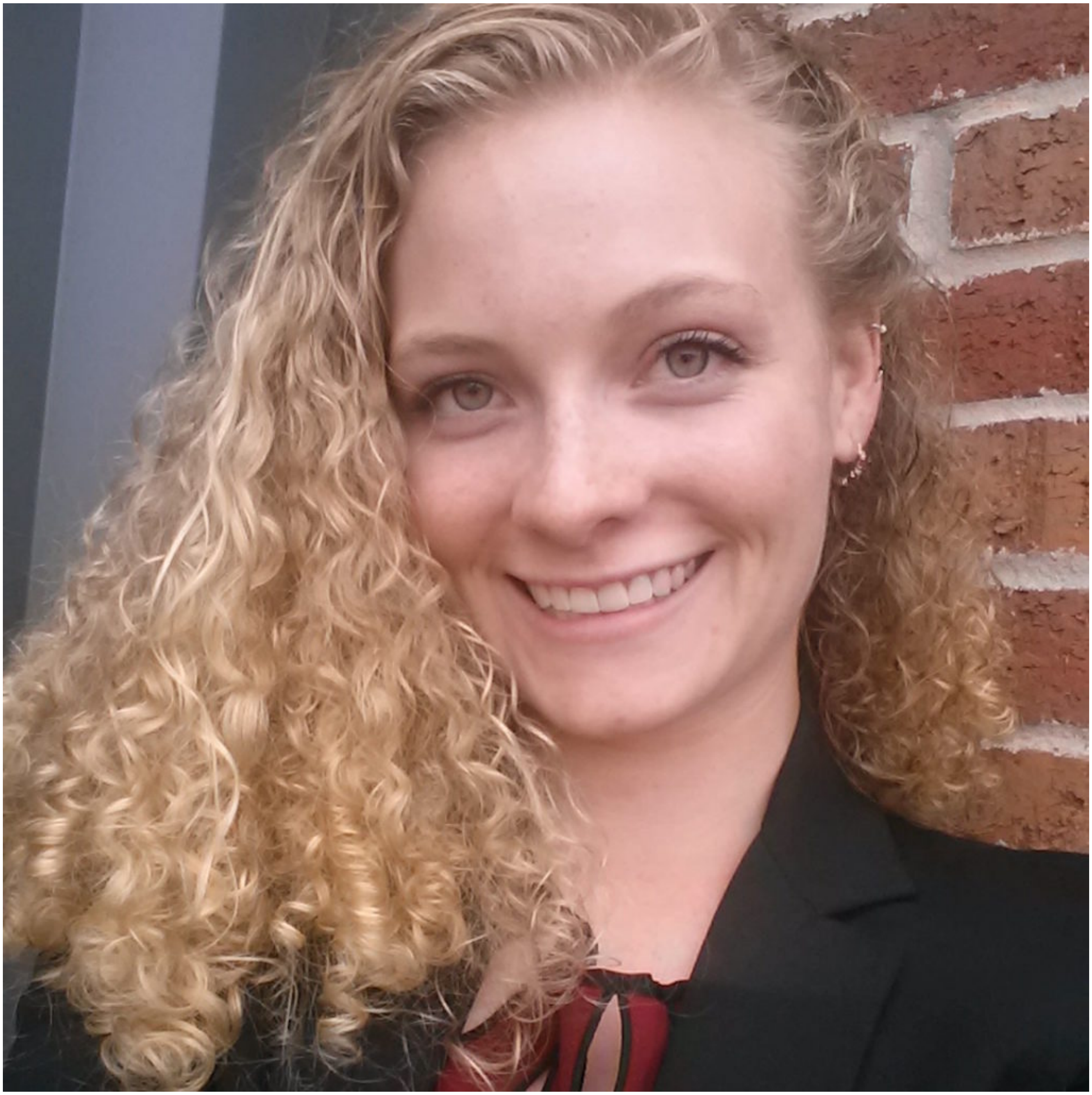
The Ohio State University

210 Kottman Hall,

2021 Coffey Road,

Columbus, OH 43210

About the Editors



Kylienne A. Clark, M.S.,

is an avid world traveler and runner. She is an instructional designer in the School of Environment and Natural Resources at The Ohio State University. She graduated in 2014 with her B.S. in

Environmental Science and M.S. in Environment and Natural Resources from The Ohio State University.

Travis R. Shaul, M.S., M.P.A.,

is a trained environmental advocate and triathlete. He graduated from The Ohio State University in 2015 with his M.S. from the School of Environment and Natural Resources and his M.P.A. from the John Glenn College of Public Affairs.

Brian H. Lower, Ph.D.

is an associate professor in the The School of Environment & Natural Resources at The Ohio State University. He has taught the course "Introduction to Environmental Science" since 2009 and is the recipient of multiple teaching awards. Brian received his Ph.D. in Biochemistry from Virginia Tech in 2001. He served as a senior scientist at the U.S. Department of Energy Environmental Molecular Sciences Laboratory (EMSL) in Richland, Washington from 2004-2008. Brian has been a professor at OSU since 2008 and his research interests are in environmental microbiology.

Letter to the Readers

Dear Reader,

This book was written by undergraduate students at The Ohio State University (OSU) who were enrolled in the class Introduction to Environmental Science. The chapters describe some of Earth's major environmental challenges and discuss ways that humans are using cutting-edge science and engineering to provide sustainable solutions to these problems. Topics are as diverse as the students, who represent virtually every department, school and college at OSU. The environmental issue that is described in each chapter is particularly important to the author, who hopes that their story will serve as inspiration to protect Earth for all life.

All of the chapters in this book were written by first-time authors. In writing these chapters, our students learned a great deal about the publication process. They learned: (1) How to find information from primary and secondary sources and critically evaluate topics, issues, results and conclusion. (2) How scientific research is conducted and how results and conclusions are reported to the public so that people can make more informed decisions in their own lives. (3) That the peer-review evaluation system is an integral part of the scientific process, which enables scientists to maintain high quality standards and provides credibility to research and scholarly works. And (4) that peer reviews are a necessary part of the writing process because it focuses attention on particular details and considers the input of an actual audience.

We are very proud of the work of our student authors and hope that this book will serve as encouragement for other first-time authors.

Sincerely,

Brian H. Lower

Acknowledgements

We are grateful to The Ohio State University (OSU) Office of Distance Eduction and eLearning, the OSU School of Environment & Natural Resources and U.S. National Science Foundation (NSF) for their generous financial support. We thank Ashley Miller and Michael Shiflet for their assistance in writing this book. We would also like to thank the student reviewers who provided valuable feedback to our authors.

CLIMATE CHANGE

Photograph by St. Louis Julie, U.S. Fish and Wildlife Service, 2013. Public Domain.

1.1 Climate Change Opens the Door to more Intense Tropical Storms

Sydney R. Morrison

Planet Earth's climate is changing and ocean water temperature is warming. Is this change leading to increased intensity of tropical storms?

Many scientists argue that **tropical storms** are becoming stronger and more destructive.[1,2,3,4,5,8] However, there is debate whether the increase in tropical storm intensity is caused by natural weather patterns, or if **climate change** is responsible.[6] **Global warming**, an increase in global surface temperature, has been attributed to **anthropogenic** greenhouse-gas concentrations.[4] **Greenhouse gases**, such as carbon dioxide (CO_2), trap heat on the earth's surface. This increase also affects the temperature of sea water, called sea surface temperatures (SSTs). Warmer waters create ideal conditions for more powerful storms to form, particularly in areas where tropical storms derive. Tropical storms originating in the Atlantic Ocean are called hurricanes (Figure 1), whereas tropical storms that form in the Pacific Ocean are called cyclones.[7]

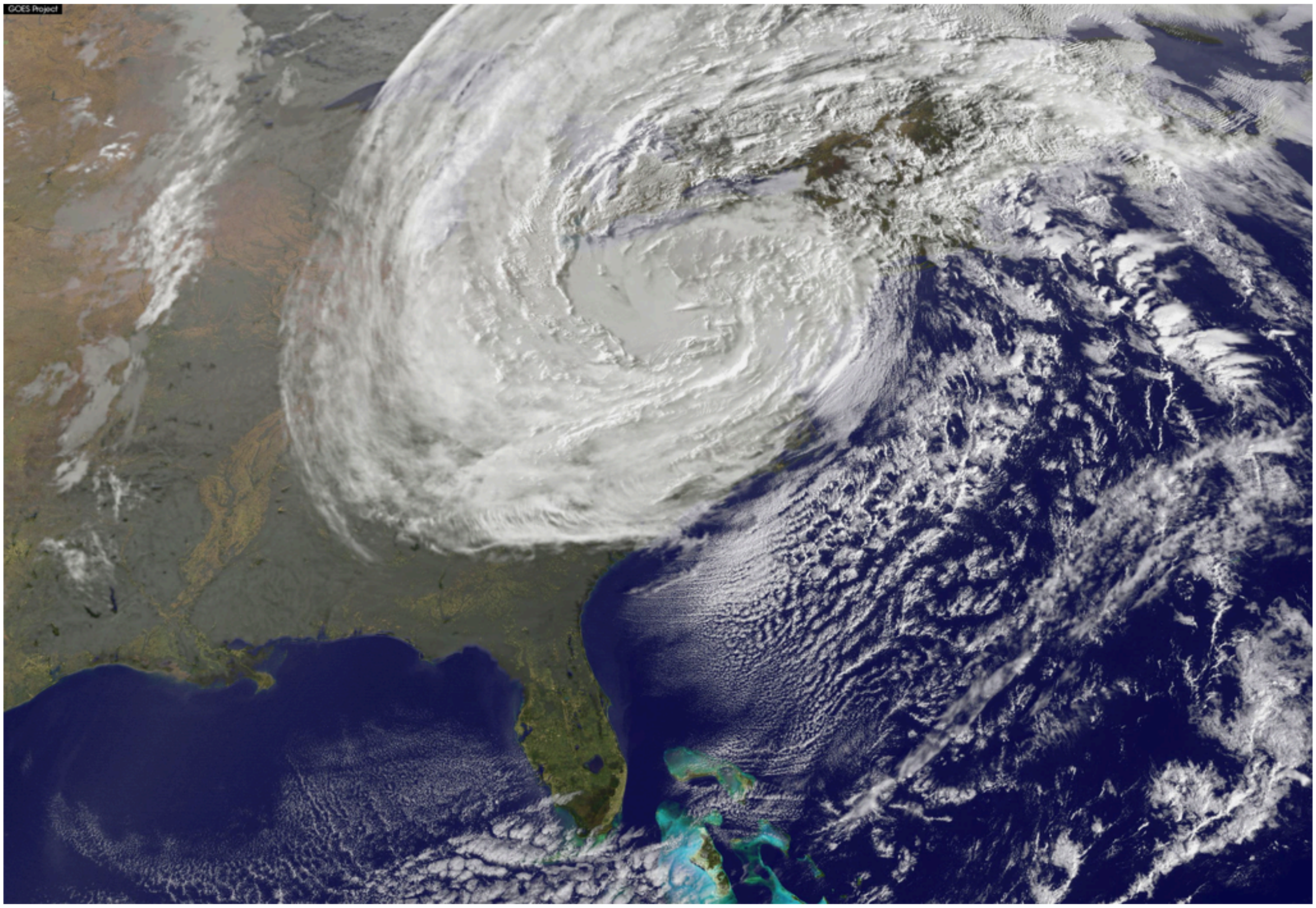


Figure 1. Satellite image of Superstorm Sandy which devastated the U.S. East Coast in 2012.
Photo by NASA, 2013. Public Domain.

There is a difference in temperature between the sea and upper air that drives tropical storm formation (Figure 2). The air closer to the sea is warm, while the upper air is cool. The warm, moist air on the surface rises into the cooler air, and as this happens, more warm air fills in closer to the sea to take the previously risen air's place. The warm air **condenses** and forms clouds that release heat. This process of warm air cycling continues until the earth's rotation gives the whole system a push, causing the storm to spin.[8] Because tropical storms are energized by the difference in temperature between the sea's surface and the upper air, an increase in sea surface temperature means a greater difference between the temperature of the sea and the temperature of the upper air. This process adds more "fuel" to the storm, causing warm air to rush into the system, making it larger, faster, and more powerful.[8]

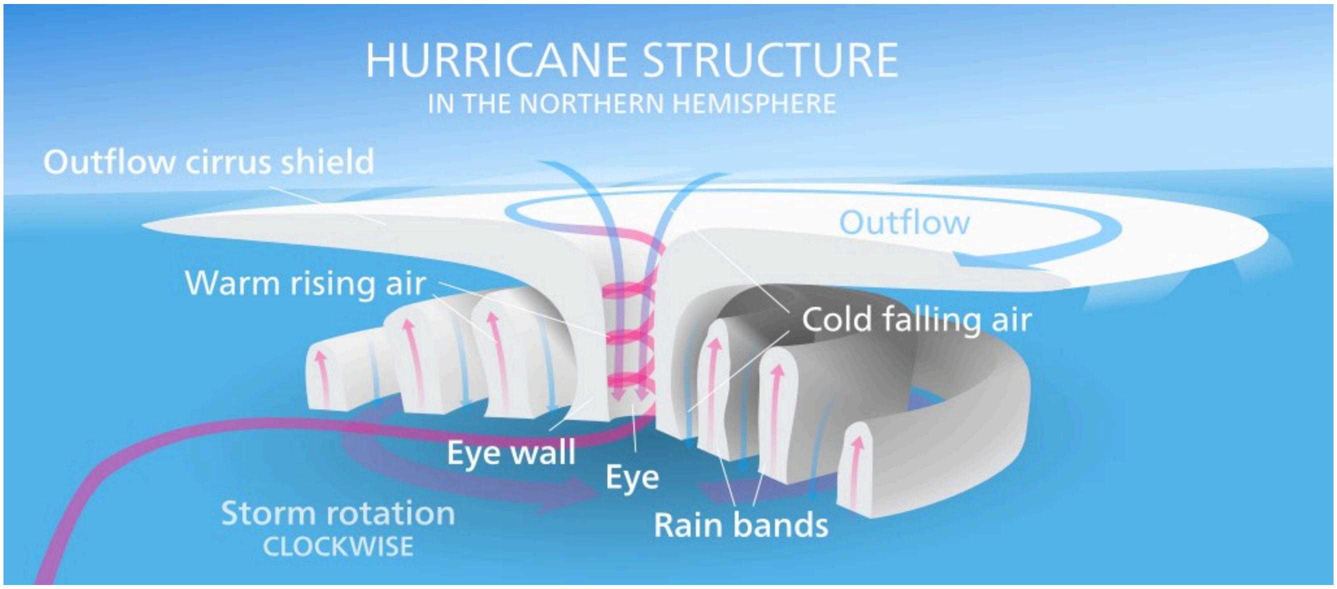


Figure 2. Cross Section Diagram of a Hurricane.
The difference in air temperature between the ocean's surface and in the atmosphere drives storm formation.
The larger the temperature difference, the larger the storm.
Diagram by Kelvinsong, 2012 CC BY 3.0

It is difficult to ascertain if increased storm intensity is the result of human pollution or of natural causation. It is not possible to know the exact pattern of tropical storms but by utilizing the historical record a trend emerges. Scientists have created **climate** models that allow synthetic weather events to be simulated and observed. These models are used to test the theory of the **correlation** between higher SSTs and intensity of tropical storms.[9,10] In a study conducted by Mendelsohn et. al. a scenario was created to predict greenhouse gas **emissions** for the next century.[11] The scenario was applied to several climate models to see how the climate might change by 2100. Climate and cyclone models are used together which allowed the authors to look at changes in frequency, intensity, and location of tropical storms. When the study was performed, the authors observed a set of 17,000 synthetic storms in each climate scenario. Tropical storm intensity was measured using minimum barometric pressure, and the results of the study indicated storms are more intense over warmer waters near the equator.[11]

With Earth's **population** growing, pollution and greenhouse gas emissions are increasing. SSTs also continue to rise, which may result in stronger storms. There is a greater concentration of the global population in coastal areas and these areas are more sensitive to storm destruction.[11] Thus, a greater population leads to more pollution, which can lead to stronger storms, and then the stronger storms lead to more damage. These growing coastal areas have increasingly valuable **infrastructure** that can be damaged. With higher populations and more expensive infrastructures, greater economic damage occurs from strong tropical storms. Tropical storm intensity is increasing and repairing infrastructure damage from storms is becoming more expensive.

Figure 3. In 2005, Hurricane Katrina caused over $100 billion in property damage, leaving thousands without homes.

In 2012, Hurricane Sandy affected many U.S. states and demonstrated the destruction of increasingly strong tropical storms[6] (Figure 1). According to a New York Times article by Justin Gillis, scientists cannot agree on whether this storm was intensified by climate change, however climatologists interviewed after the storm said that the surface temperatures of water in the Atlantic Ocean were higher than normal before the storm occurred.[6] This does not necessarily mean that climate change was to blame for the storm's power. However, it does support the theory that warmer waters cause stronger storms. Although it is uncertain if Hurricane Sandy was caused by climate change, future studies may determine climate change is the primary cause of increased tropical storm intensity. SSTs can be increased by heat trapped from greenhouse gases and warmer waters cause stronger storms. So, are higher SST's caused by climate change? There is no definite answer to this, but hopefully future research can answer this question.

References

1. Greenough, G., et. al. (2001). The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. Environmental Health Perspectives, 109:191-198
2. McDonald, R.E., et. al. (2005). Tropical storms: representation and diagnosis in climate models and the impacts of climate change. Climate Dynamics, 25: 19-36
3. Michener, W.K., et. al. (1997). Climate change, hurricanes and tropical storms, and rising sea level in coastal wetlands. Ecological Applications, 7:770-801
4. National Geographic. Sea Temperature Rise. Retrieved from http://ocean.nationalgeographic.com/ocean/critical-issues-sea-temperature-rise/
5. Walsh, K.J.E., et. al. (2012). Climate change impacts on tropical cyclones and extreme sea levels in the South Pacific- A regional assessment. Global and Planetary Change, 80:149-164
6. Gillis J. (2012, October 7). Did Global Warming Contribute to Hurricane Sandy's Devastation? The New York Times. Retrieved from www.nytimes.com
7. Khutson, T.R. et. al. (2010). Tropical cyclones and climate change. Nature Geoscience, 3:157-163
8. Byrn, A. et. al. (2013). The Future of Storms (online video), USA: The New York Times
9. Intergovernmental Panel on Climate Change. (2013). What is a GCM? Retrieved from http://www.ipcc-data.org/guidelines/pages/gcm_guide.html
10. Walsh, K.J.E. et. al. (2004). Fine-resolution regional climate model simulations of the impact of climate change on tropical cyclones near Australia. Climate Dynamics, 22:47-56
11. Mendelsohn, R. et. al. (2012). The impact of climate change on global tropical cyclone damage. Nature Climate Change, 2:205-209
12. NASA. (2013). [Photograph of Superstorm Sandy from Space]. Retrieved from Wikimedia Commons. Public Domain.
13. Kelvinsong. (2012). [Diagram of a hurricane]. Retrieved from Wikimedia Commons. CC BY 3.0.
14. Louisiana Sea Grant College Program at Louisiana State University. (2005). [Photograph of property damage caused by Hurricane Katrina]. Retrieved from FlickrCommons. CC BY 2.0.

1.2 History of Drought in California Paints Troublesome Outlook

Jaymes T. StClair

A lack of winter precipitation in California, alongside a previously dry environment, threatens a recurrence of the 1970s drought conditions and subsequent water restrictions. What is causing the prolonged series of droughts? Do recent drought events foretell the future of water supply management in California?

Figure 1. During drought conditions, many properties, including California's state house in Sacramento, conserve water by foregoing non-essential practices.
Photograph by Kevin Cortopassi, 2014. CC BY-ND 2.0.

California has always had a water problem. The **aqueduct system** that was developed for the city of Los Angeles was a feat of spectacular engineering. However, a moderately large percentage of the water that the state uses derives from **snowpack** in the **Sierra Nevada mountain range.**

Many studies have developed models that can predict winter **precipitation** so California is able to properly allocate water resources for the dry summer months. In a recent study, Peter Caldwell questions the reliability of two prominent precipitation models.[1] These models, namely regional **climate** models and general circulation models, have performed poorly in predicting the amount of precipitation that California will receive.[1] Results have shown that regional climate models regularly over predict precipitation totals, while conversely, most general circulation models underestimate precipitation totals.[1] Local officials use precipitation models to determine how much water will need to be purchased and diverted into the many agricultural valleys of the state. There may be devastating economic and political consequences if these officials rely on unpredictable models such as regional climate models and general circulation models.

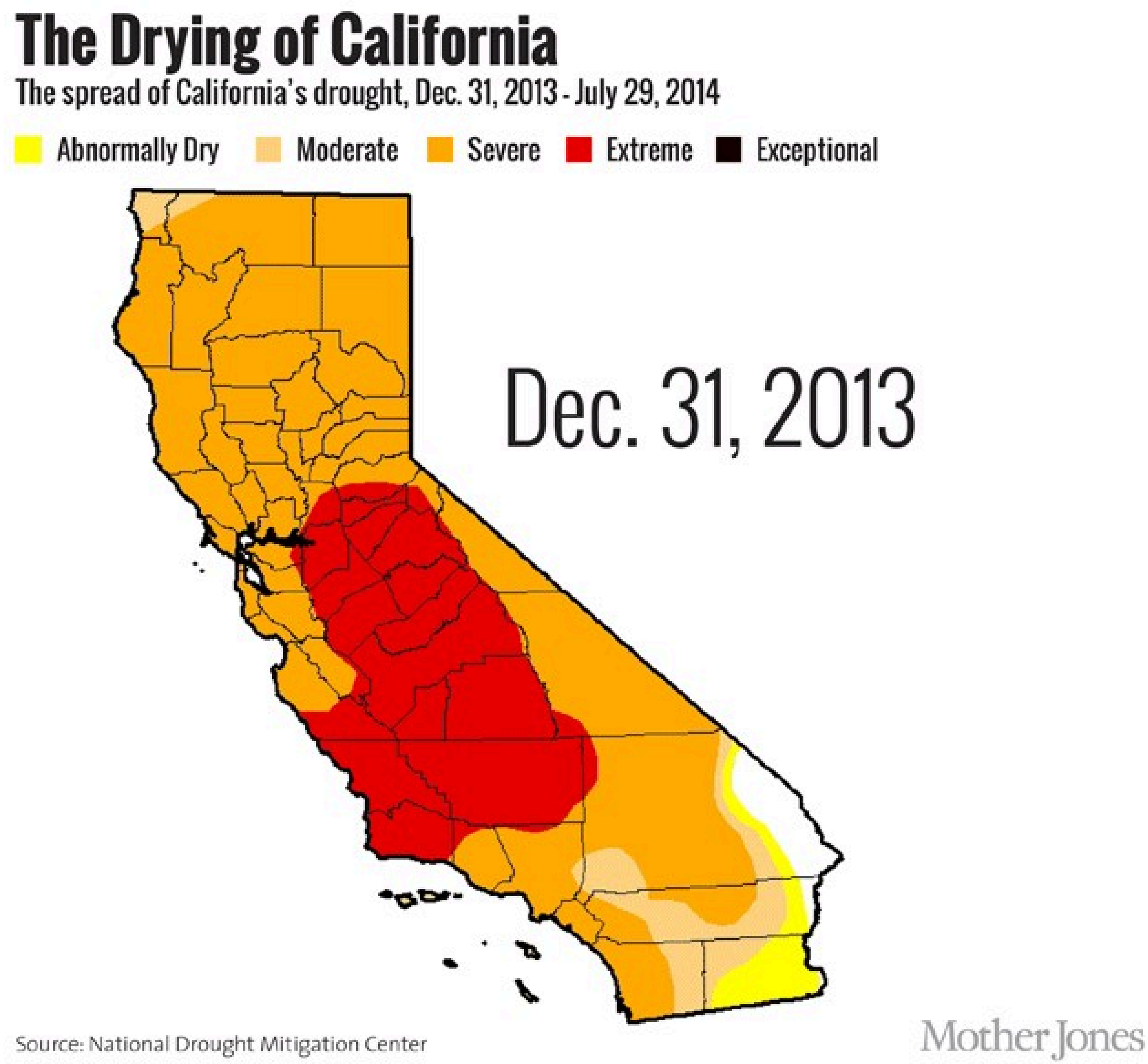


Figure 2. Drought Conditions in California from December 2013 through July 2014. Courtesy of National Drought Mitigation Center, 2014. Public Domain.

One location where recent **droughts** can be clearly witnessed is the **Folsom Lake** watershed, which is located near the slopes of the Sierra Nevada mountain range (Figure 3). The current **reservoir** level of the lake is so low that the remnant of a **ghost town** from the Gold Rush era is visible.[2] The water districts that rely on water from Folsom Lake have urged consumers to reduce water usage by at least twenty percent. This is similar to standards implemented during the drought periods of the 1970s. A hydrologic research study done by Jianzhong Wang and Konstantine Georgakakos used simulation models to look at the sensitivities of dynamic precipitation during the winter over the Lake Folsom watershed.[3] The simulation spanned thirty-five years and utilized data from sixty-two winter storms. The results suggested that precipitation prediction models were not as accurate for light and moderate precipitation levels.[3] This inaccuracy is similar to the inaccuracies found in the precipitation models previously mentioned, and can lead to similar problems for local officials trying to control water consumption during dry summer season.

Figure 3. Lake Folsom is one of California's reservoirs that is heavily impacted by drought. These before and after pictures show the water levels in Folsom Lake before and during the 2012-2014 North American Drought. Photographs by the California Department of Water Resources, 2014. Public Domain.

There are many water reservoirs around the Sierra Nevada Mountains that rely on the winter snowpack. More than 25 million people and the $44.7 billion agricultural industry of California use the water from snow that melts off the 650 kilometers (400 mile) mountain range.[4] In January 2014, the snowpack was just twenty percent of the historical average.[2] The visual evidence from a satellite image of this lessened snowpack is staggering (Figure 4). In a study by Kim et al., ten to thirty percent of cold season precipitation derives from atmospheric river landfalls.[5] With high pressure systems diverting nearly all forms of precipitation north, droughts are exacerbated as expected precipitation is diverted away from the coast.[6]

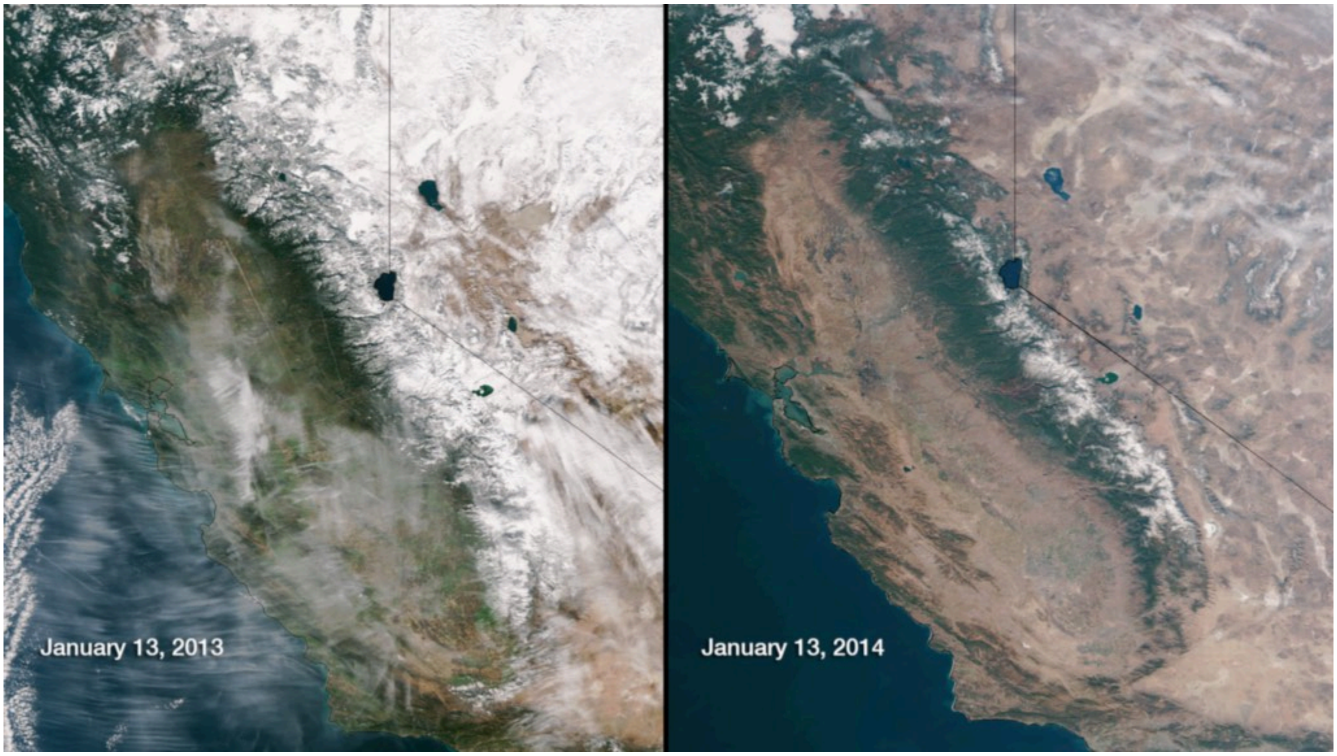


Figure 4. Snowpack on the Sierra Nevada Mountain Range. In the southwestern United States, snowpack from the Sierra Nevada mountains is an important source of freshwater. Record low snowfall in 2014 prolonged the already severe drought.
Photographs by NASA/NOAA, 2014. Public Domain.

Studies conducted on the possible impacts of severe and sustained droughts in California are numerous because bringing water to the many valleys of the state is complex and costly. California faces the enduring challenge of high evaporation paired with low precipitation. In a historical study examining a medieval climate Glen MacDonald discovered an anomaly that consisted of prolonged episodes of **arid** conditions and severe droughts spanning five hundred years.[7] These conditions are linked to the abandonment of the affected regions by local native tribes and to increased violence between the tribes over precious fertile lands.[7] MacDonald suggests that a similar event could occur in the future due to natural or **anthropogenic** causes.[7] MacDonald also looked at the impacts of a "perfect" drought on southern California. The "perfect" drought consists of a prolonged drought in southern California paired with simultaneous similar conditions in the Sacramento River basin and upper Colorado River basin.[8] There is evidence that all these conditions occurred in the 11th and 12th centuries during this climate anomaly.[8] Therefore, the scientists believe California is experiencing prolonged periods of drought caused by climate change.

California is currently undergoing a series of droughts that could possibly rival the severe droughts witnessed during the 1970s. The current drought is caused by an unprecedented **high pressure ridge** that is just offshore of the west coast. This high pressure ridge is blocking all of the winter storms needed to provide the necessary precipitation for the dry summer months and has been diverting weather systems to the north for the past thirteen months (as of January 2014). This is an abnormal amount of time for a system like this to remain uninterrupted. Climatologists say that the longer the system persists, the less likely approaching winter storms will be able to break through.[4]

Scientists working with the American Meteorological Society are conducting a study to determine whether this extreme weather event is caused by natural variability or human-caused **climate change**. A 2012 study found that a drought from that same year was primarily due to natural variation. However, the study also indicated that climate change was a factor in the heat waves that occurred during the spring and summer months.[9] Scientists are unsure whether to attribute the drought to natural variation, climate change, or a combination of both for this weather event. Long term precipitation changes are particularly difficult to predict, especially for mid-latitude countries such as the United States. One factor that cannot be overlooked is the loss of the **ozone layer** over the past century. Another study examined forest mortality by considering different levels of ozone exposure.[10] The study established a **correlation** between the diminishing ozone layer and increasing global temperatures, determining that regions exposed to high levels of ozone were deemed vulnerable to increased droughts and fires.[10] These findings should be a great concern for California officials and to the forests in the state.

Figure 5. Photograph on the shore of Folsom Lake when the reservoir was filled to only 18% capacity. Photograph by Robert Couse-Baker, 2014. CC BY 2.0.

California officials are employing lessons learned during the 1970s drought to understand how to conserve the public water supply. One lesson state officials learned is that the general public can help in **conservation** efforts. The coastal community of Goleta was provided with low-flow shower heads and other water saving devices and reduced water consumption by thirty percent, which was double the expected reduction.[11] California's total **population** has increased by 18 million since the 1970s drought period and many conservation programs from that era will need to be updated to properly manage the water supply.[12] The current mindset of punishing citizens for not conserving water should be amended to instead reward citizens for conserving water. This will make water conservation efforts more successful.

References

1. Caldwell, P. (2010). California Wintertime Precipitation Bias in Regional and Global Climate Models. Journal of Applied Meteorology and Climatology, 49: 2147-2158.
2. Onishi, N. & Wollan, M. (2014 January 17). Severe Drought Grows Worse in California. The New York Times.
3. Wang J. & Georgakakos, K.P. (2004). Validation and Sensitivities of Dynamic Precipitation Simulation for Winter Events over the Folsom Lake Watershed: 1964-99. Monthly Weather Review, 133: 3-19.
4. Goodale G. (2014 January 21). California drought: Scientists puzzled by persistence of blocking "ridge." The Christian Science Monitor.
5. Kim, J. et. al. (2012). Effects of atmospheric river landfalls on the cold season precipitation in California. Climate Dynamics, 40: 465-474.
6. Martin, K. (2014 January 12). The California Drought Finally Explained With Both Upper and Lower Levels of Atmosphere to Blame. BeforeItsNews.com
7. MacDonald, G.M. (2007). Severe and sustained drought in southern California and the West. Quaternary International, 173-174: 87-100.
8. MacDonald, G.M. et. al. (2008). Southern California and the perfect drought. Quaternary International, 188: 11-23.
9. Lochhead, C. (2014 January 22). California drought: Scientists to probe cause. The San Francisco Chronicle.
10. Panek, J. et. al. (2013). Ozone distribution in remote ecologically vulnerable terrain of the southern Sierra Nevada, CA. Environmental Pollution, 180: 343-356.
11. Warren, J. (1991 February 19). Lessons of the 1970s Shape Water Rationing Plans. Los Angeles Times.
12. Fimrite, P. (2014 January 19). California drought: Water officials look to rules of '70s. The San Francisco Chronicle.
13. Cortopassi, Kevin. (2014). Sacramento Capital During the Drought. [Photograph]. Retrieved from FlickrCommons. CC BY-ND 2.0.
14. National Drought Mitigation Center. (2014). Progression of the 2012-2014 historic California drought, from December 2013 to July 2014. [Animation]. Retrieved from Wikimedia Commons. Public Domain.
15. California Department of Water Resources. (2014). [Photograph of Lake Folsom Before and

During the 2012-14 North American Drought]. Retrieved from http://www.nasa.gov/jpl/multimedia/california-drought-20140225/#.VRLyq5PF_7W. Public Domain.

16. NASA/NOAA. (2014). [Photograph from space comparing the Sierra Nevada snowpack in 2013 and 2014]. Retrieved from http://www.nnvl.noaa.gov/MediaDetail2.php?MediaID=1483&MediaTypeID=1. Public Domain.
17. Robert Couse-Baker. (2014). Dry Folsom. [Photograph] Retrieved from FlickrCommons. CC BY 2.0.

1.3 The Effects of Climate Change on the Syrian Uprising

Levi J. Cramer

The Middle Eastern country of Syria has been in a state of civil war since 2011. One factor influencing the current situation is climate change. Climate change is responsible for desertification in the region, which is leading to increased dissent among the citizens of Syria.

Since March of 2011, a small Middle Eastern country named Syria (Figure 2) has been combating an uprising that has been a central focus of international news to this day. The people are rebelling because they are upset with the regime of **Bashar al-Assad**, the president of Syria (Figure 1). More than seventy-five thousand people have been killed since the inception of the uprising. Casualties have come from citizens either defending the country, or rebelling against it. To understand the frustrations of the Syrian people, one needs to look to the root cause of the uprising.

Figure 1. Demonstration in Kafranbel, Idlib against the Assad Regime.
Photograph by Freedom House, 2013. CC BY 2.0.

There are many reasons for the conflict in Syria. First, the people were upset that the Assad regime refused to yield any of its power and hold a democratic election. Second, the Assad regime was arresting large sums of people for protesting against its rule, including school children. The third and often overlooked reason for the conflict is that **climate change** has caused large losses for the Syrian agricultural industry, and the government was unwilling to help. Climate change is occurring in Syria by means of depleting water supply and advancing **desertification**, both of which are closely linked. These effects of climate change are expected to continue through 2050.

Figure 2. Syria is located in the East Mediterranean within the Middle East. Its capital, Damascus, is located in the southwest near the Lebanon boarder.
Map data ©2015 Google. Public Domain.

Click Here to Explore Damascus, Syria in Google Maps

The Figeh Spring is an important source of water for Syria and is located near its capital city **Damascus**.[1] Researchers found that between 1961 and 1990, **precipitation** during the winter had dropped by approximately 11%, and by approximately 8% during the spring.[1] This drop in precipitation is expected to continue, and between 2070 and 2099 the rate will likely be 22%, with an annual mean temperature increase of 4°C.[1] Syria is not the only country in the region experiencing a decrease in precipitation, however its decrease is the largest.[2] Between 2007 and 2008, precipitation dropped by 50% in some areas of the country (Figure 3). This is troubling because the region is dependent on precipitation to provide the water needed to grow food. The loss of precipitation becomes dire when run-off from countries north of Syria is also down. Substantial changes in the regional **climate** are likely to increase the challenges placed on the physical and biological components of riverine **ecosystems**.[3]

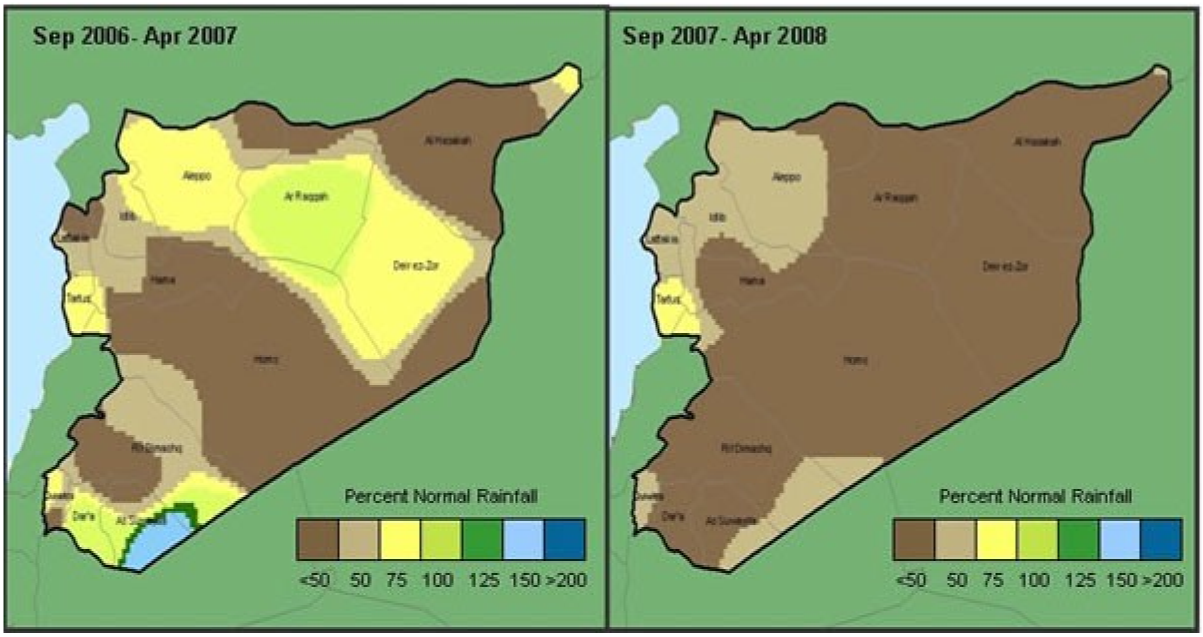


Figure 3. Comparison of rainfall in Syria to the normal season average (%).
Courtesy of the USDA Foreign Agricultural Service, 2008. Public Domain.

The decrease in precipitation has also triggered lasting **droughts**.[4] The effects of drought and desertification are further conflated considering that the population of Syria has increased by 50% in the past few years. Increased land use is needed to support this growing population, which contributes to **erosion** and makes much of the land unusable.[5]

Desertification is directly correlated with the decrease in precipitation. Since the 1940's, desertification has been increasing in Syria. Desertification is also affecting regions such as the Khabur River in northeastern Syria. The Khabur River is on the opposite side of the country from Damascus, demonstrating the widespread effects of desertification.[6]

Figure 4. The desert in Syria is expanding due to desertification and the lack of precipitation. Photograph by Marc Veraart, 2010. CC BY-ND 2.0.

How do the effects of climate change contribute to the insurrection that is occurring? Droughts are making crops more difficult to grow and causing food prices to rise dramatically. Rise in food prices is leading to impoverished people going hungry, fueling the uprising against the Bashar al-Assad government, and adding to the numbers of refuges and rebels.[7] Tragically, the drought has impacted more than 1.3 million people and 160 villages had to be abandoned due to crop failure.[8] There has also been a loss of 85% of the livestock.[8] These displaced people migrated to the major cities in Syria, including Damascus, and were quickly inundated by rebel **propaganda**. This propaganda added to the already high levels of dissent that farmers felt for the Assad government. Fueling this preexistent hatred, the farmers subsequently joined the rebels.[9]

Climate change has led to the increasing number of rebels in Syria. The Syrian crisis is an issue that must be addressed through international systems, as the effects of climate change are likely to increase. Analysts are in agreement that the current effects of climate change in the **Middle East** are alarming. Nine of the world's top importers of grain are located in North Africa and the Middle East, and expanding desertification will make growing crops increasingly more difficult.[10] The uprising in Syria may be first of many conflicts to arise in the Middle East as a result of climate change.

References

1. Smiatek, G., et. al. (2013). Hydrological Climate Change Impact Analysis for the Figeh Spring near Damascus, Syria. Journal Of Hydrometeorology, 14:577-593
2. Terink, W., et. al. (2013). Climate change projections of precipitation and reference evapotranspiration for the Middle East and Northern Africa until 2050. International Journal Of Climatology, 33:3055-3072
3. Bozkurt, D. & Sen, O.L. (2013). Climate change impacts in the Euphrates-Tigris Basin based on different model and scenario simulations. Journal of Hydrology, 480:149-161
4. Kaniewski, D., et. al. (2012). Drought is a recurring challenge in the Middle East. Proceedings Of The National Academy Of Sciences Of The United States Of America, 109:3862-3867
5. Haktanir, K., et. al. (2004). The prospects of the impact of desertification on Turkey, Lebanon, Syria and Iraq. Environmental Challenges In The Mediterranean 2000-2050, 37:139-154
6. Hole, F. (2009). Drivers of Unsustainable Land Use in the Semi-Arid Khabur River Basin, Syria. Geographical Research, 47:4-14
7. Abrams, L. (2013 September 10). How climate change is linked to Syria's war. Salon, Webpage
8. Shank, M. & Wirzba, E. (2013 September 13). How Climate Change Sparked the Crisis in Syria. USNews, Webpage
9. Ghose, T. (2013 December 10). Human-Caused Climate Change May Have Worsened Syrian Unrest. Live Science, Webpage
10. Plumer, B. (2013 September 10). Drought helped cause Syria's war. Will climate change bring more like it? The Washington Post, Webpage.
11. Freedom House. (2013). Demonstration against ASSad regime in Kafranbel, Idlib. [Photograph]. Retrieved from FlickrCommons. CC BY 2.0.
12. USDA Foreign Agricultural Service. (2008). [Diagram of seasonal rainfall in Syria during the 06-07 and 07-08 planting seasons]. Retrieved from http://www.pecad.fas.usda.gov/highlights/2008/05/syria_may2008.htm. Public Domain.
13. Veraart, Marc. (2010). [Photograph of man on a motorcycle in the Syrian desert]. Retrieved from FlickrCommons. CC BY-ND 2.0.

1.4 Hawaii Votes - Yes or No to G.M.O.s?

Alyssa Marie Jones

In 2013, Hawaii passed a bill banning the use of genetically modified organisms (GMOs). However, research on GMOs is inconclusive. Do GMOs put Hawaiians at risk of adverse health effects? What does the passage of a GMO ban in Hawaii signify for the future of food production in the United States?

Figure 1. Protesters on the Hawaiian island of Maui demonstrate against Monsanto and the use of genetically modified organisms on the island. Monsanto is an agricultural biotechnology company and a world leader in the production of genetically engineered crops.
Photograph by Alexis Baden-Mayer, 2010. CC BY 2.0.

The controversial debate regarding the role of genetically modified organisms (**GMOs**) in Hawaii has ended. A bill to ban GMOs was introduced in May, 2013 by Margaret Wille, the chairwoman of the Council's Agricultural Committee of Hawaii. This ban was originally proposed to the nine-member Hawaii County Council.[1] The bill bans growing any genetically engineered crop on the island, with the exception of the two already grown there: corn and papaya. Field tests to study new GMOs are also be banned and violations result in fines as high as $1,000 per day.

GMOs continue to be heavily debated throughout the United States. In response to a warming world and a growing global population, the food industry is under pressure to grow healthy food more efficiently. As a result, several companies have started using GMOs. The use of GMOs has led to increasing concerns among the public. According to a poll conducted by the New York Times, 3 out of 4 Americans surveyed are concerned about the health risks associated with GMOs in their food.[1] Approximately 20 states have proposed bills that would require food that contains GMOs to be labeled.[1] For instance, Whole Foods Markets, a national grocery store chain, has stated that it will label or replace foods that contain GMOs by 2018.[1]

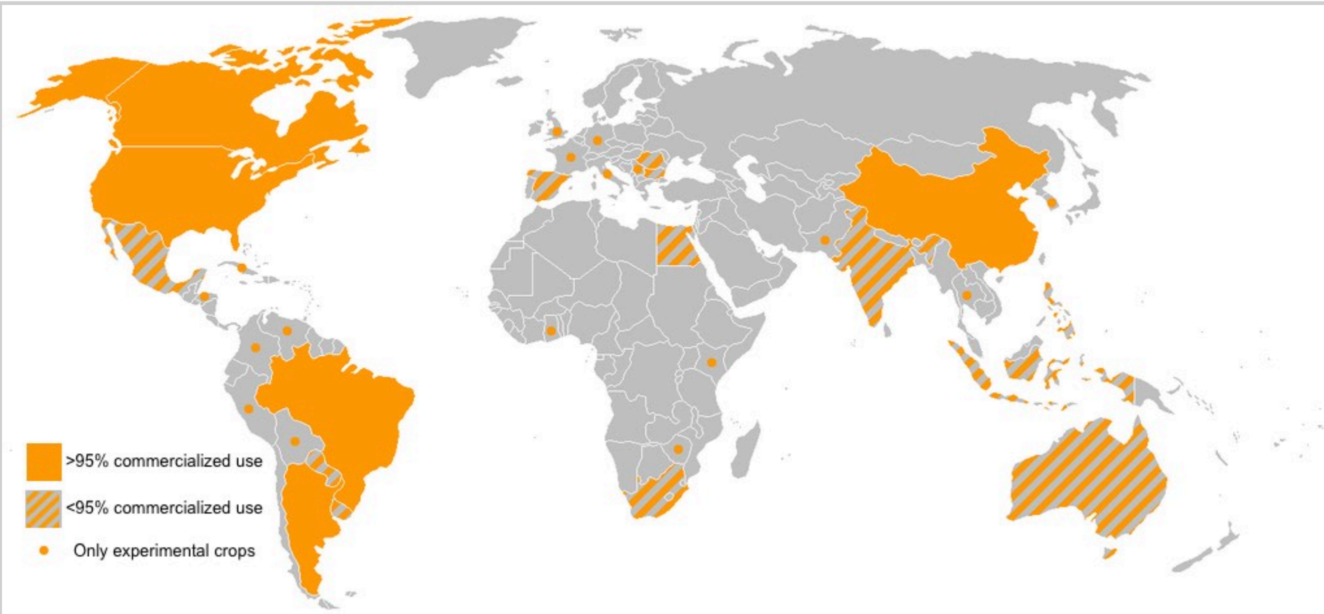


Figure 2a. While many countries are taking a precautionary approach to GMO's, only planting experimental crops, other countries, like the United States, have embraced GMO production. Data as of 2005.Map by Pixeltoo, 2005. Public Domain.

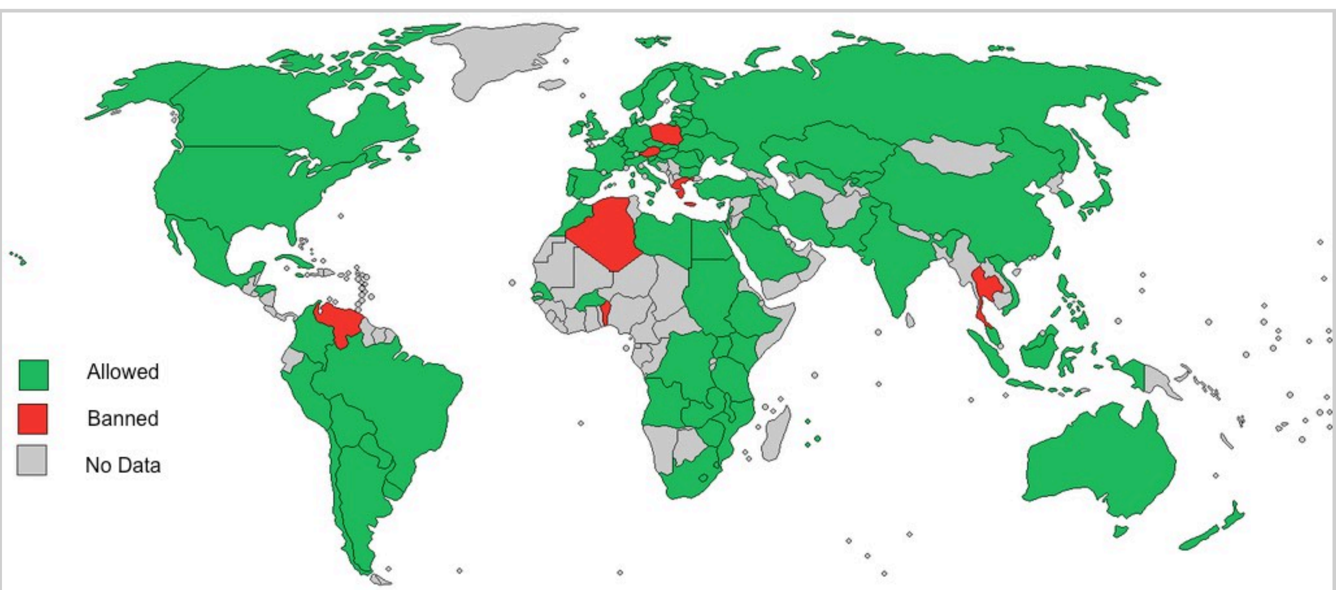


Figure 2b. Laws regarding GMO production are diverse. Green indicates that some form of GMO use is allowed. Red indicates that the country has fully prohibited the use of GMO's or GMOs can only be used for scientific

purposes. Map by Zhitelew, 2009. Public Domain.

GMOs have been commercially grown for the past two decades. In 2010, approximately 10% of crops planted worldwide were GMOs. Thirty countries are growing GMOs, while increasingly more countries are performing **field trials**. The four primary types of GMOs are soybean, maize, cotton, and rapeseed. GMOs are usually handled under high scrutiny.[2] In the European Union (E.U.), goods and feed containing as little as 0.9% modification must be labeled as a GMO. Food is tested by **Polymerase Chain Reaction (PCR)** to determine which contain GMOs and then it is labeled accordingly.[3] The E.U. has a zero-tolerance policy in which non-authorized GMOs cannot be placed on the market.[4] In the United States, there is no standard for labeling GMOs. However, there is an organization called the **Non-GMO Project**, which tests individual ingredients for GMOs by using a third party testing facility. Many GMO-free foods display the Non-GMO Project verified seal on their label.[5]

In 1998, the papaya was among the first genetically modified (GM) fruits to be approved by the **Food and Drug Administration (FDA)**. It was created in response to the **papaya ringspot virus (PRSV)** that was infecting and ultimately destroying papaya production[6] (Figure 3). The papaya ringspot virus would have decimated papaya production worldwide were it not for scientific engineering. The GM papaya serves as the impetus for further GMOs (Figure 4). As of 2012, the FDA has approved over 40 seeds and plants for genetic modification.[7]

Figure 3. A Hawaiian Papaya infected with ringspot virus (PRSV).
Photograph by Scot Nelson, 2014. CC BY 2.0.

The focus of the GMO debate in Hawaii involves the people's desire to live in a GMO free state, versus the aspirations of farmers to grow virus free crops. Distrust of GMO seed-producing companies like **Monsanto** helped inspire the bill. The people of Hawaii are worried that their island will be overtaken by large agricultural companies, in which profit is often valued more than sustainability and public safety. Hawaiian residents have the added challenge of deciding what to believe regarding information on GMOs. Stories of mice developing tumors after consuming GM corn have been publicized, although one week later, scientists denounced these articles as false. Butterflies were also rumored to be disappearing due to GMOs. However, it was discovered that butterfly disappearances were not directly caused GMOs, but by the **herbicides** used in conjunction with the GMOs.[1] These accounts of GMOs causing harm in organisms have damaged the public image of the product.

Hawaiian farmers are concerned that the ban will create a negative perception of GMOs and their crop sales will decline. Supporting farmers' concerns is Dr. Suzie, who suggests that humans have bred crops of the same species to produce desired traits for millenniums. Through technological advances it has become possible to borrow features not found within a crop family and input these features within an organism.[1] For example, rice can be modified to have vitamin A. This type of rice is called **Golden Rice**, and is used to aid the world's poor populations, which are often deficient in this crucial vitamin. The scientists that created Golden Rice argue that GMOs have had an exemplary safety record since their introduction into commercial production over 17 years ago. These scientists believe that GMOs benefit farmers, the environment, and consumers. GM crops have been adopted faster than any other agricultural advance in humanity's history.[8]

In attempt to address the prevailing uncertainty with GMOs, scientists have conducted various research projects. Six thousand five hundred (6500) members of the **Ecological Society of America** conducted research on GMOs. Results suggest that assessing the ecological risk of GMOs is complex because many factors are involved. Such factors include the organism that is being modified, the engineered **gene**, and the environment in which the organism will be placed. Due to these factors, GMOs need to be carefully handled and monitored. The scientists also cautioned that GMOs will be less fit than their parents and that natural selection would act on GMOs as it does with other organisms. If a GMO does not perform as intended or malfunctions, it will take many generations for the GMO to dissipate from the environment. GMOs will not fully replace their predecessors and the scientists express that utmost carefulness must be exercised with these organisms.[9]

Figure 4. A healthy papaya plantation on Kuma Farms in Hoolehua, Hawaii.
Photograph by J. Shyun, 2010. CC BY-NC-ND 2.0.

Following the cautionary advice of the Ecological Society of America, Hawaii has implemented a ban on GMOs. The bill was signed December 5th, 2013 postponing the use of GMOs in Hawaii.[1] It remains uncertain how the rest of the United States will respond to GMOs. Debate over GMOs will likely continue and further research is needed to determine the short and long term effects of these manufactured organisms.

References

1. Harmon, Amy (2014 January 5). A Lonely Quest for Facts on Genetically Modified Crops. The New York Times, pp A1.
2. Holst-Jensen, A., et al. (2012). Detecting un-authorized genetically modified organisms (GMOs) and derived materials. Elsevier: Biotechnology Advances, 30:1318-1335.
3. Holst-Jensen, A., et al. (2002). PCR technology for screening and quantification of genetically modified organisms (GMOs). Analytical and Bioanalytical Chemistry, 375:985-993.
4. Guertler, P. et al. (2012). Development of a CTAB buffer-based automated gDNA extraction method for the surveillance of GMO in seed, European Food Research and Technology, 236:599-606.

5. Novak, Sara. (2012). Why is America One of the Only Industrialized Nations With No GMO Labeling? TLC Retrieved from http://recipes.howstuffworks.com/why-is-america-one-of-the-only-industrialized-nations-with-no-gmo-labeling1.htm
6. Lin, H.T., et al. (2013). Toxicity Assessment of Transgenic Papaya Ringspot Virus of 823-2210 Line Papaya Fruits, Journal of Agricultural and Food Chemistry, 61:1585-1596.
7. Hennessey, Rachel. (2012, November 03). GMO Food Debate In The National Spotlight. Forbes. Retrieved from http://www.forbes.com/sites/rachelhennessey/2012/11/03/gmo-food-debate-in-the-national-spotlight/2/.
8. Alberts, B., et al., (2013). Standing up for GMOs. Science, 341:1320.
9. Tiedje, J.M., et al., (1989). The Planned Introduction of Genetically Engineered Organisms: Ecological Considerations and Recommendations, Ecology, 70:298-315.
10. Baden-Mayer, Alexis. (2010). [Photograph of protesters against GMOs in Hawaii]. Retrieved from FlickrCommons. CC BY 2.0.
11. Pixeltoo. (2005). World GMO production. [Diagram] Retrieved from Wikimedia Commons. Public Domain.
12. Zhitelew. (2009). Laws regarding GM food. [Diagram]. Retrieved from Wikimedia Commons. Public Domain.
13. Nelson, Scot. (2014). [Photograph of papaya with ringspot virus (PRSV)]. Retrieved from FlickrCommons. CC BY 2.0.
14. Jshyun. (2010). [Photograph of Papaya trees on Kuma Farms in Hawaii]. Retrieved from FlickrCommons. CC BY-NC-ND 2.0.

1.5 Warming Oceans Cause Coral Reef Bleaching

Brittany L. Sulainis

Coral reefs are important to the survival of many ocean dwelling organisms and the tourism industry of certain coastal regions. Algae and coral reefs share an important relationship. What will happen if this symbiotic relationship is disrupted due to coral bleaching? Will the remaining organisms in this ecosystem survive without living coral?

Figure 1. A colony of the soft coral known as the "bent sea rod" stands bleached on a reef off of Islamorada, Florida.
Photograph by Kelsey Roberts, 2014. CC BY 2.0.

Coral reef communities have helped shape the dominate **ecosystems** of the oceans for over 200 million years. They contain a collection of biological communities and make up one of the most diverse ecosystems in the world. Coral are classified as **cnidarians**, and they are sessile aquatic animals that can only catch small prey (fish and planktonic animals) by using their tentacles.[1] Individual **polyps** live in **colonies** that form coral reefs and are able to retract inside their skeleton for protection when predators approach. The reefs are composed of hard **calcium carbonate** skeletons that coral secrete over time and the growth rate of these structures depends upon the specific coral species alongside other environmental conditions. Coral reefs are critical to the survival of a large amount of ocean dwelling organisms because they provide a food source and shelter.[2]

Coral has an important **symbiotic relationship** with algae. A symbiotic relationship is one that is considered mutually beneficial to both of the organisms involved. Algae lives inside of the coral polyps and produces food through the process of **photosynthesis**, which it then shares with the coral. This relationship works well since coral reefs are located in water that is shallow and clear, which allows large amounts of sunlight to reach the algae. Sunlight is needed for algae to produce food for both species.[3]

A phenomenon that has become a large global concern is known as **coral bleaching**. Coral bleaching occurs when the symbiosis between algae and the coral is disrupted due to the algae being expelled from the polyp. When this occurs, coral loses its color as the white calcium carbonate skeletons of the coral colony are exposed (Figure 1 and 2). Coral reef communities are sensitive to changes within the ecosystem, especially to water quality.[4] These communities can only endure a small range of temperatures and other chemical characteristics, thus scientists use coral reefs as indicators for when something may be wrong in the environment. Mass bleaching events are causing large coral mortality, which is endangering the ecosystem.[4]

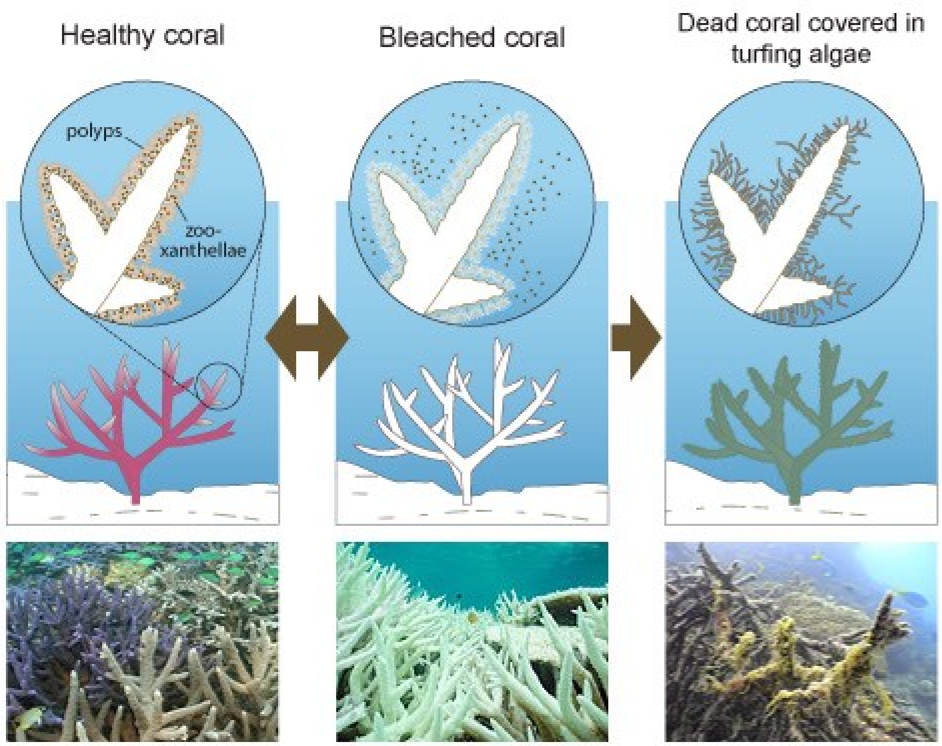


Figure 2. A comparison of coral in various states of health. Coral is visually distinct depending on its state of health.
Used by permission from the Commonwealth of Australia, Great Barrier Reef Marine Park Authority, 2011. CC BY-ND-NC 2.0.

In 2009, eighty three coral species were petitioned to be listed under the U.S. Endangered Species Act.[5] There was great concern that these coral species were going to become functionally extinct, followed quickly by absolute **extinction**. At the time, eighty two of the eighty three species were given a pending status due to the necessity of proof of their endangerment. In each case, **climate** and ocean change was cited as the cause of species decline.[5] Mass bleaching events have shown a positive **correlation** with the increase in average seawater temperature. Approximately 25% of the carbon dioxide produced by human activity has been absorbed by the oceans.[5] This CO_2 absorption creates changes in seawater chemistry called **ocean acidification.**[6] Not only are ocean acidification and rising sea temperature causing corals to bleach, these changes also have negative effects on the developmental stages of larval coral and the adult coral's ability to reproduce.[7] The effects on coral are immediate and if they do not cause mortality, they reduce coral growth and cause several other harmful long term effects.[8]

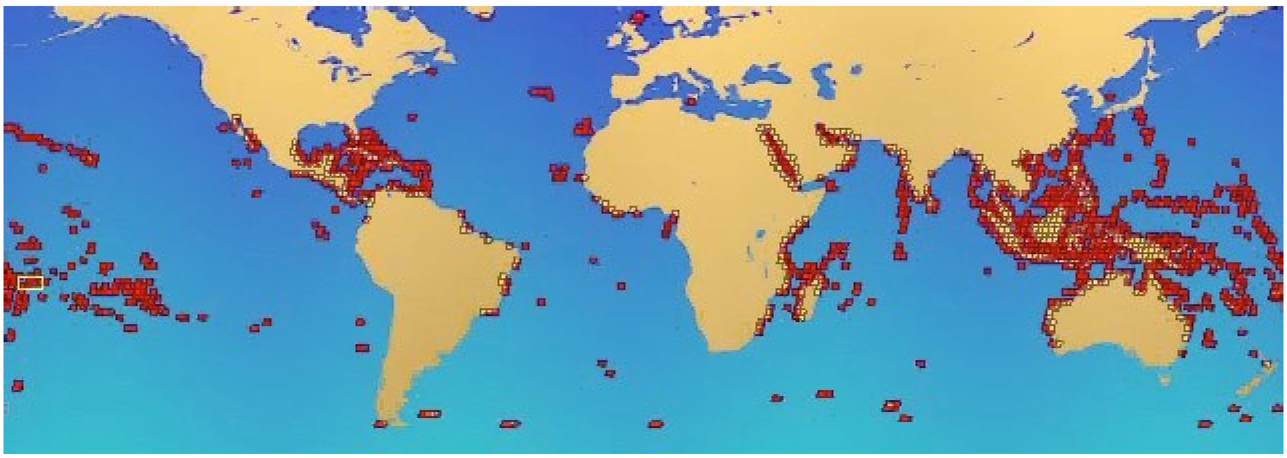


Figure 3. Location of coral reefs around the world.
Courtesy of NASA, 2006. *Public Domain.*

Naturally, **conservationists** find themselves concerned about the loss of coral reefs as coral bleaching continues to increase. Several reefs around the world are immensely degraded and studies have yet to uncover whether they have the ability to regenerate. Scientists fear that coral species will not survive the end of this century.[8]

The loss of coral reefs assures grim consequences because they attract great amounts of tourists that constitute a large portion of income for coastal areas. The Caribbean has lost nearly 90% of its reefs, which attract up to one hundred million tourists each year. With the loss of its coral reefs, the Caribbean will experience a decrease in revenue from the tourism industry.[9] Coral reefs also play a key role in protecting coastlines from flooding, **erosion**, and storm damage. Without this protection, repair costs would total hundreds of billions of dollars each year.[3]

In the journal article, *Incorporating Climate and Ocean Change into Extinction Risk Assessments for 82 Coral Species*, the authors collected and analyzed data to determine whether the most prominent coral species were at risk of extinction.[5] The conclusions of the study were derived from analyzing other in-depth studies and looking at predictions of future climate conditions.

The Coral Biological Review Team determined that the biggest threats to coral were disease, ocean warming, and ocean acidification. The team then estimated the importance of each threat relative to extinction risk, and ocean warming was ranked as the highest (Figure 4). The team concluded that there was insufficient evidence to show that corals can adapt to this new climate, especially considering the rate ocean temperature is expected to increase over the next century.[5] The scientists found that corals do not possess effective adaption mechanisms for these new conditions.[5, 10]

Scale	Threat	Importance
Global	Ocean warming	High
Local	Disease	High
Global	Ocean acidification	Medium-high
Local	Reef fishing - trophic effects	Medium
Local	Sedimentation	Low-medium
Local	Nutrients	Low-medium
Global	Sea-level rise	Low-medium
Local	Toxins	Low

Figure 4. Coral communities are affected by many threats. When considering a coral species' vulnerability to extinction, various factors need to be taken into consideration.
Modified from Brainard et al., 2005.

The fate of coral reefs is still uncertain. It is nearly impossible to predict what will happen in the long term since the two largest threats to coral extinction are caused by **climate change**, a science that's consequences are not fully understood. Human activity is inflicting terrible damage to our planet and it is unknown how long it will take the oceans to return to their prior average temperature once CO_2 **emissions** are reduced. It is also unclear whether coral reef communities can reestablish themselves after ocean temperatures stabilize or if other organisms can fill coral reef's vital role as a diverse ecosystem.

References

1. Brown, B.E. (1997). Coral bleaching: causes and consequences. Coral Reefs, 16:S129-S138.
2. U.S. EPA. (2012). Coral Reef Protection: What are Coral Reefs?, EPA, Retrieved from http://water.epa.gov/type/oceb/habitat/coral_index.cfm
3. Hoegh-Guldbuer, O. (1999). Climate change, coral bleaching, and the future of the world's coral reefs, Marine Freshwater Research, 50:839-966
4. Penin, L., et al. (2013). Response of coral assemblages to thermal stress: are bleaching intensity and spatial patterns consistent between events?, Environmental Monitoring Assessment, 185:5031-5042.
5. Brainard, R.E., et al. (2013). Incorporating Climate and Ocean Change into Extinction Risk Assessments for 82 Coral Species, Conservation Biology, 27:1169-1178.
6. Fang, J.K.F., et al. (2013). Sponge biomass and bioerosion rates increase under ocean warming acidification, Global Change Biology, 19:3581-3591.
7. Rodríguez-Troncoso, A.P., et al. (2013). The effects of an abnormal decrease in temperature on Eastern Pacific reef-building coral Pocillopor verrucosa, Conservation Biology, 161:131-139.
8. Bell, J.J., et al. (2013). Could some coral reefs become sponge reefs as our climate changes?, Global Change Biology, 19:2613-2624.
9. Harder, Ben (2001 July). Is Bleaching Coral's Way of Making the Best of a Bad Situation? National Geographic. Retrieved from http://news.nationalgeographic.com/news/2001/07/0725_coralbleaching.html
10. Billé, R., et al. (2013). Taking Action Against Ocean Acidification: A Review of Management and Policy Options, Environmental Management, 52:761-779.
11. Roberts, Kelsey. USGS. (2014). Bent Sea Rod Bleaching. [Photograph]. Retrieved from Wikimedia Commons. CC BY 2.0.
12. Commonwealth of Australia, Great Barrier Reef Marine Park Authority. (2011). [Diagram comparing the different health states of coral]. Retrieved from http://www.gbrmpa.gov.au/managing-the-reef/threats-to-the-reef/climate-change/what-does-this-mean-for-species/corals/what-is-coral-bleaching. © Copyright Commonwealth of Australia 1996 – 2007. CC BY-ND-NC 2.0.
13. NASA. (2006). [Model of coral reef locations on Earth]. Retrieved from Wikimedia Commons. Public Domain.

ECOSYSTEM DEGREDATION

Photograph by Matt Zimmerman, 2007. CC BY 2.0.

2.1 An Assessment of the Invasive Asian carp Threat on The Great Lakes

Jeremie E. Beverstock

The Great Lakes have seen over 180 non-native species introduced since the establishment of closer monitoring procedures. Asian carp are the latest and possibly the most threatening species to the Great Lakes ecosystem. What makes the potential Asian carp invasion different and a cause for concern? How susceptible are the Great Lakes to an Asian carp invasion and what could happen if such an invasion were to take place?

Figure 1. The five bodies of water that make up The Great Lakes is the largest source of accessible freshwater in the world.
Courtesy of NASA, 2000. *Public Domain.*

Over time, the Great Lakes have accumulated over 180 aquatic non-native species.[1] Some of these species were introduced intentionally to serve as sport fish and others, as **biological controls**. However, many species were introduced unintentionally through the transfer of live food fish, bait release, or the release of **ballast water**.[1] Not all non-native species are threats to the Great Lakes because many are either unable to sustain a **population** or do not significantly disrupt existing **ecosystems**. Some species are disruptive because on their eating habits, rate of reproduction, and adaptability among other factors. These **invasive species** pose a threat to existing ecosystems and also to the economies of the region. The Great Lakes Basin is the largest source of freshwater in the world. It is also creates a $7 billion fishing industry, making the region vitally important ecologically and economically.[1]

Currently, two of the five species collectively known as Asian carp, bighead (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*), are causing a great concern for the Great Lakes Basin (Figure 1 and 2). These fish were first brought to the United States in the 1970s as a means to improve the water quality of **aquaculture** facilities. Flooding allowed the carp to escape into the **Mississippi River Basin** and quickly spread upstream. Asian carp are now established and thriving throughout the Upper Mississippi River System (Figure 2).

Figure 2. A school of invasive Asian Carp in Chicago, Illinois.
Photograph by Kate Gardiner, 2009. CC BY-NC 2.0.

Asian carp present a threat to existing ecosystems in the United States because of their fast growth rate, ability to reproduce multiple times per year, adaptability, and their ability to dominate an ecosystem. In some parts of the Illinois River, Asian carp account for nearly 90% of animal life.[2] Asian carp can weigh as much as 100 pounds, although they commonly weigh between 20 – 40 pounds. At such a size, there are no North American fish that are able to prey upon adult carp.[3,4] There are only a few predators that are able to prey upon young Asian carp because the carp grow very fast and the window of opportunity is narrow, making natural methods of population control difficult.[3,4] Asian carp are constant and voracious eaters, able to consume between 20-120% of their body mass in **plankton**. The insatiable appetite of Asian carp could lead to a plankton shortage for native fish that eat plankton as they grow, and those that consume it throughout their lives. Bighead and silver carp in Illinois rivers are believed to be the cause of the reduced fitness of at least two native **planktivorous** fish.[5] In less productive ecosystems, such as Lake Michigan, the effect could be far more devastating as Asian carp could negatively affect the condition of native or commercially desirable species. This could lead to lower quality and reduction in the number of eggs, as well as an increased susceptibility to disease among native fish.[2,5] Silver carp also pose a direct physical threat to humans. The species has a tendency to leap high out of the water when disturbed by noise, such as the sound of a boat engine. This can lead to injury and property damage. Thus, silver carp are a threat to the prevalent recreational boating culture of the Great Lakes (Figure 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/sciencebites/?p=302

Figure 3. Asian Carp jump out of the water when disturbed by the sound of a boat engine. Video by the BBC, 2013. https://youtu.be/tLmJjRqXDCo

An important part of preventing the spread of Asian carp is predicting where they may be able to establish a population. This is rather difficult as Asian carp are a very adaptable species. In their native Asian environment, Asian carp inhabit a broad range of climactic conditions which are similar to many areas of the United States and southern Canada.[6] There are twenty-two known tributaries in the Great Lakes Basin that match the criteria of an ideal spawning ground for Asian carp based on length, temperature, current velocity, and water quality of the tributary.[7] In 2012, four grass carp were caught in Ohio's Sandusky River. These fish possessed traits indicating that they lived their entire lives in this river.[8] While grass carp are not as great a concern as silver or bighead carp, they have similar spawning habits. The grass carp caught in the Sandusky River suggest to researchers that bighead and silver carp may be able to spawn in shorter rivers, and therefore more locations than previously expected. A recent report indicates that four tributaries of the Great Lakes Basin, the Sandusky, Maumee, Milwaukee, and St. Joseph rivers, could be suitable for Asian carp spawning.[9] This same report suggests that Asian carp may be able to spawn in as little as 25 kilometers (16 miles) of un-dammed river, which is far less than the previous estimate of 100 kilometers (62 miles).[9] Although the common understanding is that Asian carp eggs require a long stretch of unbroken river current to hatch, reports exist of silver and bighead carp spawning in stagnant water.[9] These reports are few, but raise concerns that the carp may be able to spawn even further outside of predicted areas.

Figure 4a. Reported Asian carp sighings as of 1980.

Courtesy of the U.S. Geological survey, 2015. Public Domain

Figure 4b. Reported Asian carp sighings as of 1990.

Courtesy of the U.S. Geological survey, 2015. Public Domain

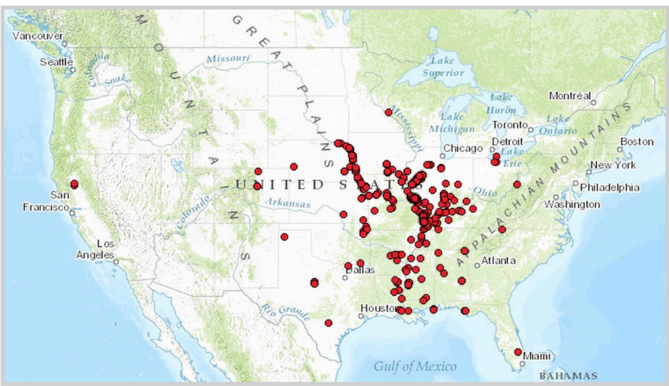


Figure 4c. Reported Asian carp sighings as of 2000.

Courtesy of the U.S. Geological survey, 2015. Public Domain

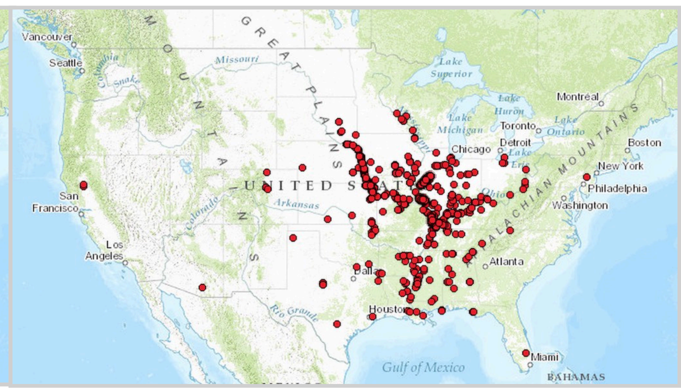


Figure 4d. Reported Asian carp sighings as of 2010.

Courtesy of the U.S. Geological survey, 2015. Public Domain

Taking preventative measures will ultimately be far less costly than long-term attempts to manage the Asian carp invasion. However, to fully address the problem, scientists and governments will need utilize both measures to manage the carp.[1] While preventative methods greatly reducing the risk of a sudden and full-fledged invasion, they are never guaranteed to work. Various governments and environmental groups are working to educate fishermen on the species, although it is nearly impossible to prevent accidental introduction through the use of live baitfish. One method of preventative measures to control Asian carp is the use of an **electric fish barrier** in the man-made Chicago Sanitary and Ship Canal. This canal is the best direct connection between the Mississippi River and the Great Lakes Basin and also the most likely site of Asian carp introduction. The electric fish barrier placed in the canal has proved to be largely effective, though it could potentially be bypassed during ship crossings, floods, equipment malfunctions, or repair efforts.[7] Despite these and other measures, positive **eDNA** detections for both silver and bighead carp have been found upstream of the electric barrier near Lake Michigan. There have been a relatively small number of detections and the uncertainty surrounding eDNA testing suggests that while a few Asian carp may be present, a successful and reproductive population has yet to be established. eDNA detectors search for genetic material and cannot prove that the source is a live fish. In anticipation of an imminent Asian carp invasion, officials are considering closing the entire

Chicago Sanitary and Ship Canal. This is a more permanent and costly solution. Although the Chicago Sanitary and Ship Canal is the most likely route for Asian carp to reach the Great Lakes Basin, many possible introduction sites remain.

It is difficult to know exactly how and to what extent an Asian carp invasion will disrupt existing ecosystems. Based on reports of past invasions, as well as predictions for the Great Lakes, it is clear that there will be a great impact. The three most important factors surrounding this potential Asian carp invasion are the likelihood of introduction, ability to establish a population, and ability to spread. Steps can be taken to prevent the introduction of non-native species. The focus remains on Lake Erie and Lake Michigan as they are the most likely sites of introduction due to their proximity to the established populations of Asian carp. However, a large interconnected system such as the Great Lakes Basin, coupled with human activity in the region makes prevention difficult. Once the Asian carp are introduced, their reproductive adaptability, wide climactic range, and the availability of food and **habitat** suggest that they will be able to establish in any number of areas throughout the Great Lakes. When established, their voracious appetite, fast growth rate, and reproductive capabilities will allow them to spread throughout the Great Lakes. All lake and river systems will require consistent monitoring to prevent the carp from establishing in the region. With such a high likelihood of infiltration and a $7 billion fishing industry at stake, conducting wildlife and resource management for the Great Lakes Basin will need greater and more permanent solutions to address the Asian carp problem.

References

1. Zander, M. et al. (2010). Journal of Great Lakes Research. 36: 199-205.
2. Soth, A. (Producer). (2011, November 1). Asian Carp: Threat to the Great Lakes. USA: QUEST Wisconsin. http://science.kqed.org/quest/video/asian-carp-threat-to-great-lakes/
3. Asian Carp Regional Coordinating Committee. (2011). The Problem. Retrieved from http://www.asiancarp.us/problem.htm
4. Asian Carp Regional Coordinating Committee. FAQ. Retrieved from http://www.asiancarp.us/faq.htm
5. Irons, K. S. et al. (2007). Journal of Fish Biology. 71 (Supplement D): 258-273.
6. Mendrak, N., & Cudmore, B. (2004). Risk Assessment for Asian Carps in Canada. Fisheries and Oceans Canada. http://www.dfo-mpo.gc.ca/csas
7. Rasmussen, J. et al. (2011). Journal of Great Lakes Research. 37: 588-592.
8. Borre, L. (2013, October 11). Asian Carp Reproducing Naturally in Great Lakes Tributary. National Geographic: Newswatch. Retrieved from http://newswatch.nationalgeographic.com/2013/10/31/asian-carp-reproducing-naturally-in-great-lakes-tributary
9. Murphy, E., & LaVista, J. (2013, June 18). Determining Rivers Vulnerable to Asian Carp Spawning in the Great Lakes. U.S. Geological Survey. Retrieved from http://www.usgs.gov/newsroom/article.asp?ID=3618#.UxVYb_SwIn8
10. NASA. (2000). Satellite image of the Great Lakes from space. [Photograph]. Retrieved from

Wikimedia Commons. Public Domain.
11. Gardiner, Kate. (2009). Asian Carp – Shedd Aquarium. [Photograph]. Retrieved from FlickrCommons. CC BY-NC 2.0.
12. JohnDownerProd & British Broadcasting Corporation (BBC). (2013). Thousands of fish leap out water at same time!. [Video]. Retrieved from YouTube. https://youtu.be/tLmJjRqXDCo
13. U.S. Geological Survey. Nonindigenous Aquatic Species Database. Accessed March 2015. Retrieved from http://nas.er.usgs.gov//queries/SpeciesAnimatedMap.aspx?speciesID=551. Public Domain.

2.2 A Bitter Brew- Coffee Production, Deforestation, Soil Erosion and Water Contamination

Amanda L. Varcho

Brew. Sip. Sigh. A morning cup of coffee is a routine habit for many people worldwide. Coffee is the second most popular drink in the world, trailing only water. What are the costs involved in producing enough coffee to satisfy the ever increasing demand?

Figure 1. Roasted coffee beans.
Photograph by Goele, 2008. Public Domain.

Coffee is the world's second most tradable **commodity**. This $10 billion industry is not harmless because there are many environmental and ecological problems that result from coffee production.[1] For every cup of coffee consumed, it is almost certain that one square inch of rainforest was destroyed.[2] Chemical buildup in soils and loss of forest shade are consequences of mass coffee production. This leads to chemical **runoff** polluting rivers, land and aquatic wildlife dying, soil eroding, and land degradation. Once lush rainforests are twisted into barren landscapes, which forever alters the ecological balance of this **ecosystem**.

Exploitative coffee production leads to massive **deforestation**. There are two types of coffee plants, those that grow in sun (Figure 2) and those that grow in shade. The sun grown coffee plant has been tailored to produce nearly three times as much coffee as the shade version. Increased production of sun grown coffee plants results in greater loss of rainforest. In the 1950s, approximately 15% of the earth's surface was covered by rainforest, whereas today there is merely 6% rainforest coverage.[2] In addition, the remaining 6% of the rainforests could be destroyed in 40 years, as more than 200,000 acres are burned each day to clear the land for agricultural and industrial purposes.[3]

Figure 2. Coffee is most efficiently grown in full sun within monocrop plantations. The coffee plant (Coffea arabica) produces clusters of white flowers and red berries which contain the desired coffee bean. Photographs by Lukas, 2008. CC BY 2.0 (top), Ben3john, 2012. CC BY-SA 3.0 (right), and Simmon Taylor, 1772 CC BY 4.0 (left).

Deforestation decreases the **biodiversity** of wildlife and plants. These deforested **habitats** are left altered and unsuitable for the previous species (if any) to thrive, as only certain species can survive the destruction and habitat loss. With the loss of forested areas, moisture in the air decreases and soil composition and foliage is altered (Figure 3). The widely used practice of burning the forests and then subsequently tilling the land, changes the temperature of the land area and chemical composition of the soil.[3] The forest canopy is no longer providing protection from the sun and the soil lacks decomposing foliage. This combination allows moisture that was previously trapped escape, leaving the land warmer and drier. The balance of organisms in the soil ecosystem, which includes termites, nematodes, earthworms, **bacteria**, and fungi is then altered.[4] Lastly, the chemical composition of an agricultural system which replaced the rainforest no longer supports the same equilibrium of plants and organisms. This contributes to further negative environment impacts.[4]

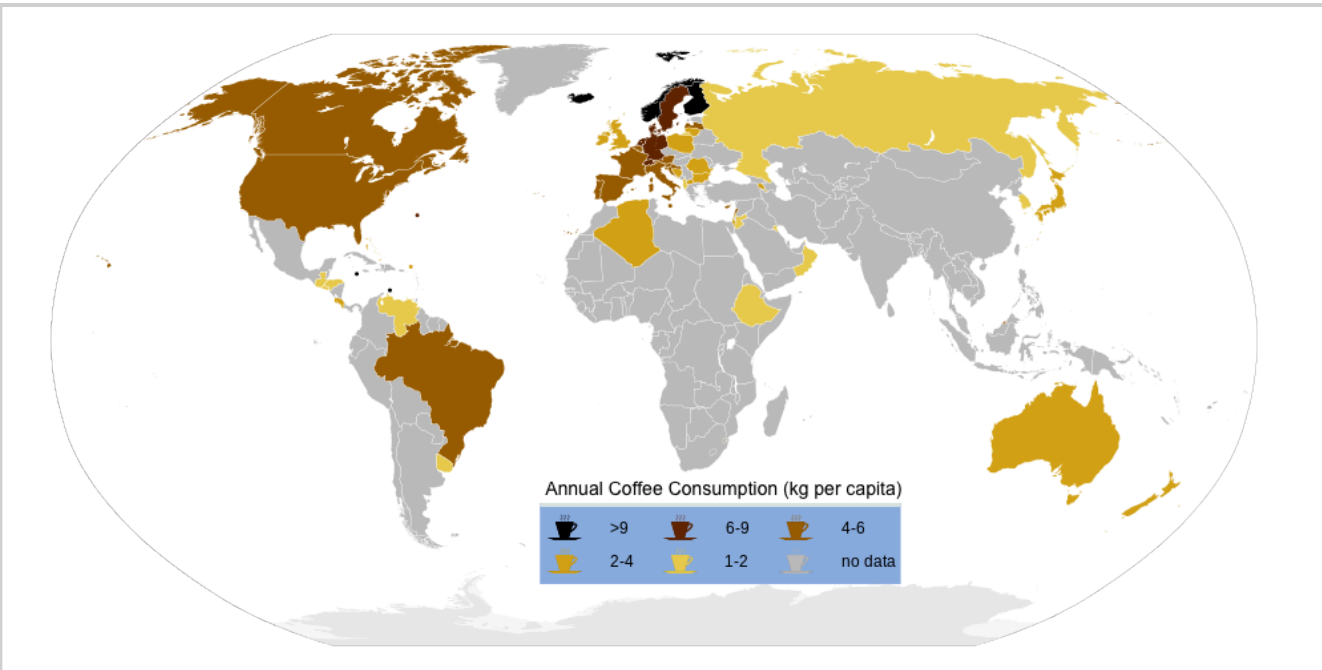


Figure 3a. The demand for coffee continues to increase. Marking this popular drink the second most traded commodity in the world.

Diagram by Bamse, 2007. CC BY-SA 3.0

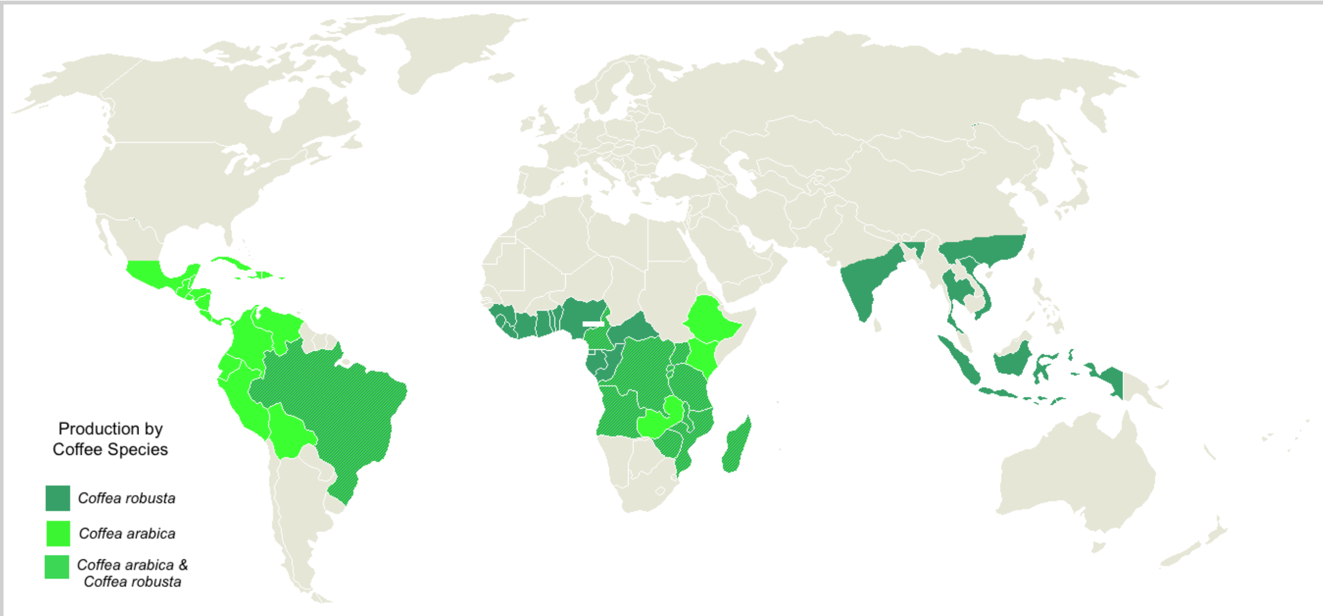


Figure 3b. Although there are 10 different species of coffee plants, two species are predominantly grown in the world's tropical regions: Coffea robusta and Coffea arabica.

Diagram by Brhaspati, 2007. Public Domain

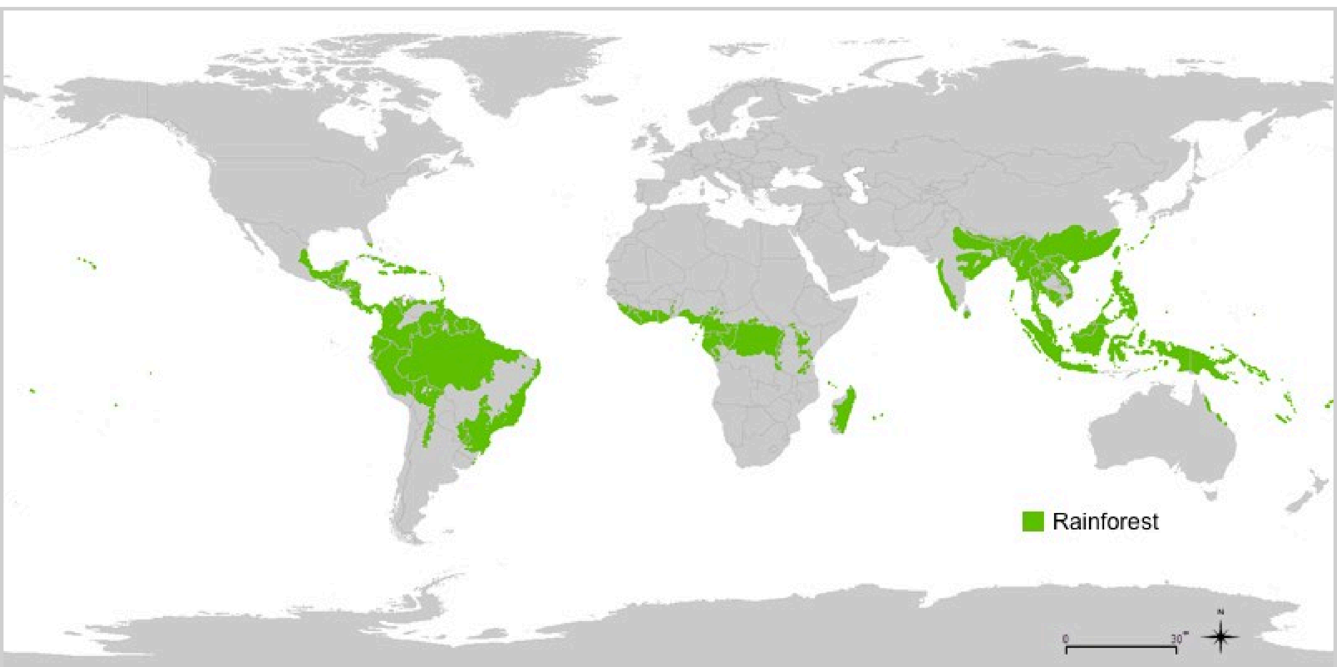


Figure 3c. Tropical forests can be found around the world's equatorial regions.

Diagram by Hansen, M.C. et al, 2008. Public Domain

Soil **erosion** is another byproduct of deforestation. When natural ecosystems (such as rainforests) are permanently converted into agricultural lands, there is a loss of valuable organic soil components, such as soil carbon. "In temperate zone agriculture, soil organic matter losses are most rapid during the first 25 years of cultivation, however, in tropical soils such losses may occur within 5 years after conversion."[4]

The fertilizers used on coffee plants leech nitrate into nearby water sources, depleting the oxygen supply and killing aquatic life. The once rich soil loses health as **monocropping** alters the pH and nutrient balance in the soil. Monocropping involves producing only a single, dominant crop without rotation. For a sustainable and functioning **agro-ecosystem**, certain factors such as depth and bulk, mineral density, salinity, and nutrients need to be maintained.[5] The opposite of a sustainable agro-ecosystem is occurring in these tropical, coffee-producing areas. Without crop rotation, nutrients cannot restore the soil, and it is deemed worthless for production. When the soil is fully exposed to the sun and direct heat, it dries out, loses its density, and is carried away by wind and water erosion. **Sediment** from erosion flows into water sources, affecting both the water and land ecosystems.[6] Soil particles also increase air pollution since wind erosion changes atmospheric conditions and **climate**. These erosive processes leave a land once occupied by rainforest as acres of **inhospitable**, dry, depleted dirt.

Water pollution, mainly in the form of **eutrophication**, occurs due to waste-dumping and fertilizer run-off into water sources. Coffee produces an enormous amount of waste, "fifty-seven percent of the coffee bean is made up of contaminants which, when discarded destroy fauna in rivers and streams and harm people."[1] Coffee harvesting begins with the process of separating the useable coffee bean from its surrounding pulp. A whole coffee cherry is comprised of outer layers and the inner coffee bean. These are soaked and fermented, breaking down the bean coating and leaving a slimy, pulpy residue behind once the inner bean is removed. This remaining organic matter is then dumped into nearby rivers and streams where it's decomposition uses up the available oxygen and kills aquatic species.[1] While there are anti-dumping laws in place by various governments, enforcement of the laws is ineffective. Heavy **pesticide** use for coffee production also contributes to the pollution. In 2005, 5 million tons of pesticides were applied to crops worldwide.[7] Pesticide use will only increase as the targeted species become more tolerant to the chemicals. Aquatic ecosystems will continue to be negatively affected by water pollution from soil **contamination**, coffee byproduct disposal, and pesticide runoff.

Figure 4. The climate and soil conditions in tropical regions, force farmers to clearcut the rainforest to gain access to fertile soil. As more land is converted to agriculture, farmers must begin to farm on less desirable terrain such as hillsides, which are more prone to soil erosion.
Photograph by Rod Waddington, 2014. CC BY-SA 2.0.

Coffee production is altering rainforest ecosystems which negatively affect plant and animal species living within. Worldwide, the use of monocrop coffee production is leading to deforestation, soil erosion, and water pollution. Soil composition changes from agricultural land use are causing moisture to evaporate, a lack of crop rotation is depleting nutrients without replacing them, and exposure to direct sunlight is drying out the land. Chemical pollutants and physical contaminants increase in rivers and bodies of water, changing the aquatic ecosystems. Scarce rainforest acreage continues to rapidly decline. More sustainable land use and agricultural practices will be needed because it is unlikely coffee consumption will decrease in the near future.

References

1. Lee, J.R., (1997). Coffee Exports from Costa Rica. TED Case Studies: Coffee and the

Environment. Retrieved from http://www1.american.edu/ted/coffee.htm
2. Lee, J. (2014) How Coffee Aids in Deforestation of our Rainforests. Going Green Today. Retrieved from http://blog.goinggreentoday.com/how-coffee-aids-in-deforestation-of-our-rainforests/
3. NASA Earth Observatory. (2014). Sustaining Tropical Rainforests. Earth Observatory. Retrieved from http://earthobservatory.nasa.gov/Features/Deforestation/deforestation_update5.php
4. Matson, P.A., et al. (1997). Agricultural Intensification and Ecosystem Properties, Science, 277(5325): 504-409.
5. Gliessman, S.R., (2001). Agroecosystem Sustainability: Developing Practical Strategies, Washington D.C., CRC Press LLC.
6. Fearnside, P.M. (2006). Fragile soils and deforestation impacts: The rationale for environmental services of standing forest as a development paradigm in Latin America. pp. 158-171. In: D.A. Posey & M.J. Balick (eds.) Human Impacts on Amazonia: The Role of Traditional Ecological Knowledge in Conservation and Development. Columbia University Press, New York, U.S.A. 366 pp.
7. McAllister, L.M. (2005). Environmental Issues in Latin America and the Caribbean, 207-230. Public Prosecutors and Environmental Protection in Brazil, Torre, A. et al., Washington, D.C., The World Bank.
8. Goele. (2008). Roasted coffee beans. [Photograph]. Retrieved from Wikimedia Commons. Public Domain.
9. Ben3john. (2012). Arabi Coffee of Anakkara. [Photograph]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
10. Taylor, Simon (1772). Coffea arabica. [Engraving with etching, with watercolor]. Wellcome Library no. 25333i. Retrieved from Wikimedia Commons. CC BY 4.0.
11. Lukas. (2008). Coffee plantation, Kaua'i, Hawaii, USA. [Photograph]. Retrieved from Wikimedia Commons. CC BY 2.0.
12. Bamse. (2007). Coffee consumption map. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
13. Brhaspati. (2007). Carte Coffea robusta arabic. Retrieved from Wikimedia Commons.Public Domain.
14. Hansen, M.C., et al. (2008) Humid tropical forest clearing from 2000 to 2005 quantified using multi-temporal and multi-resolution remotely sensed data. PNAS, 105(27), 9439-9444. Retrieved from Wikimedia Commons. Public Domain.
15. Waddington, Rod. (2014). After the Rainforest, Uganda. [Photograph]. Retrieved from Wikimedia Commons. CC BY-SA 2.0.

2.3 From Desalination to Destruction

Kelly E. Peterson

Desalination of seawater is an emerging solution to California's fresh water scarcity. Communities along California's coastline have expressed concerns for the well-being of coastal aquatic ecosystems surrounding desalination plants. Is the desalination process harmful to these ecosystems? Are there safer alternatives to obtaining fresh water?

Figure 1. A view of the reverse osmosis system within a desalination plant.
Photograph by James Grellier, 2010. CC BY-SA 3.0.

Worldwide, fresh water has become increasingly scarce due to global climate change, rising demand, and diminishing local water sources. Although the earth consists of about 71% water, only about 1% of that water is drinkable[1] (Figure 2). To sustain growing populations, humanity must be able to fully utilize this abundant resource. Desalination of seawater is one solution that has been proposed to coastal areas, which are inhabited by 50% of the human population. While this option could increase the amount of available fresh water, it may also create problems for the surrounding ecosystems and organisms living within. California plans to build a multitude of desalination plants along its coastline. However, scientists are actively researching the effects, costs, and benefits of these water treatment facilities.

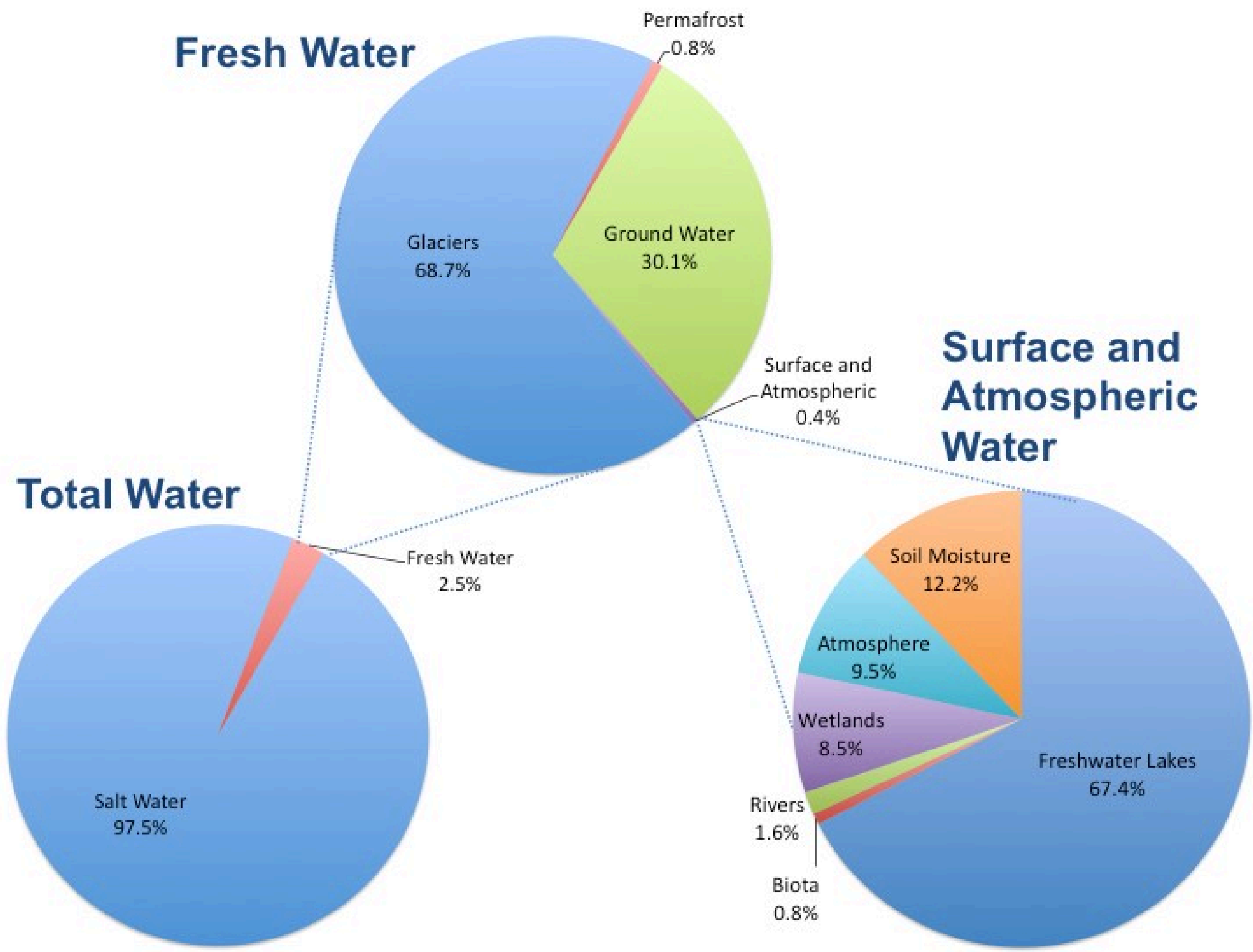


Figure 2. While earth consists of about 71% water, much of that water is non-potable or is inaccessible to humans.
Courtesy of Brian Lower. Data from Shiklomanov, 1993. Public Domain.

The desalination process involves taking seawater and forcing it through reverse osmosis membranes to clean it (Figure 1 and 3). This process can negatively impact community land use, increase erosion, cause visual and acoustic disturbances, and spread emissions into the water and atmosphere.[2] Coastal ecosystems around desalination plants are being threatened by large decreases in primary and secondary consumers as well as the destruction of their fragile environment. When a desalination plant is taking in seawater it also draws in numerous species of aquatic life. The screens contained within the plants will kill these vital microorganisms, which are needed for consumption by larger species.[3] A commission staff residing in San Diego estimates that the desalination plants will intake more than 80 million fish larvae, eggs, and invertebrates annually along the 160 kilometers (100 miles) of the Southern California coast.[1] These desalination plants cause severe harm to coastal ecosystems, especially considering that the plants are drawing in seawater that is part of the National Marine Sanctuary (Figure 4).

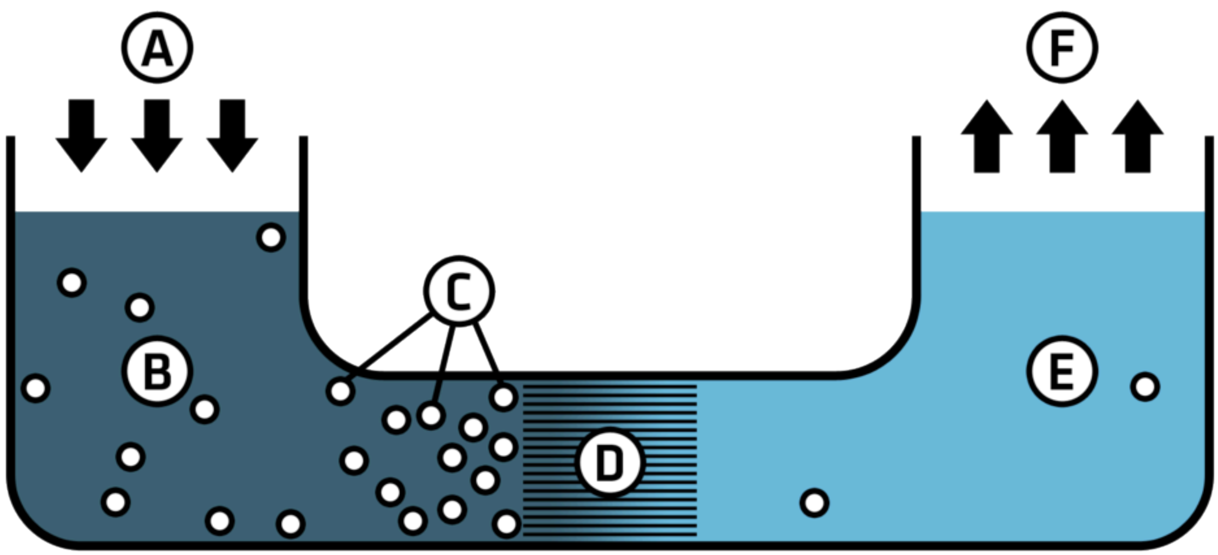


Figure 3. Reverse osmosis is one technique used to transform salt water into fresh water.
(A) Pressure is applied to the
(B) Saltwater, which contains
(C) Contaminants (such as salt molecules and microorganisms) through a
(D) Semi-Permeable Membrane
(E) Fresh, potable water is produced on the far side of the membrane where it can then be
(F) Distributed as drinking water
Image by Colby Fisher, 2013. CC BY-SA 3.0.

The suction of seawater into the plants directly diminishes the livelihood of coastal ecosystems and the treatment of water with chemicals may be equally harmful to the environment. Once the water is treated, a discharge of concentrated saltwater is released into the areas surrounding the desalination plant. This effluent is nearly twice as concentrated as the original seawater solution and contains harmful chemicals which were used in the pretreatment of the water such as anti-scalants, surfactants, and acid.[4] If the desalination plants stored this chemically toxic waste, it would require large amounts of space and ongoing maintenance. A potential solution to this problem is the creation of a brine stream, which will help redirect runoff and diffuse waste, and is separate from a new freshwater stream.[5] Chlorine dioxide could also be added to intake water as a means of reducing "biofouling" of seawater. This method is still undergoing testing because the use of chlorine dioxide may lead to the formation of hypochlorite and hypobromite. These harmful chemicals can impose health risks on humans as well as aquatic life. People may be exposed to these toxins while swimming in coastal waters or by consuming contaminated seafood.[6]

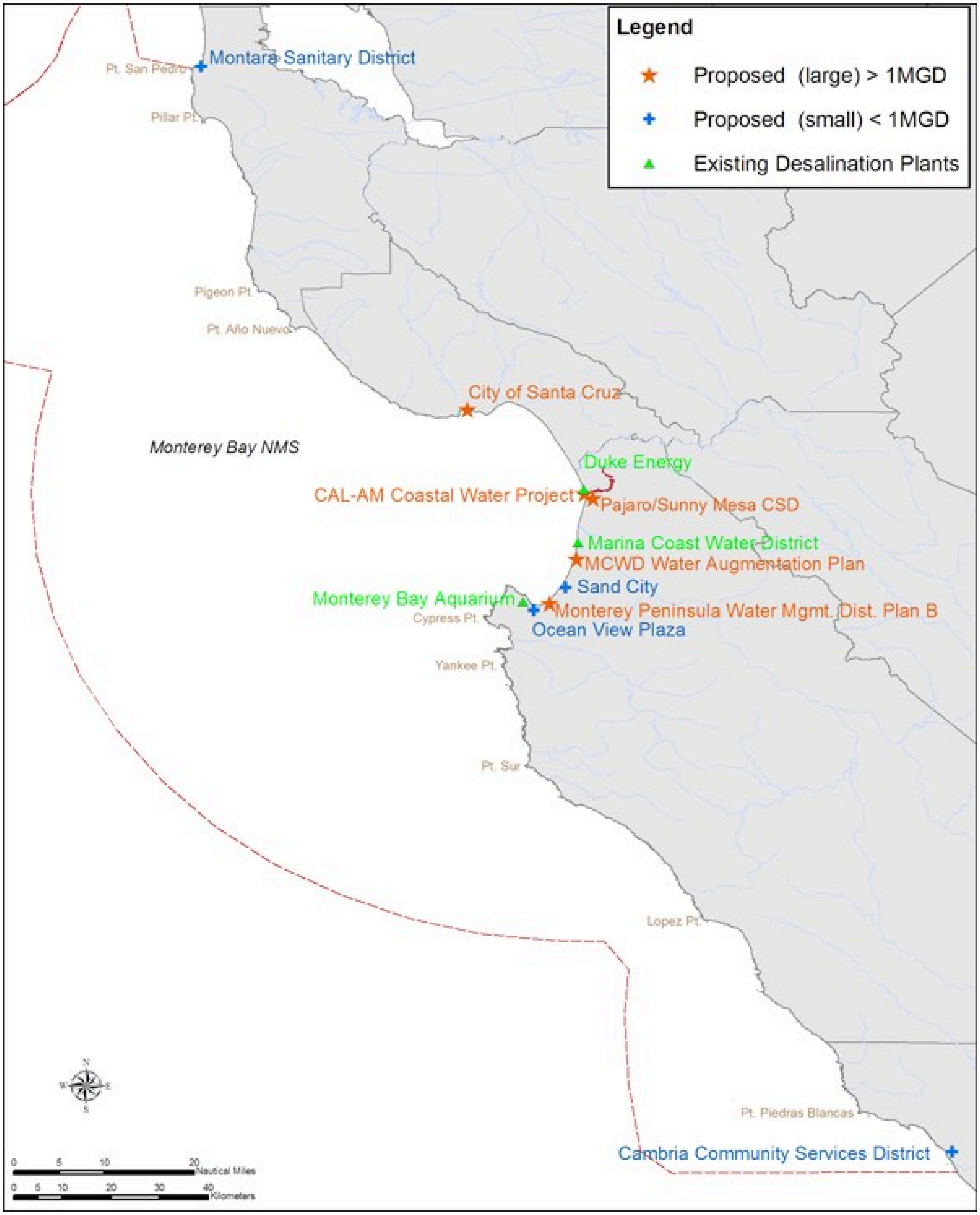


Figure 4. Map of Existing and Proposed Desalination Plants in the Monterey Bay National Marine Sanctuary.
National Marine Sanctuaries are meant to protect coastal ecosystems from industrial harm. However, desalination plants negatively impact these protected areas.
Courtesy of NOAA, 2015. Public Domain.

Many environmental factors can reduce the effectiveness of the desalination process. Algal biomass and other organic loads can negatively affect the desalination operation within the pretreatment system, and may force a plant to shut down.[6] Harmful algal blooms may have two potential impacts on seawater desalination facilities. First, the toxins produced by these algal blooms can complicate the reverse osmosis system and cause the water to only be partially cleaned. Second, the suspended solids and organic content from the algal blooms can increase turbidity and delay the facility's treatment process.[7] Changes in weather and temperature are important when considering installing desalination plants. Desalination plants are becoming larger not only due to growing populations, but also because of changes in climate and geography.

Coastal ecosystems, especially coral reefs, are highly sensitivity and are expected to change seasonally in upcoming years. During certain seasons the seawater contains nutrients, plankton, and suspended solids that are not suitable for intake into desalination plants.[8] Additionally, seawater level variation could result in unpredictable changes in absorption and efficiency. According to a report by the U.S. Geological Survey, California will be experiencing more frequent and intense droughts along with flash flooding in the near future.[9] Desalination plants contribute to these climate change related factors by emission of carbon and sulfur dioxides.

There are alternatives to desalination, such as multi-stage flash distillation and multiple-effect distillation. Currently, neither of these distillation techniques is less harmful, or more productive than conventional desalination.[2] Due to scattered application and limited public attention, the true environmental impacts of desalination are unknown. Although desalination plants may be an effective solution to California's need for an increased supply of fresh water, the lingering effects of this treatment process may be detrimental to the coastal environment. The beauty of California's coastline is indispensable for many communities and cannot be compromised to establish a single solution for fresh water scarcity.

References

1. Boxall, B. (2013, November 10). Proposed desalination plant could harm ocean environment, report says. Los Angeles Times. Retrieved from http://www.latimes.com/
2. Kipps, J. (1991). IDA World Conference on Desalination and Water Reuse, Washington. 1: 1-9.
3. Lattermann, S. & Höpner, T. (2008). Desalination. 220(1-3): 1-15. http://www.sciencedirect.com/science/article/pii/S0011916407006005
4. Ebensperger, U. & Isley, P. (2005). Review of the Current State of Desalination. 1: 1-20.
5. Khawaji, A.D., et al. (2008, March). Desalination. 221(1-3): 47-69.
6. Petry, M. et al. (2007). Desalination. 203(1–3):141–152.
7. Caron, D., & Garneau, M.E. (2010). Water Research. 44(2):385-416.
8. Hopner, T. & Windelberg, J. (1997). Desalination. 103(1-3): 11-18.
9. Helvarg, D. (2014, February 7). Desalination could help California – but only if it's done right. Los Angeles Times. Retrieved from http://www.latimes.com/
10. Grellier, James. (2010). Reverse osmosis desalination plant. [Photograph]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.

11. Lower, B.H. (2015). Introduction to Environmental Science: Freshwater Resources. [Powerpoint slides]. Retrieved from http://go.osu.edu/enr2100.
12. Shiklomanov, I.A., (1993). World fresh water resources. 13-24. Gleick, P.H. (Ed.), Water in Crisis: A Guide to the World's Fresh Water Resources. Oxford University Press, New York.
13. Fisher, Colby. (2013). Simple RO Schematic. [Diagram]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
14. National Ocean Service. (2015). Monterey Bay National Marine Sanctuary Desalination Map. [Diagram]. Retrieved from http://montereybay.noaa.gov/materials/mappages/desalinizationmap.html. © National Oceanic and Atmospheric Administration. Public Domain.

2.4 Hunger for Resources Leaves Sumatra's Orangutans Without Homes

Chayli T. Buenger

Orangutans in Sumatra, Indonesia are losing their habitat due to deforestation from palm oil production. What is palm oil and why is its production causing deforestation? What efforts are being implemented to save the orangutan and combat deforestation?

Figure 1. Orangutans face hardship because their habitat is being destroyed by deforestation. Photograph by Java Bogor, 2010. CC BY-NC-ND 2.0.

The world's rainforests play a vital role in capturing carbon dioxide, providing habitat to many species of animals, and providing resources for human use. The rainforests in Sumatra, Indonesia are home to many different species, including the Pongo abelii, or the Sumatran orangutan[1] (Figure 1 and 2). Deforestation of the Sumatran rainforest is occurring because Indonesia is the world's largest exporter of palm oil, and to expand palm oil plantations, more land is needed[2] (Figure 3). The World Wildlife Fund suggests that 50 percent of Sumatra's rainforests were decimated from 1985 to 2008.[3] This deforestation has greatly damaged the ecosystem. The hope of saving the rainforest remains, as there is ongoing work by both the government and other organizations to prevent further deforestation.

Figure 2a. Distribution of the Sumatran orangutan in the wild.
Image modified from anonymous, 2014. Public Domain.

Figure 2b. Distribution of the Sumatran orangutan in the wild.
Modified from Udo Schroter, 2010. Public Domain.

Figure 2c. The Sumatran orangutan is considered to be Critically Endangered and is on the IUCN Red List of Threatened Species.
Modified from Greg Hume, 2012. CC BY-SA 3.0.

The demand for palm oil is driven by its versatile properties. Palm oil is used for cooking, and also as a biofuel.[4] It is often on the ingredient lists of many processed foods such as cookies, candy, and cereal bars. To feed the world's increasing demand for palm oil, forests are being cleared to create new space for plantations. This deforestation is occurring primarily in the lowland area, which is the habitat of the orangutans.[5] With plans to double their palm oil production by 2020, Indonesia will likely suffer greater deforestation as more rainforest is cleared for the palm oil plantations.[6]

Figure 3. Palm oil is derived from the colorful palm nut.
Photograph by oneVillage Initiative, 2008. CC BY-SA 2.0.

Preventing deforestation becomes more difficult considering the circumstances faced by the farmers who grow palm oil. Most farmers will choose to earn extra money rather than preserve the rainforest because these farmers are able to profit from clearing the forest to plant palm trees and also from selling the wood of the cut rainforest trees.[5] Tourism is another booming industry in Indonesia which is damaged by deforestation.[7]

Currently, there are approximately 7,000 Sumatran orangutans remaining in the wild.[2] However, the orangutan population continues to decline as their habitat is destroyed. When the rainforest is cleared for palm oil plantations, survival is decreased for female orangutans and their offspring because they unable to move from the deforested areas due to their small home ranges.[1] A decline in orangutan population threatens rainforest biodiversity. Orangutans disperse seeds by consuming fruit throughout the forest.[5] Therefore, without orangutans to disperse seeds, there will be damaging effects to the rainforest ecosystem.

Research conducted by Pin Koh and other researchers (2011) has mapped deforested areas and areas of palm oil plantations. Palm oil plantations were mapped out with daily MODIS images.[8] These images showed that palm oil plantations are contributing to deforestation. The researchers concluded that the remaining untouched forests are at risk, and that reforestation of deforested areas is necessary.[8]

David Gaveau and his research team (2009) mapped out deforested areas from 1990 to 2006 using Landsat Thematic Mapper (LANDSAT TM), Landsat Enhanced Thematic Mapper (LANDSAT ETM), and satellite images. Their results indicated that greater than eight percent of the land was lost to deforestation and that the percentage is increasing.[1] Gaveau also learned that if REDD was implemented, less deforestation would occur.[1]

Figure 4. Deforestation near Riau, Sumatra makes way for the expanding palm oil industry. Photograph by Hayden Dagon, 2007. CC BY 2.0.

One approach to address deforestation is the introduction of sustainable palm oil production. Farmers are being taught environmentally sustainable methods to produce palm oil, as well as how to reduce their logging impact.[4] Farmers are also being encouraged to plant in non-forested areas in the hope that the government will offer tax breaks and subsidies for their cooperation.[4] The use of carbon credits could encourage the reduction in tree cutting. Carbon credits can be used by large industries that cannot reduce their own emissions. These industries pay money to people in other countries to protect forests, thus reducing the overall carbon dioxide in the world. REDD and RSPO are two different organizations that are helping to create a more sustainable palm oil industry, reduce deforestation, and by extension, save the orangutans. Rainforest reconstruction is an interesting solution that is currently being implemented in Borneo by microbiologist Willie Smits.[9] Smits bought a former palm oil plantation and is working to restore the land to rainforest. His restoration efforts seem to be working because birds have already returned.[9] Smits solution to deforestation demonstrates it is possible to restore the rainforest.

Another potential solution to help palm oil plantations become more sustainable is to increase their crop yields.[5] Crop yields can be increased by planting mature plants instead of seedlings. A mature palm oil plant produces more oil than an immature palm oil plant. If farmers planted crops at maturity, and removed them after the plants reach their peak period, more palm oil would be produced and less land would be needed.[8] Consumer pressure would also be beneficial to resolving the palm oil issue.[10] Consumers may demand sustainable sourced palm oil if they realize that palm oil is used in most of the processed foods they eat, and its production is causing harm to the Sumatran rainforest and orangutans. If this occurs, producers would be forced to become sustainable to meet consumer demands.

Research has shown that deforestation in Sumatra, Indonesia is a chronic problem that is exacerbated as the worldwide demand for palm oil increases. Orangutans are losing habitat from deforestation to create plantations for palm oil production. By working towards more sustainable palm oil plantations, researching innovative techniques to mitigate deforestation, and by reducing global demand for palm oil, the Sumatran rainforest and orangutans can be saved.

References

1. Gaveau, D.L.A., et al. (2009). The future of forest and orangutans (Pongo abelii) in Sumatra: predicting impacts of oil palm plantations, road construction, and mechanisms for reducing carbon emissions from deforestation. Environmental Research Letters 4, 1-11.
2. Bradshaw, H. (2013, November 26). Sumatran orangutans: Meeting the refugees of the lost rainforest. BBC News.
3. Watts, J. (2013, October 14). The devastation of Indonesia's forests. CNN World.
4. Pin Koh, L. & Wilcove, D.S. (2007). Cashing in palm oil for conservation. Nature 448, 993-994.
5. Nantha, H.S. & Tisdell, C. (2009). The orangutan-oil palm conflict: economic constraints and opportunities for conservation. Springer 18, 487-502.
6. Walsh, B. (2011, March 7). Palm oil plantations equal deforestation. Time.
7. Beukering, P.J.H.,et al. (2003). Economic valuation of the Leuser National Park on Sumatra, Indonesia. Ecological Economics 44, 43-62.
8. Pin Koh, L., et al. (2011). Remotely sensed evidence of tropical peatland conversion to palm oil. PNAS 1-6.
9. Little, J.B. (2008). Regrowing Borneo, tree by tree. Scientific American 18, 64-71.
10. Gilbert, N. (2012). Palm-oil boom raises conservation concerns. Nature 487, 14-15.
11. Bogor, Java. (2010). Sumatran Orangutan (Pongo abelii). [Photograph]. Retrieved from FlickrCommons. CC BY-NC-ND 2.0.
12. Anonymous. (2014). [Diagram of World Map]. Retrieved from Wikimedia Commons. Public Domain.
13. Schroter, Udo. (2010). [Diagram of Sumatran Orangutan range map]. Retrieved from Wikimedia Commons. Public Domain.
14. Hume, Greg. (2012). Sumatran Orangutan. [Photograph]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
15. oneVilliage Initiative. (2008). Palm oil production in Jakwa Villiage, Ghana. [Photograph]. Retrieved from Wikimedia Commons. CC BY-SA 2.0.
16. Dragon, Hayden. (2007). Oil Palm Concession in Riau, Samatra. [Photograph]. Retrieved from Wikimedia Commons.CC BY 2.0.

2.5 The Attack of the Emerald Ash Borer in The United States

Wyatt T. Susich

The Emerald ash borer beetle has wreaked havoc on all species of ash trees since its arrival in the United States. It has spread from Michigan and is responsible for the deaths of tens of millions of ash trees. It has also caused hundreds of millions of dollars worth in damages to municipalities and tree nurseries. What can be done to solve this problem?

Figure 1. An adult Emerald ash borer beetle (Argilus planipennis) perched an ash tree leaf. Photograph by David Cappaert, 2014. CC BY-NC-SA 3.0.

The Emerald ash borer beetle (EAB) (Figure 1) has created an incredible pest problem for many Midwestern and Northeastern states. The insect slowly deprives ash trees of nutrients, killing them over a period that may take several years. This issue has captured the attention of many governmental and environmental agencies, which are working together with researchers to understand and halt the destruction triggered by the spread of EAB. Current estimates suggest that EAB will cause $11 billion worth of damages from 2009-2019.[1]

The EAB beetle was discovered in Michigan in 2002. The beetle had not been previously seen in the United States, and it possibly arrived sometime in the 1990's.[2] Since then, the beetle has spread to states surrounding Michigan and into Quebec, Canada. It was likely transported to the United States on a cargo boat or plane carrying infected ash wood from Asia, its natural habitat. EAB has already killed tens of millions of North American ash trees.[3]

The Emerald ash borer is known to feed off all species of ash trees. Ash mortality occurs as a result of its larvae feeding on phloem within the trees during the beetle's development. The larvae emerge from their eggs on the tree and burrow their way into the phloem layer, destroying the tree's vascular system in the process (Figure 2). Once mature, the adult beetles will fly from their current tree to repeat the process on another ash tree. The timeline from initial infestation to death ranges from a single year in smaller trees, to 3-4 years in large trees. Within a forest stand, larger trees are more likely to be attacked and also attract more beetles than their smaller counterparts.[4] EAB are also more likely to infest unhealthy ash trees, which will generally die faster than healthy trees once the larvae are inside the bark. The larvae feed downwards from the top of the tree towards the root structure. A 2011 study concluded that tree moisture content and nutrition drove this behavior.[3] The life development, mating, and feeding patterns of EAB are well understood, but applying this information to find a solution to ending its North American invasion is an ongoing challenge.

Figure 2. In the larva stage, the Emerald ash borer feeds on the phloem of ash trees. This greatly damages the ash tree's vascular system and destroys the tree's ability to transport nutrients and water between its leaves and roots. Photograph by the USDA Forest Service, 2004. Public Domain.

Despite all efforts to eradicate EAB, progress has been limited. It is estimated that eventually nearly all ash trees in North America will be decimated.[5] One recent study conducted in Ohio concluded that for a given population of ash trees in a stand, nearly complete mortality is experienced for all trees in six years, in all circumstances. In addition, relatively lower densities of ash trees were found to be more susceptible to early deaths.[6] North American ash trees do not have the natural defenses that their counterparts in Asia have to fend off the beetle. EAB is classified as an invasive species, and it currently lacks sufficient predators in North America to keep its population under control. There are now regulations in place to limit the spread of EAB, such as quarantining the transportation of firewood to prevent potentially infested wood from affecting new areas (Figure 5). A variety of different methods for killing EAB have been proposed, including traps, decoys, and introducing new predators (Figure 3).


1980

Figure 3. Sticky traps attract Emerald ash borer, however they also harm non-target, native insects.
Courtesy of the Delaware Department of Agriculture, 2013. CC BY 2.0 (Top, Left) and the USDA Forest Service, 2004. Public Domain (Right).

Traps have seen limited success thus far due to difficulties in producing a reliable trap on an industrial scale. One study conducted in Hungary attempted to solve this production problem by producing a replica trap of a female EAB. EAB's general mating pattern involves a male copulating with a female on an ash leaflet.[2] The male spots the female on the leaflet by visually detecting the iridescent green color of the female's elytra. With this knowledge, the scientists made traps that resembled the upper body of females by using positive and negative dies (created from a dead female) stamped onto a polymer sheet. The traps were somewhat successful in capturing EAB males but they also caught other species of beetles, signifying a need for further design modifications. This trapping strategy would be able to be replicated on an industrial scale because nearly 100 decoys were made from only one dead female. The female decoy trap may hold promise for the future of EAB control, especially considering females mate with multiple males to ensure maximal fecundity.[2,7]

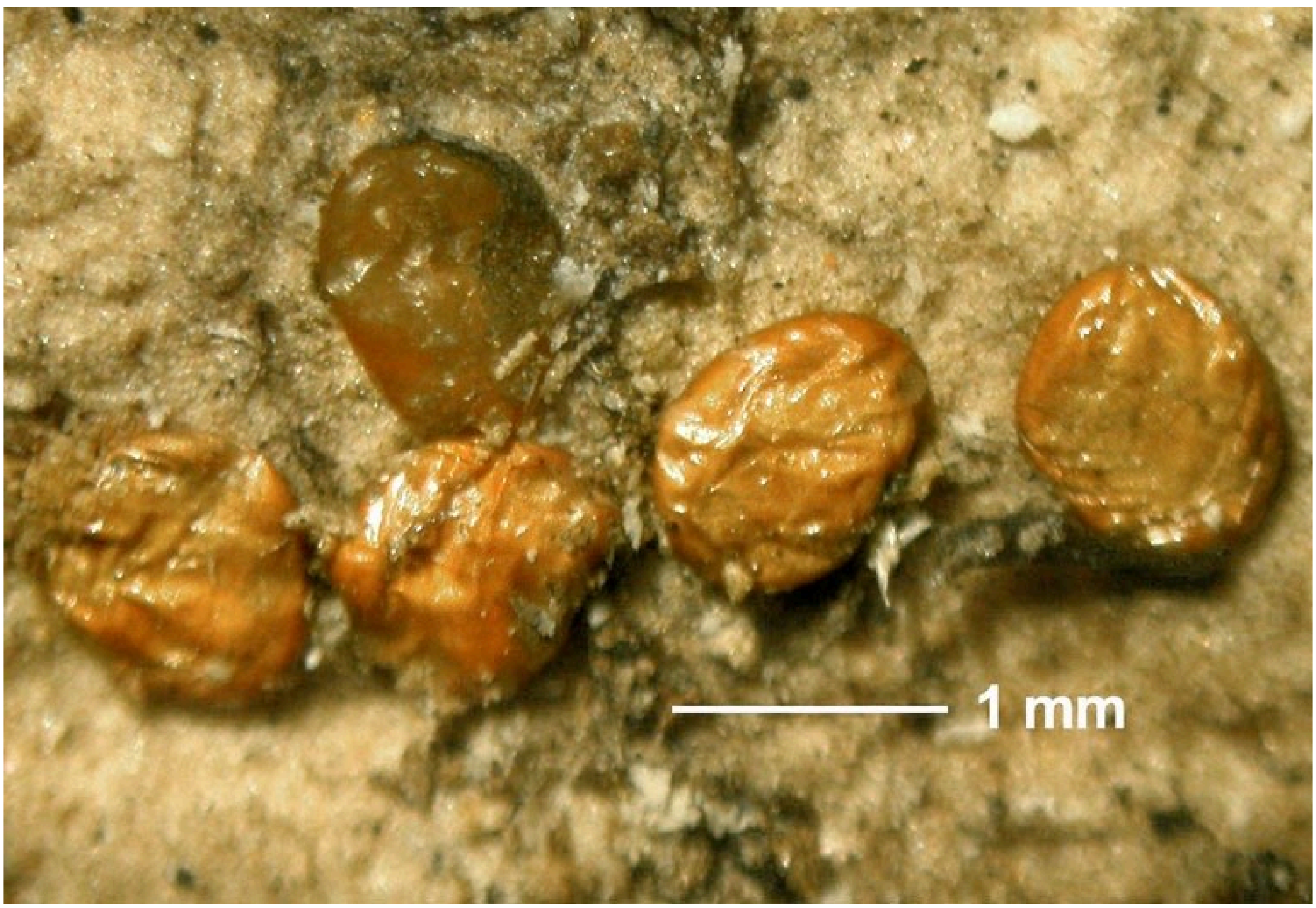


Figure 4a. Life cycle: eggs are laid in clusters on ash tree bark.
Photograph by David Cappeart, 2014. CC BY-NC-SA 3.0.

Figure 4b. Life cycle: upon hatching, the Emerald ash borer larva bores into the ash tree. Photograph by David Cappaert, 2014. CC BY-NC-SA 3.0.

Figure 4c. Life cycle: while burrowed under bark, larva become pupa
Courtesy of the USDA Forest Service, 2004. Public Domain.

Figure 4d. Life cycle: upon maturation, adult Emerald ash borer emerge from the ash tree. Photograph by Benjamin Smith, 2014. CC-BY 2.0.

Figure 4e. Life cycle: adult emerald ash borer beetles mate and restart the life cycle for the next generation.
Photograph by David Cappaert, 2010. CC BY 2.0.

Placement and density of traps is as important as choosing the type of trap. Research results regarding this area have been mixed. One study suggested that an effective way to slow EAB population growth is to deploy a large number of trap trees in a heavily infested area which will attract beetles from surrounding areas. Once the beetles arrive, the trap trees are destroyed.[8] Another study concluded that trap location and abundance of ash phloem near traps had no significant effect on EAB captures.[9] More research on traps and decoys is needed to create an easily replicated and effective trap that is suitable for long term use.

The deployment of a predator species against EAB could be the most effective way to combat the invasion. The Emerald ash borer is not heavily preyed upon in North America. There are however, some natural predators in the United States such as wasps and bark-foraging birds that may be able to effectively prey upon EAB. One small-sample size study conducted in Ohio closely monitored woodpecker activity around a few ash trees for two years.[10] The study discovered that the woodpeckers killed 85 percent of emerald ash borers in infested trees. In addition, woodpecker populations appeared to rise in response to an increase in EAB populations. The researchers suggested that while woodpeckers will not save a tree that has already been infested, they have the potential to save a forest and perhaps control the spread of EAB on a large scale.

Figure 5. Given the costly effects of an infestation, local governments hope to limit the spread of Emerald ash

borer by preventing the transport of possibly infested firewood.
North Dakota Forest Service, 2011. CC BY-NC-SA 3.0.

While none of these methods have yet to demonstrate the ability to completely exterminate a population of Emerald ash borers in a given area, understanding that complete eradication of EAB is not necessary to save North America's ash trees. As demonstrated in Asia, lower EAB densities may not cause ash mortality.[5] Complete eradication of EAB in North America may never be feasible, but controlling its numbers is a manageable challenge. With increased research, there is hope that scientists will develop a protocol to protect the ash trees from extirpation in the near future. Meanwhile, people and businesses are faced with huge costs resulting from unprecedented ash tree loses. Companies involved in logging and tree industries (e.g. nurseries) cannot afford the financial burden imposed by EAB and the problem will likely worsen if a effective population control mechanism is not found.

References

1. Kovacs, K.F., et al. (2010). Cost of potential emerald ash borer damage in US communities, 2009-2019, Ecological Economics, 69:569-578
2. Pulsifer, D.P., et al. (2013). Fabrication of Polymeric Visual Decoys for the Male Emerald Ash Borer (Agrilus planipennis), Journal of Bionic Engineering, 10:129-138
3. Chen, Y.G., et al. (2011). Moisture content and nutrition as selection forces for emerald ash borer larval feeding behaviour,Ecological Entomology, 36:344-354
4. Marshall, J.M., et al. (2013) Estimates of Agrilus planipennis Infestation Rates and Potential Survival of Ash, American Midland Naturalist, 169:179-193
5. DeSantis, R.D., et al. (2013). Effects of climate on emerald ash borer mortality and the potential for ash survival in North America, Agricultural and Forest Meteorology, 178:120-128
6. Knight, K.S., et al. (2013). Factors affecting the survival of ash (Fraxinus spp.) trees infested by emerald ash borer (Agrilus planipennis), Biological Invasions, 15:371-383
7. Rutledge, C.E., & Keena, M.A., (2012). Mating Frequency and Fecundity in the Emerald Ash Borer Agrilus planipennis (Coleoptera: Buprestidae), Annals of the Entomological Society of America, 105:66-72
8. Fierke, M.K., et al. (2013). Delimitation and management of emerald ash borer (Coleoptera: Buprestidae): case study at an outlier infestation in southwestern New York State, United States of America, Canadian Entomologist 145:577-587.
9. McCullough, D.G., et al. (2011). Effects of Trap Type, Placement and Ash Distribution on Emerald Ash Borer Captures in a Low Density Site, Environmental Entomology, 40:1239-1252
10. Galatzer-Levy, J. (2013, December). Emerald ash borer may have met its match. University of Illinois at Chicago News Center. Retrieved from: http://news.uic.edu/emerald-ash-borer-may-have-met-its-match

11. Cappaert, David. (2014). EAB Collection Gallery [Photographs]. Michigan State University. Retrieved from http://www.ag.ndsu.edu/ndae4hyw/invasives/emeral-ash-borer. CC BY-NC-SA 3.0.
12. Forest Service, USDA. (2004). Green ash killed by Emerald Ash Borer. [Photograph]. Retrieved from Wikimedia Commons. Public Domain
13. Delaware Department of Agriculture. (2013). Emerald Ash Borer traps 1. [Photographs]. Retrieved from FlickrCommons. CC BY 2.0.
14. Delaware Department of Agriculture. (2013). Emerald Ash Borer traps 2. [Photographs]. Retrieved from FlickrCommons. CC BY 2.0.
15. Forest Service, USDA. (2004). An adult Emerald Ash Borer on a penny. [Photograph]. Retrieved from Wikimedia Commons. Public Domain.
16. Forest Service, USDA. (2004). Dorsal view of Emerald Ash Borer pupae. [Photograph]. Retrieved from Wikimedia Commons. Public Domain.
17. Smith, Benjamin. (2014). Agrilus planipennis – Emerald Ash Borer. [Photograph]. Retrieved from Wikimedia Commons. CC BY 2.0.
18. Cappaert, David. (2010). Emerald Ash Borer mating. [Photograph]. Michigan State University. Retrieved from FlickrCommons. CC BY 2.0.
19. North Dakota Forest Service. (2011). 2011 Firewood Alert. [Flyer]. Retrieved from http://www.ag.ndsu.edu/ndae4hyw/invasives/emeral-ash-borer. CC BY-NC-SA 3.0.

ENERGY

Image Courtesy of U.S. National Archives and Records Administration, 1972. Public Domain.

3.1 Environmental Impacts of the Grand Coulee Hydroelectric Dam

Chris Ebersole

Hydroelectric power plants, such as the Grand Coulee Dam, provide benefits such as renewable energy and irrigation, but also produce adverse costs to human and wildlife populations. Careful consideration must be given before a hydroelectric power plant can be responsibly implemented.

Figure 1. The Grand Coulee Dam.
Photograph by Gregg M Erickson, 2009. CC BY 3.0.

Hydroelectric power plants provide a very efficient, renewable method of generating electricity without producing air pollution. Hydroelectric produced electricity currently accounts for nearly 7% of the total electricity generated in the United States. However, currently less than 3% of all dams in the United States are used to generate electricity.[3] This discrepancy presents a great opportunity to increase the use of renewable energy production through hydroelectric power.[3] There are many factors which make hydroelectric energy a desirable alternative to the burning of fossil fuels, yet the construction and operation of hydroelectric plants also involves a number of disadvantages. These drawbacks include environmental changes which could adversely affect the health of humans and animals.

Figure 2. Dams have long been known to adversely affect some aquatic species, such as the Chinook salmon.
Photograph from Oregon State Special Collections and Archives, 2004. Public Domain.

To produce electricity, hydroelectric power plants harness the gravitational energy of falling water to turn turbines. This process is similar to burning coal, which creates steam used to turn turbines. Hydroelectric turbines are connected to a generator which translates this rotational mechanical energy into electrical energy through Faraday's Law (Figure 3). In accordance with this law, a generator's rotor is made to behave as an electromagnet. When the wicket gates are opened and water causes the rotor connected to the turbine to spin, these magnets move past conductors mounted in the stator, resulting in the flow of electricity. For this process to be effective, water must be stored at a high elevation and released at a low elevation to yield the maximum gravitational energy, thus hydroelectric dams are constructed on rivers to form a high-elevation reservoir behind the dam.

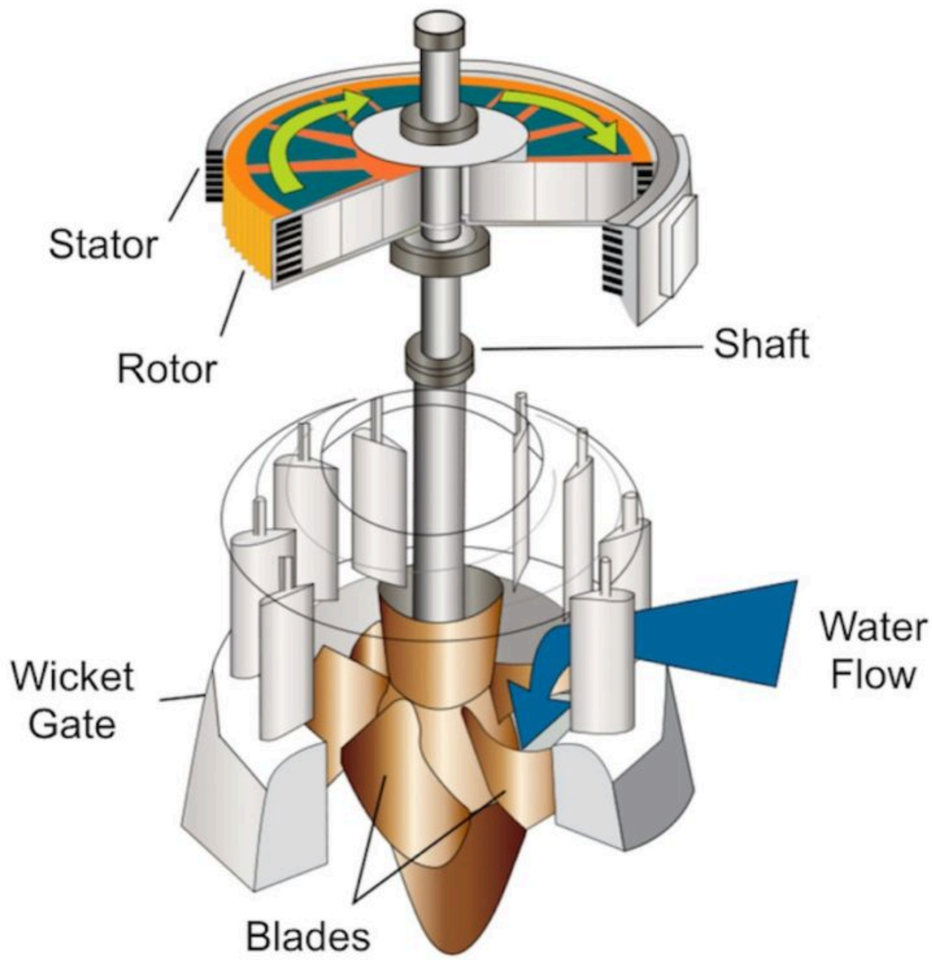


Figure 3. The wicket gates of the water turbine can be opened to an arbitrary degree to control the inflow of water. The flow of water spins the turbine, which in turn causes the turbine shaft and the attached rotor to spin as well. Because the rotor contains an electromagnet, its rotation induces an electric current on conductors housed on the stator.
Courtesy of U.S. Army Corps of Engineers, 2012. Public Domain.

Demand for electricity fluctuates from day to day and month to month. During periods of low demand, such as nighttime, stored electricity can be used to pump water up into a backup reservoir. This process allows for the recycling of water in hydroelectric production. Pumped storage systems allow for rapid adjustments in plant output, resulting in a more efficient system which is relatively inexpensive to build.[11]

The Grand Coulee Dam, located on the Columbia River 145 km west of Spokane, Washington, is three times the size of the Great Pyramid and two and a half times the volume of Hoover Dam (Figure 1, 4).[1] Constructed between 1933 and 1942, the Grand Coulee Dam was a major source of economic stimulus during the Great Depression. Construction of the dam provided roughly 8,800 jobs, and resulted in a large economic boom in neighboring towns.[9] Since its completion, the Grand Coulee Dam has provided many long-term jobs, annual irrigation to more than 2,000 Washington farmers, and is one of the top producers of hydroelectric power in the United States. The revenue produced by this dam has far outweighed its cost. The Grand Coulee Dam was vital in providing the electricity necessary to produce aluminum for airplanes and plutonium for nuclear weapons during World War II.[9] With the addition of a third power plant in 1974, the Grand Coulee Dam is now capable of producing 7,200 megawatts of power.[7]

Figure 4. Interactive Google Map of the Grand Coulee Dam. The Grand Coulee Dam resides on the Columbia River in Washington.
Map data ©2015 Google. Public Domain.

Click Here to Explore the Grand Coulee Dam in Google Maps

Despite the many economic opportunities provided by the Grand Coulee Dam, there are a number of detriments which limit its overall utility. Hydroelectric dams alter the environment in numerous ways which include altering natural hydrographs, diverting waterways, changing abiotic factors such as water temperature, and changing biotic factors such as secondary productivity.[10] The construction of a series of dams on the Columbia River, including the Grand Coulee Dam, has limited the available riverine salmon habitat to 13% of the river.[2] Fall chinook salmon currently use only 85 km of the 2,000 km river as breeding grounds.[2] The first two of the fourteen hydroelectric dams built on the Columbia River included fish ladders which allowed anadromous salmonids to travel through the dams.[2] Dams constructed later, including the Grand Coulee Dam, were not constructed with this feature.[2] At the start of the 20th century, an estimated 10 to 16 million anadromous fish runs occurred annually in the Columbia River.[2] Currently, an estimated average of 2.5 million runs occur each year.[2] In addition, hydroelectric dams can cause changes in food and water security, an increase in communicable diseases among humans and animals, social disruption caused by construction and involuntary resettlement, and a loss of biodiversity (Figure 5).[8]

From 1995 to 2004, a study was conducted by McLellan et al. (2011) to determine if a correlation exists between reservoir elevation fluctuations and the rainbow trout (Figure 6) population in Franklin D. Roosevelt Lake. This lake was created by the Grand Coulee Dam blocking the flow of the Columbia River (Figure 3).[10] Since 1987, 500,000 coastal rainbow trout have been stocked annually in the lake. Some of these fish were marked using Floy Tags before being released into the lake and anglers were asked to return the tags of any fish caught. The fewest return of tags occurred during deep drawdown events, in which the elevation of the reservoir was lowered to less than 372 meters. These events are typically used as a method of flood control between February and May. During this time period the reservoir experiences its lowest annual elevations. The findings of the McLellan et al. (2011) study suggest a correlation between deep drawdown events and fish entrainment and mortality.

Impact Area	Effect of Dam	Health Impact
Upstream Catchment & River	Loss of biodiversity, increased agriculture, sedimentation & flooding, changes in river flow regime	Changes in food security, water-related diseases, difficulties, with transportation & access to health facilities
Reservoir Area	Inundation of land, presence of large manmade reservoir, pollution, changes in mineral content, decaying organic material	Involuntary resettlement, social disruption, vector-borne diseases, water-related diseases, reservoir-induced seismicity
Downstream River	Lower water levels, poor water quality, lack of seasonal variation, loss of biodiversity	Food security affected on flood plains & estuaries (farming & fishing), water-related diseases, dam failure & flooding
Irrigation Areas	Increased water availability & agriculture, water weds, changes in flow &mineral content, pollution	Changes in food security, vector-borne & water-related diseases
Construction Activities	Migration, informal settlement, sex work, road traffic increase, hazardous construction	Water-related diseases, sexually transmitted diseases, HIV/AIDs, accidents & occupational injuries
Resettlement Areas	Social disruption, pollution, pressure on natural resources	Communicable diseases, violence & injury, water-related disease, loss of food security
Country/Regional/Global	Reduced fuel imports, improved exports, loss of biodiversity, reallocation of funding, sustainability	Macro-economic impacts of health, inequitable allocation of revenue, health impacts of climate change

Figure 5. Potential Health Impacts of Large Dam Projects
Data adapted from L. B. Lerer and T. Scudder, 1999.

Although hydroelectric power plants do not produce air pollution, they create water pollution in the form of heat and chemical pollutants. Hydroelectric dams are often a source of polychlorinated biphenyls (PCBs).[6] Plasma taken from fish in the Columbia River have been found to contain all 18 of the chlorinated pesticides for which tests were conducted.[4] These chemicals are dangerous to all aquatic life, including salmonids, as well as humans living downstream from these dams. Most notably these chemicals have affected Native American populations who depend heavily on the Columbia River Basin for fish. As a result of biomagnification, those individuals who consume fish taken from the Columbia River Basin are exposed to concentrations of contaminants such as PCBs, arsenic, and mercury.

Hydroelectric power plants provide a clean, renewable alternative to fossil fuels for generating electricity. Nevertheless, hydropower can affect the environment in a many ways that are detrimental to local fish and human populations. These factors must be carefully considered before installing a hydroelectric dam. Fortunately, scientists and engineers are continuously researching new methods of producing hydroelectric power which minimize the potential harm to the environment.

Figure 6. Rainbow Trout (Oncorhynchus mykiss).
Rainbow trout are greatly affected by the water levels within the Grand Coulee Dams reservoir (also known as the Franklin D. Roosevelt Lake).
Photograph by Eric Engbretson, 2013. Public Domain.

References

1. Barbour, G.B. (1940). Harnessing the Columbia River: The Grand Coulee Dam and Its Geographical Setting. The Geographic Journal, 96:233-242.
2. Dauble, D.D. et. al. (2011) Impacts of the Columbia River Hydroelectric System on Main-Stem Habitats of Fall Chinook Salmon. North American Journal of Fisheries Management, 23:641-659.
3. Energy 101. (2013 April 19) [Video discussing the science behind hydroelectric power generation]. U.S. Department of Energy. Retrieved from http://www1.eere.energy.gov/water/hydropower_resources.html
4. Feist, G.W. et. al. (2005). Evidence of Detrimental Effects of Environmental Contaminants on Growth and Reproductive Physiology of White Sturgeon in Impounded Areas of the Columbia River. Environmental Health Perspectives, 133:1675-1682.
5. Grand Coulee Dam. (April 3, 2014). U.S. Department of the Interior. Retrieved from http://www.usbr.gov/pn/grandcoulee/photogallery/aerials/pic3.html
6. Hinck, J.E. et al. (2006). Environmental contaminants and biomarker responses in fish from the Columbia River and its tributaries: Spatial and temporal trends. Science of the Total Environment, 366:549-578.
7. Horn, F.J., & Johrde, P. S. (1975). Electrical and mechanical design features of the 615 MVA generators for Grand Coulee Dam. IEEE Transactions on Power Apparatus and Systems, 94(6):2015-2022.
8. Lerer, L.B. & Scudder, T. (1999). Health impacts of large dams. Environmental Impact Assessment Review, 19:113-123.
9. McClung, C. (2009). Grand Coulee Dam: Leaving a Legacy, University of Washington. Retrieved from http://depts.washington.edu/depress/grand_coulee.shtml
10. McLellan, H.J. et. al. (2011) Effects of Reservoir Operations on Hatchery Coastal Rainbow Trout in Lake Roosevelt, Washington. North American Journal of Fisheries Management, 28:1201-1213.
11. Perlman, H. (2013 March 6). Hydroelectric power: How it works. USGS – U.S. Geological Survey.
12. Erickson, Gregg M. (2009). Grand Coulee Dam. [Photograph]. Retrieved from Wikimedia Commons. CC BY 3.0.
13. OSU Special Collections & Archives. (2004). Fall Chinook Salmon. [Photograph]. Retrieved via Wikimedia Commons.© 2015, Special Collections & Archives Research Center. Public Domain.
14. U.S. Army Corps of Engineers. (2012). Water Turbine. Retrieved via Wikimedia Commons. Public Domain.
15. Engbretson, Eric, U.S. Fish and Wildlife Service. (2013). [Photograph of Rainbow Trout]. Retrieved from Wikimedia Commons. Public Domain.

3.2 Dispersion of Radioactive Material from the Fukushima Daiichi Disaster

Brandon S. Wator

In 2011, an earthquake off the coast of Japan set in motion a series of events that allowed radiation to escape from the Fukushima Daiichi Nuclear Power Plant. The radioactive contaminants that were released have long-term implications for residents both locally and globally.

Figure 1. Members of the International Atomic Energy Agency's (IAEA) Remediation Expert Mission examines Reactor Unit 3 during the team's visit to the Fukushima Daiichi Nuclear Power Plant.
Photograph by Giovanni Verlini, 2011. CC BY-SA 2.0.

The Fukushima Daiichi Nuclear Power Plant (Figure 2) is one of the foremost power generation sites for the Fukushima prefecture in Japan (Figure 3). In 2011, an earthquake off the coast of Japan caused major havoc for the residents inhabiting the coastal area. This destruction was a result of the tsunami created by the earthquake. The tsunami overwhelmed levees protecting the Fukushima Daiichi Nuclear Power Plant and flooded the basement levels of the facility. These levels housed the backup generators for the cooling systems at the plant. The destruction of the backup generators caused default cooling systems to go offline, and forced the Tokyo Electric Power Company to take drastic measures to prevent a catastrophic nuclear meltdown. The Tokyo Electric Power Company opted to open intakes and pump seawater into the reactors. At the time this seemed like a good alternative, however there was no system to store the contaminated water shortly after this cooling technique was implemented. With nowhere to go, the contaminated water was released, resulting in radioactive material dispersion into the ocean, surrounding land, and the atmosphere. Predictably, this can cause major, far-reaching effects despite the assurances made by parties associated with the Fukushima Daiichi Nuclear Power Plant.

Figure 2. Audio Pronunciation

Click here to hear the Native Japanese Pronunciation of "Fukushima Daiichi".[13]

Theanphibian, 2011. Public Domain.

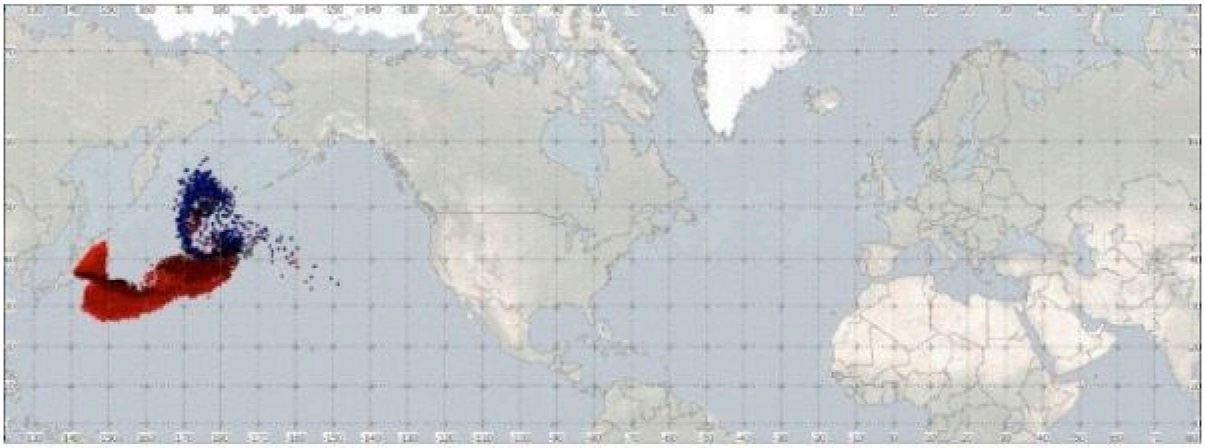
The original estimations of contamination levels were high enough to warrant concern.[1] The levels of radiation cited in the most conservative estimates warranted the investigation of the actual dispersion of radiation and its effects. To explore and examine these far-reaching effects, quantitative data was gathered and analyzed. Researchers relied on a network of noble gas monitoring stations located around the globe to obtain information on radionuclides released into the atmosphere.[2] Two stations, located in Hong Kong and Tokyo, were specifically used to gather the data.[2] These stations reported definitive increases in radioactive isotopes in the atmosphere, upwards of three degrees of magnitude compared to normal levels.[2] Researchers further determined that these increases in radionuclides are correlated with the release of material from the Fukushima Daiichi plant.[2] The Hong Kong detector which is located over three thousand kilometers from the Fukushima Daiichi site detected an increase in radionuclides. Detectors often have spikes in concentrations of radionuclides shortly after explosions or the release of smoke from the reactors. Thus, the correlation of increased radionuclides from the Fukushima Daiichi plant disaster was easily established.

Figure 3. Google Map of Fukushima Prefecture, Japan.
The Fukushima Prefecture is a state-like region within Japan. The Fukushima Daiichi Power Plant provided electrical power to this region.
Map data ©2015 Google. Public Domain.

Click Here to Explore Fukushima in Google Maps.

This data suggests the potential for contamination released by the Fukushima Daiichi Power Plant to travel vast distances. To further investigate the spread of contamination, researchers used computer models of air currents to map the distribution across the globe. Researchers used a similar method to also map the dispersion of radionuclides released into the ocean by using models of ocean currents. Both models predicted extensive distribution in a short amount of time. Contaminants in the atmosphere were predicted to spread around the world (Figure 4), while contaminants in the ocean would traveling as far as the coast of California.

Researchers also stated that the concentration of radionuclides in the northwestern region of the Pacific Ocean, at the highest predicted values, would reach levels comparable to a nuclear weapons test.



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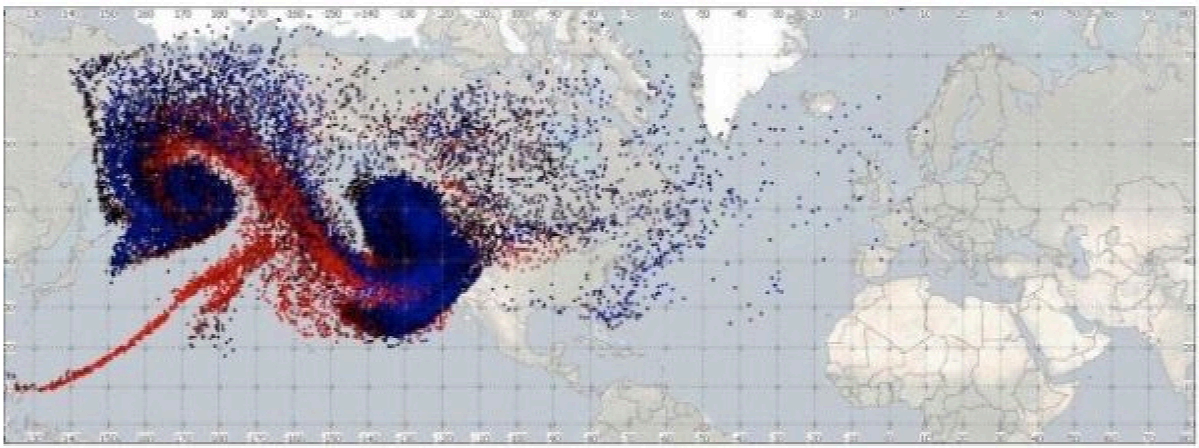
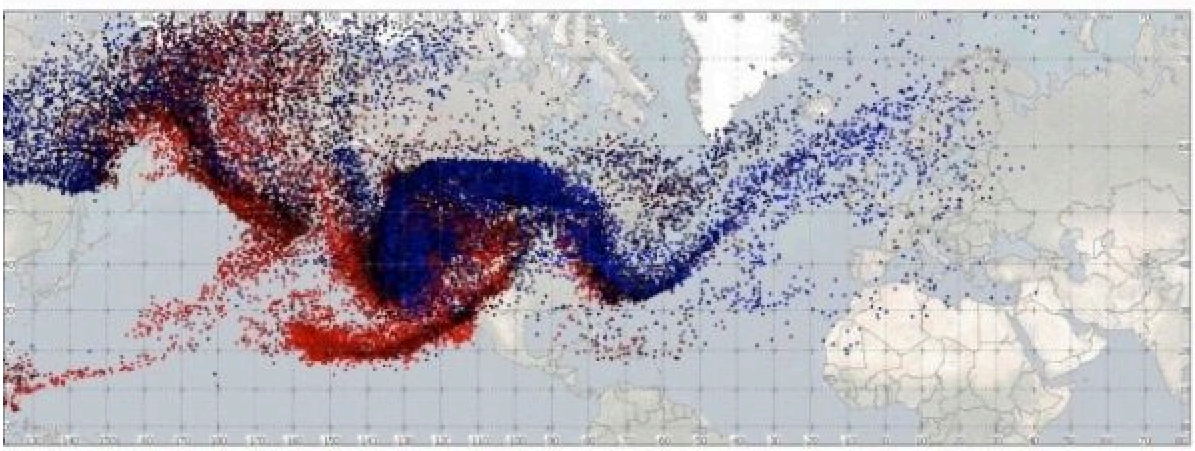


18/3/2011 at 06:00 UTC



20/3/2011 at 12:00 UTC

Figure 4. Large concentrations of radionuclides were released as a result of the March, 2011 incident that occurred at the Fukushima Daiichi Power Plant. This model, by Povinec et al. (2013), describes how air currents dispersed this material across the world. Colored points on the model indicated the height of radionuclide particles in the atmosphere
Red – Ground level to 3 km
Black – 3 – 6 km
Blue – above 6 km
Courtesy of Povinec et al., 2013. Reprinted with permissions from Elsevier.

To further determine the effects of the Fukushima Daiichi disaster, quantifiable tests were performed on microorganisms in areas near the site. Significant levels of contamination were found in these organisms. This information can be used to predict the contamination of organisms that are useful to consumers.[3] Researchers concluded that in ten years, contamination levels would be as high as those in a global nuclear fallout, and the detrimental effects of the radiation on sea life used as food sources will have diminished to a level that makes consumption by humans safe.[4,5] Nevertheless, the short-term effects on fish products are noticeable and consumers should be aware of what they are consuming to prevent exposure.[6]

The contamination of the ocean and ocean dwelling organisms is easily measurable. As radionuclides were released into the atmosphere, they were absorbed by fine particles located in the surrounding environment. For example, measurements were taken from rivers located near the Fukushima Daiichi plant. Radioactive material was present in these sediment samples.[7] Rainstorms were also found to accelerate the migration of contaminants from the inland mountainous regions to the coastal areas.[8]

Another issue related to these contaminants is their storage in the mountainous regions located near Fukushima Daiichi. The root structures of trees in the forests cover upwards of 85 percent of these mountainous areas, and this inhibits the distribution of contaminated material due to slower soil erosion rates. Because of this limited erosion, it can be deduced that the radioactive material will be stored for a longer period, and have a more prolonged release in these regions. Also, different materials can absorb different concentrations of radionuclides, which can result in some areas having higher contamination. Hypothetically, this could cause a major environmental issue if these highly radioactively contaminated areas were hit by a monsoon and a large amount of radionuclides were released at once.

This dispersion of radioactive material in the local environment, as well as the global spread of this material through the ocean currents and the atmosphere, has a direct public health impact on many populations.[9] This is particularly evident in residents of the area surrounding Fukushima. Bone health of people in the surrounding areas of the disaster has been shown to deteriorate due to radiation exposure.[10,11]

Overall, the short-term ramifications of the Fukushima Daiichi disaster has left many concerns for both local and global populations. The long-term effect of the radioactive contamination leaves the surrounding land uninhabitable. More far-reaching environmental effects will likely occur as a result of this disaster.

References

1. Chino, M. et al. (2011). Preliminary estimation of release amounts of 131I and 137Cs accidentally discharged from the Fukushima Daiichi nuclear power plant into the atmosphere. Journal of Nuclear Science and Technology, 48(7): 1129-1134.
2. Schoppner, M. et al. (2013). Estimation of the radioactive source dispersion from Fukushima nuclear power plant accident. Applied Radiation and Isotopes, 81, 358-361.
3. Buesseler, O. et al. (2012). Fukushima-derived radionuclides in the ocean and biota off Japan. Proceedings of the National Academy of Sciences, 109(16):5984-5988
4. Povinec P, et al. (2013). Dispersion of Fukushima radionuclides in the global atmosphere and the ocean. Applied Radiation and Isotopes, 81:383-392.
5. Wang H, et al. (2012). Numerical study and prediction of nuclear contaminant transport from Fukushima Daiichi nuclear power plant in the North Pacific Ocean. Chinese Science Bulletin, 57(26):3518 – 3524.
6. Chen J. (2013). Evaluation of radioactivity concentrations from the Fukushima nuclear accident in fish products and associated risk to fish consumers. Radiation Protection Dosimetry, 157:1-5.
7. Yasunari, T.J. et al. (2011). Cesium-137 deposition and contamination of Japanese soils due to the Fukushima nuclear accident. Proceedings of the National Academy of Sciences, 108(49):19530-19534.
8. Evrard, O. et al. (2013). Evolution of radioactive dose rates in fresh sediment deposits along coastal rivers draining Fukushima contamination plume. Scientific Reports, 3:3079.
9. Tilman A.R. (2013) A Public Health Perspective on the Fukushima Nuclear Disaster, Asian Perspective, 37:523-549.
10. Biello, D. (2014, January). What You Should and Shouldn't Worry about after the Fukushima Nuclear Meltdowns. Scientific American. Retrieved from http://www.scientificamerican.com/article/what-to-worry-about-after-fukushima-nuclear-disaster/
11. Ishii T, et al. (2013). A report from Fukushima: an assessment of bone health in an area affected by the Fukushima nuclear plant incident. Journal of Bone and Material Metabolism, 31(6):613 – 617.
12. Verlini, Giovanni. (2011). Visit to the Fukushima Dai-ichi Nuclear Power Plant. [Photograph]. Retrieved from IAEA Imagebank via FlickrCommons. CC BY-SA 2.0.
13. Theanphibian. (2011). Pronounce Fukushima Daiichi. Retrieved from Wikimedia Commons. Public Domain.
14. Applied Radiation and Isotopes, 81, P.P. Povinec,M. Gera,K. Holý,K. Hirose,G. Lujanienė,M. Nakano,W. Plastino,I. Sýkora,J. Bartok,M. Gažák, Dispersion of Fukushima radionuclides in the global atmosphere and the ocean, 389, (2013), with permission from Elsevier.

3.3 Fracking's Potential Impact on Water Quality

John A. Zagar

Hydraulic fracturing for natural gasses has become widespread in the United States, but the process also creates potential negative impacts on water quality. This process uses harmful chemicals to extract the gasses, which are often leaked into the environment through use of faulty equipment and inadequate disposal techniques.

Figure 1. Establishing a new fracking well requires a large amount of resources and man power. Courtesy of U.S. Geological Survey, 2013. Public Domain.

Natural gas is the source for nearly 24% of the world's energy.[1] A great majority of these natural gas deposits are found underground in shale rock layers. One of the most notable shale rock layers in the United States is the Marcellus shale formation (Figure 2), which lies underneath New York, Pennsylvania, Ohio, and Virginia. Hydraulic fracturing (a.k.a. "fracking") is a mechanical process by which drilling breaks open rock layers deep underground, allowing natural gas to escape to the surface to be collected. This process uses high quantities of "fracking fluids" which consist of sand, water, and a combination of chemicals pumped underground to fracture the shale rock layers containing the coveted natural gasses. Eleven to twenty-six million liters (3-7 million gallons) of water is used per fracking well during the fracking process.[2] Over the past few decades new drilling technology has made gas extraction more feasible (Figure 3). However, many scientists question the safety of the process due to contamination of ground and surface water around the drilling sites.

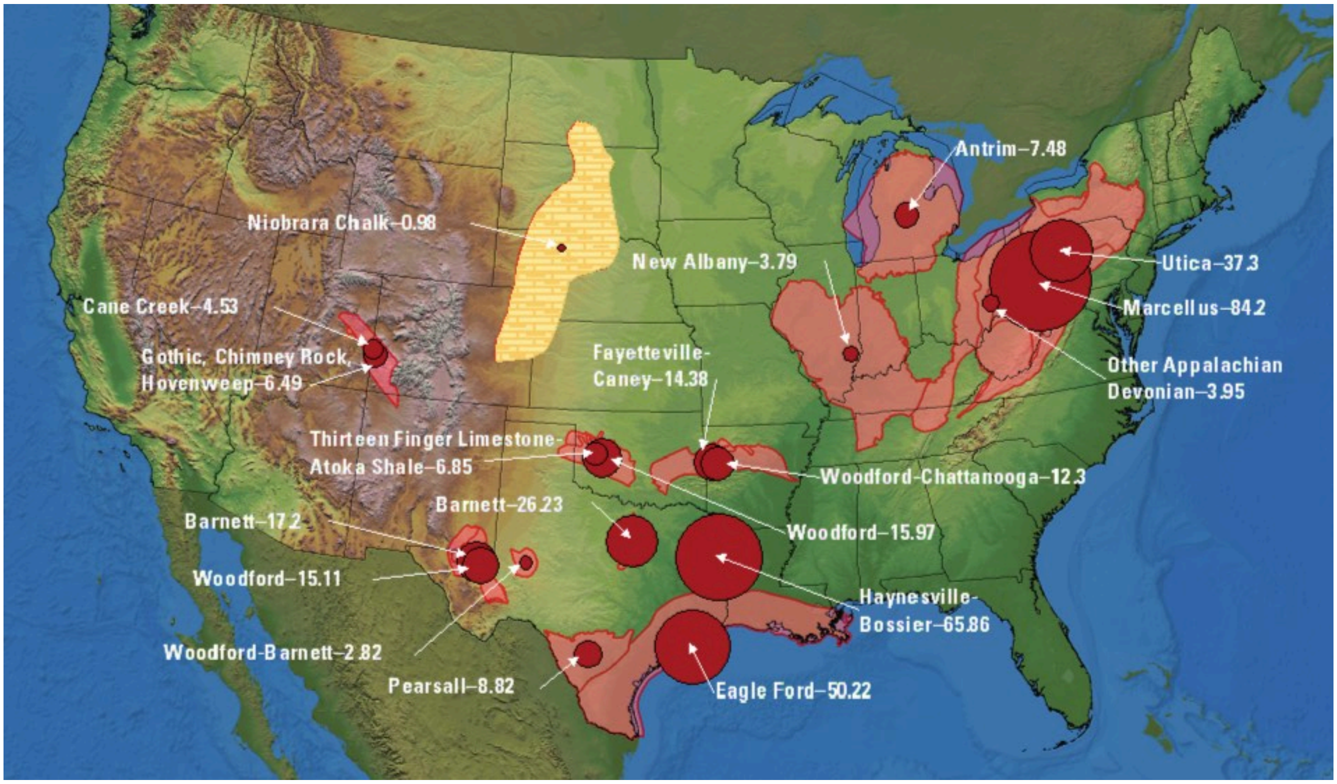


Figure 2. Natural gas deposits exist throughout the United States. Shaded areas show where natural gas deposits exist while dark red circles describe how many Trillions of Cubic Feet of Gas (TCFG) there is estimated to be within each deposit.
1 Cubic Foot = 28 Liters
Courtesy of U.S. Geological Survey, 2012. Public Domain.

In 2013, researchers from the University of Missouri found that 11 of the several hundred chemicals being used in fracking fluid are known endocrine disruptors. These chemical compounds can severely damage a human's hormonal system and are also associated with causing cancer.[3] The United Nations Environmental Programme Global Environmental Alert Service (UNEP GEAS) published findings that over 75% of the 353 chemicals used in fracking fluid can negatively impact an individual's sensory organs, respiratory system, gastrointestinal system, nervous system, immune system, and endocrine system.[4] Some of the reported chemicals were even shown to be mutagenic and carcinogenic.[4] There have been multiple agency reports, legal citations, and peer reviewed articles that claimed to find more gas in water wells located near areas where fracking was conducted.[5] In Pennsylvania, hundreds of lawsuits have been filed against fracking companies for contaminating peoples' water supply. In August of 2012, a major natural gas company reached settlements with 32 of 36 families suing for damages in Dimock, Pennsylvania, however numerous cases remain pending.[6]

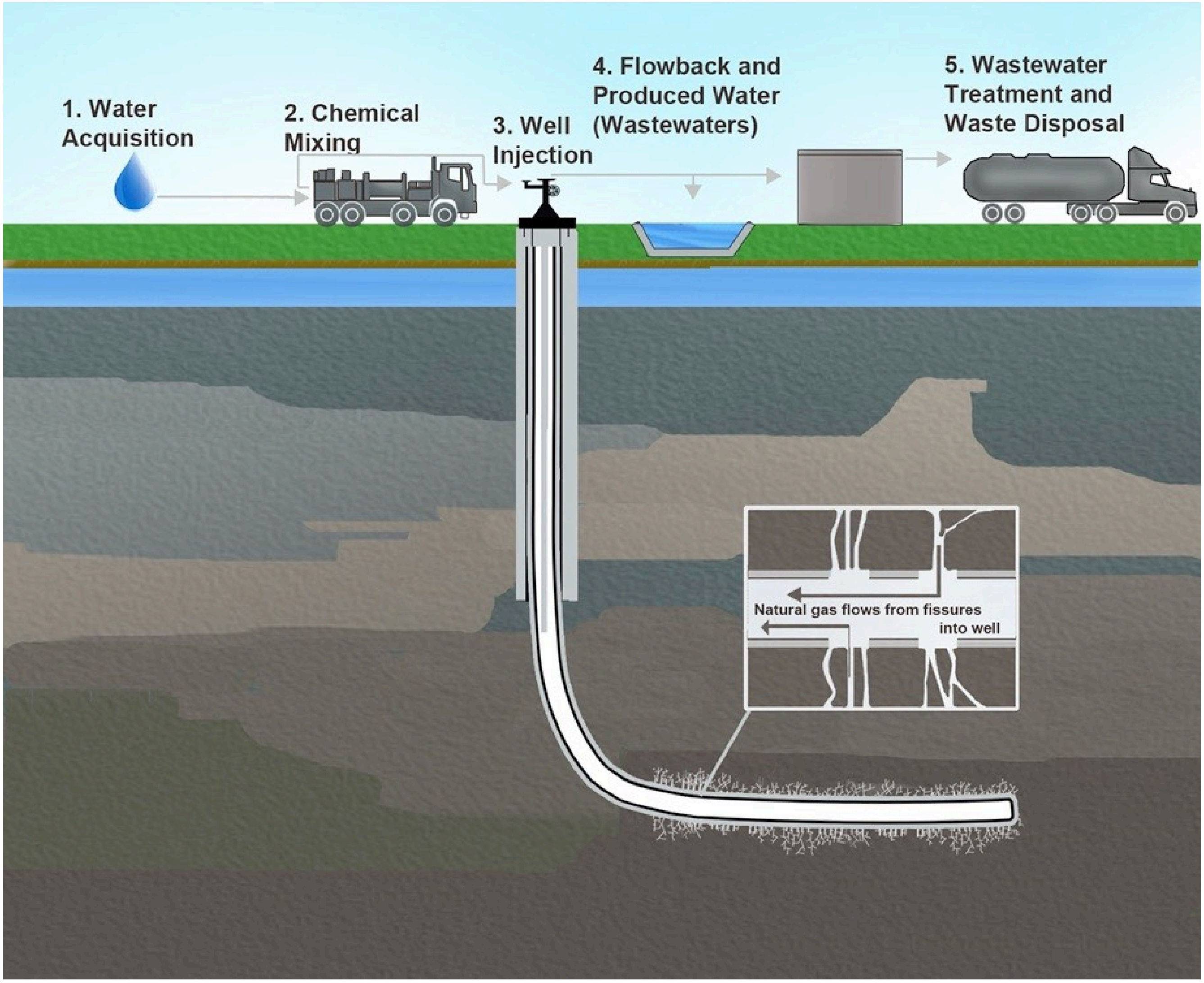


Figure 3. After a fracking well is established, natural gas deposits are extracted through 5 main steps. Courtesy of the U.S. Environmental Protection Agency, 2012. Public Domain.

Over the past few years, there have been multiple studies published confirming that fracking sites have contaminated water quality around the drilling sites. In 2013, researchers detected methane in 82% of 141 drinking water samples found within one kilometer of shale gas wells in Northeastern Pennsylvania (Figure 4).[8] Separate research teams also collected water samples located near fracking zones in Garfield County, Missouri and found an abundance of contamination caused by the fracking process.[9]

Tom Myers, a researcher in hydrogeology and water resources, argues that preferential flow through fractures allows for the transportation of contaminants from the fractured shale to aquifers. Myers states that there is enough substantial geological evidence to prove that natural vertical flow drives contaminants towards the surface.

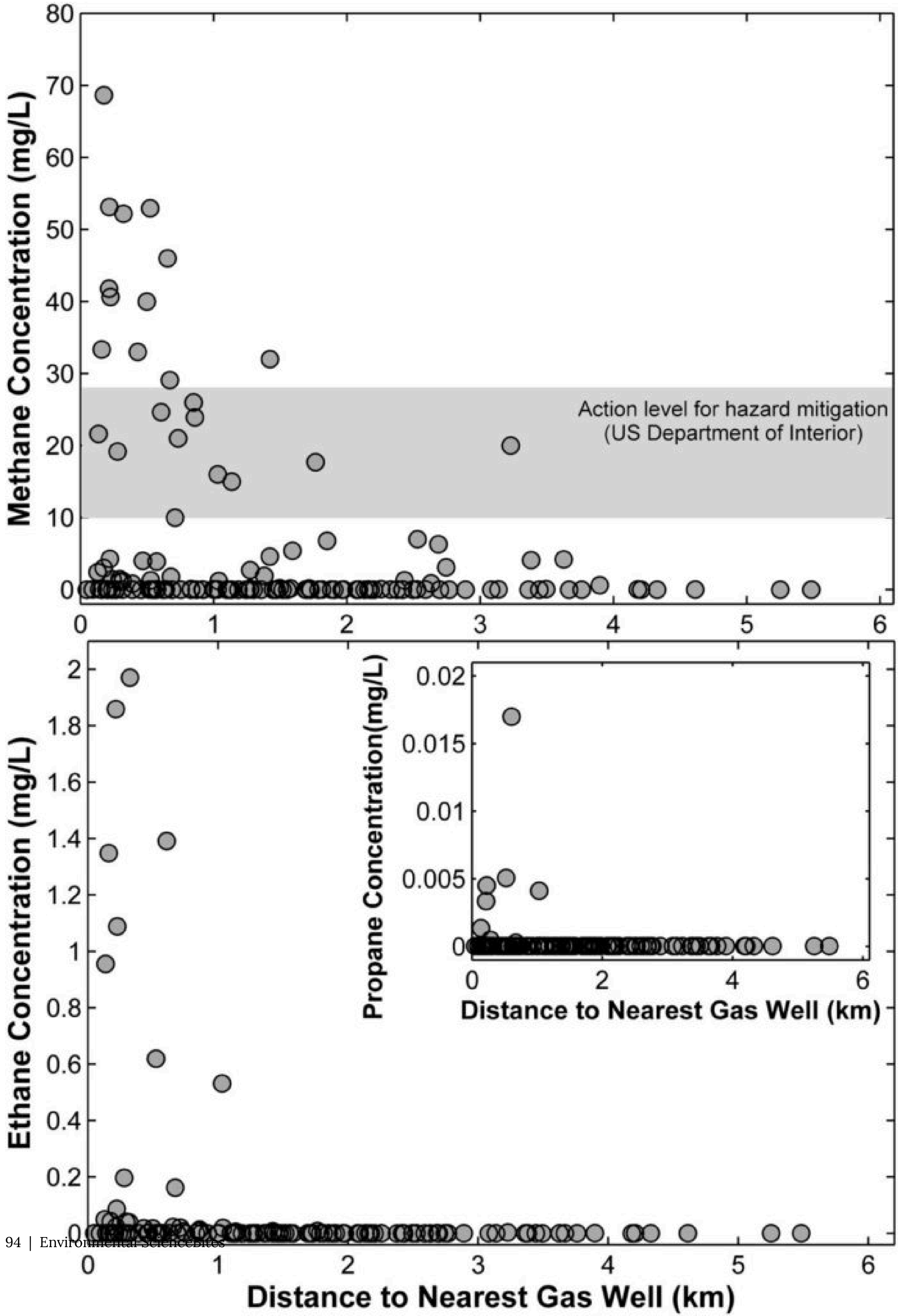

Methane Concentration (mg/L)
Action level for hazard mitigation
(US Department of Interior)
Ethane Concentration (mg/L)
Propane Concentration(mg/L)
Distance to Nearest Gas Well (km)
Distance to Nearest Gas Well (km)

Figure 4. Concentrations of methane, ethane, and propane (milligrams per liter) in sampled drinking water wells vs. distance to natural gas wells (kilometers). The gray band in the graph describing methane is the range for considering hazard mitigation as recommended by the US Department of the Interior.
Courtesy of R. B. Jackson et al., 2013.

In instances where greater amounts of methane where found in aquifers located within one kilometer of the fracking sites, Myers cites potential pathways causing this occurrence to include advection transport through sedimentary rock, fractures and faults, and abandoned wells, or open boreholes.[5]

The use of broken or faulty equipment is perhaps the leading source of unwanted byproducts of the hydraulic fracturing process in the water supply. In 2010, the Pennsylvania Department of Environmental Protection issued 90 violations for faulty casing and cementing and issued 119 more in 2011.[8] The purpose of steel casing and cement sealing is to prevent any gasses trapped within the well from escaping into the environment. Therefore, any breaks or imperfections in the casing will enable stray gasses and chemicals to leak into the water supply.[8]

Studies have confirmed that the likelihood of water contamination near fracking sites is sufficiently higher than sites not near the zones. However, research conducted by Duke University and the U.S. Geological Survey have confirmed that when operated and maintained correctly, the process of hydraulic fracturing should pose no threat towards contaminating the environment around the drilling site. Researchers found no evidence of drinking water contamination in their respective studies.[8]

Lethargy and negligence also play a major role in the contamination of the water supply around fracking sites. Madelon Finkel and Adam Law of the American Journal of Public Health argue that states simply do not have adequate rules and regulations in regards to fracking, and that regulation of polluted water disposal is practically non-existent.[6] A major byproduct of the fracking phase includes flow-back waste fluids that could potential harm the air and soil if not properly disposed. However, Finkel and Law suspect fracking companies have been secretly disposing their waste fluids into rivers and streams, many of which are sources of drinking water.[6]

In 2012, a study conducted by Peyton Flemming of Ceres suggested that 47% of fracking wells were erected in water basins with high or extremely high water stress, further emphasizing the need for reform on disposal regulations.[10]

In 2004, the U.S. Environmental Protection Agency (EPA) stated that the fracking process "pose[d] little to no threat to drinking water." Although this statement is still supported by the EPA, the New York Times has released evidence from "whistle-blowers" within the EPA. confirming that the agency's findings had been strongly influenced by industry and political pressure.[7]

Due to the "Halliburton Loophole", many major natural gas companies have been exempt from any rules and regulations cited in the Safe Drinking Water Act of 2005. To ensure safe drinking water around drilling sites, natural gas companies need to be more regulated to prevent water contamination. So the question remains what and/or who are the main culprits causing the contamination of the water supply around fracking sites, and how can these issues be resolved?

References

1. Finkel M.L., & Hays J., (2013). Public Health, 127(10):889-893
2. Schmidt C.W. (2013). Environmental Health Perspectives, 121(4):117.
3. Sandra Postel (2013 December 20). Hormone-Disrupting Chemicals Linked to Fracking Found in Colorado River. National Geographic, Web. Retrieved from http://newswatch.nationalgeographic.com/2013/12/20/hormone-disrupting-chemicals-linked-to-fracking-found-in-colorado-river
4. United Nations Environment Programme Global Environmental Alert Service. (2012, November). Gas fracking: can we safely squeeze the rocks?. Retrieved from http://www.unep.org/pdf/UNEP-GEAS_NOV_2012.pdf
5. Myers T. (2012). Groundwater, 50(6):872-882
6. Finkel M.L., & Law A. (2011). American Journal of Public Health, 101(5):784-785
7. Urbina I. (2011 March 3). Pressure Limits Efforts to Police Drilling for Gas. The New York Times. Web. Retrieved from http://www.nytimes.com/2011/03/04/us/04gas.html?pagewanted=all&_r=0
8. Jackson R.B. et al. (2013). Proceedings Of The National Academy Of Sciences Of The United States Of America, 110(28):11250-11255
9. Kassotis C.D., et al. (2013). Endocrinology. Early Release. doi: 10.1210/en.2013-1697
10. Fleming P. (2013, May). New Study: Hydraulic Fracturing Faces Growing Competition for Water Supplies in Water-Stressed Regions. Ceres. Retrieved from http://www.ceres.org/press/press-releases/new-study-hydraulic-fracturing-faces-growing-competition-for-water-supplies-in-water-stressed-regions
11. Weinhold B. (2012). Environmental Health Perspectives, 120(7):272-279
12. US Geological Survey. (2013). A hydraulic fracturing operation at a Marcellus Shale well. [Photograph]. Retrieved from Wikimedia Commons. Public Domain.
13. US Geological Survey. (2012). Map of Assessed Shale Gas in the United States, 2012. Retrieved from Wikimedia Commons. Public Domain.
14. U.S. Environmental Protection Agency. (2012). Illustration of hydraulic fracturing and related activities. Retrieved from Wikimedia Commons. Public Domain.
15. Jackson R.B. et al. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. Proceedings Of The National Academy Of Sciences Of The United States Of America, 110(28):11250-11255. © 2013 National Academy of Science, USA.

3.4 The Lingering Effects of the Chernobyl Disaster

Jace A. Ball

The meltdown at the Chernobyl nuclear power plant is one of the worst environmental disasters to befall humanity. The disaster negatively altered animal, plant and human life in the area. However one species, the grey wolf, is now thriving in the remains of the Chernobyl site.

Figure 1. Today, Reactor #4 of the Chernobyl Nuclear Power Plant is encased in a sarcophagus to help contain radioactive material.
Photograph by Tiia Monto, 2013. CC BY-SA 3.0.

On April 26, 1986, Chernobyl Nuclear Power Plant's fourth reactor exploded during a mandatory test, releasing large amounts of radioactive material into the atmosphere (Figure 1). An unexpected power surge led to a "break in one of the reactors, causing air to reach the graphite moderator, resulting in the ignition of the entire reactor".[1] This resulted in a radioactive jet emission of Iodine-131, followed by Cesium-137.[2] Most of the fallout occurred in what was at the time the western edge of the USSR and central Europe (Figure 2). The amount of radiation released during the Chernobyl meltdown was "100 times as much radiation as the Hiroshima and Nagasaki atomic bombs together".[3] This new radioactive area was subsequently referred to as "the zone".

Figure 2. Radioactive fallout was carried by the prevailing winds into Belarus and Russia. This map describes the level of Cesium-137 radioactivity as of 2006.
Courtesy of CIA Factbook, 1996. CC BY-SA 2.5.

One effect of the fallout was how it affected the plant and animal life in the surrounding area. Without animals to pollinate flowers and disperse seeds through fruit consumption, plant communities suffer. A study conducted in 2012 examined which pollinating butterflies and bumblebees were dispersed throughout the vicinity of Chernobyl.[4] The study compared radiation with pollinator abundance in the ecosystem and findings suggest that in areas with greater amounts of radiation, fruit trees (i.e. apple, pear, rowan, wild rose, and European cranberry bush) produced less fruits.[4] It was also observed that the trees located in areas with higher radiation were significantly smaller than those in areas with lesser radiation.[4]

Another study introduced mice into the environment for varied time periods.[5] The study found, that at the cellular level, these mice had mutations and disorders caused from the lingering radiation.[5] The mice also had an increase in their radiosensitivty.[5] The Chernobyl disaster occurred nearly 25 years prior to this study. The effects of nuclear radiation on plant and animal life are troubling especially considering these effects will continue to be observed for thousands of years.

One of the most mysterious and unexplained aftermaths of the Chernobyl disaster was the increase in the amount of grey wolves living in and around "the zone". Speculation arose that the leftover radioactive material was poisoning the nearly 300 wolves as well as other wildlife species living in the area. In the Public Broadcasting Service's (PBS) documentary, "Radioactive Wolves" (2011), two German scientists studied moose bones that remained after wolf predation. On average, the bones that were examined contained fifty times the normal amount of radioactive material.[6] This finding suggests that the radioactive remains of the Chernobyl reactor meltdown were poisoning the grey wolves' diets. The scientists were concerned and continued trapping wolves for study, searching for more information. After months of research, the scientists discovered that the wolves were healthy and prosperous.[6] One explanation of this phenomenon could be that as more wolf cubs were born into "the zone," they became better adapted to the radioactive material.[6]

Figure 3. Research conducted on the Eurasian Wolf (Canis lupus lupus) around Chernobyl has found that the population is thriving despite living with high levels of radiation.
Photograph by Gunnar Ries, 2007. CC BY-SA 2.5.

Humans were also greatly affected by the Chernobyl incident. In one study, "researchers have described isolated peaks in the prevalence of congenital malformations in the cohort conceived immediately after the onset of fallout".[7] Researchers discovered that many babies born within 9 months of the incident experienced birth defects (Figure 4).[7] The most affected demographic were young children due to their mothers being exposed to the radioactive material from the nuclear power plant during pregnancy.[8] One of the most common conditions that appeared was thyroid cancer (Figure 5). Psychological problems were also prevalent in displaced people (Figure 4).[9] Stress was one of these psychological problems and led to increased rates of suicide, alcoholism, and smoking.[9]

Cause	Condition	Morbidity (Incidence of Disease)	Mortality (Incidence of Death)
Whole body irradiation	Acute radiation sickness Delayed consequences (i.e. myleodysplasia)	134 ?	28 3-11
Fallout	Thyroid Cancer Other Cancers	~2000 in those exposed as children No evidence of significant increase; needs more study	10-20 ?
Fear, Social Consequences (i.e. job loss, forced relocation)	Environmental Stress Disorder	Uncertain, but large	Contributing factor to mortality though increased rates of harmful coping mechanisms (i.e. smoking & alcoholism)

Figure 4. Health Consequences of the Chernobyl Accident in the first 15 Years.
Data adapted from D. Williams, 2002.

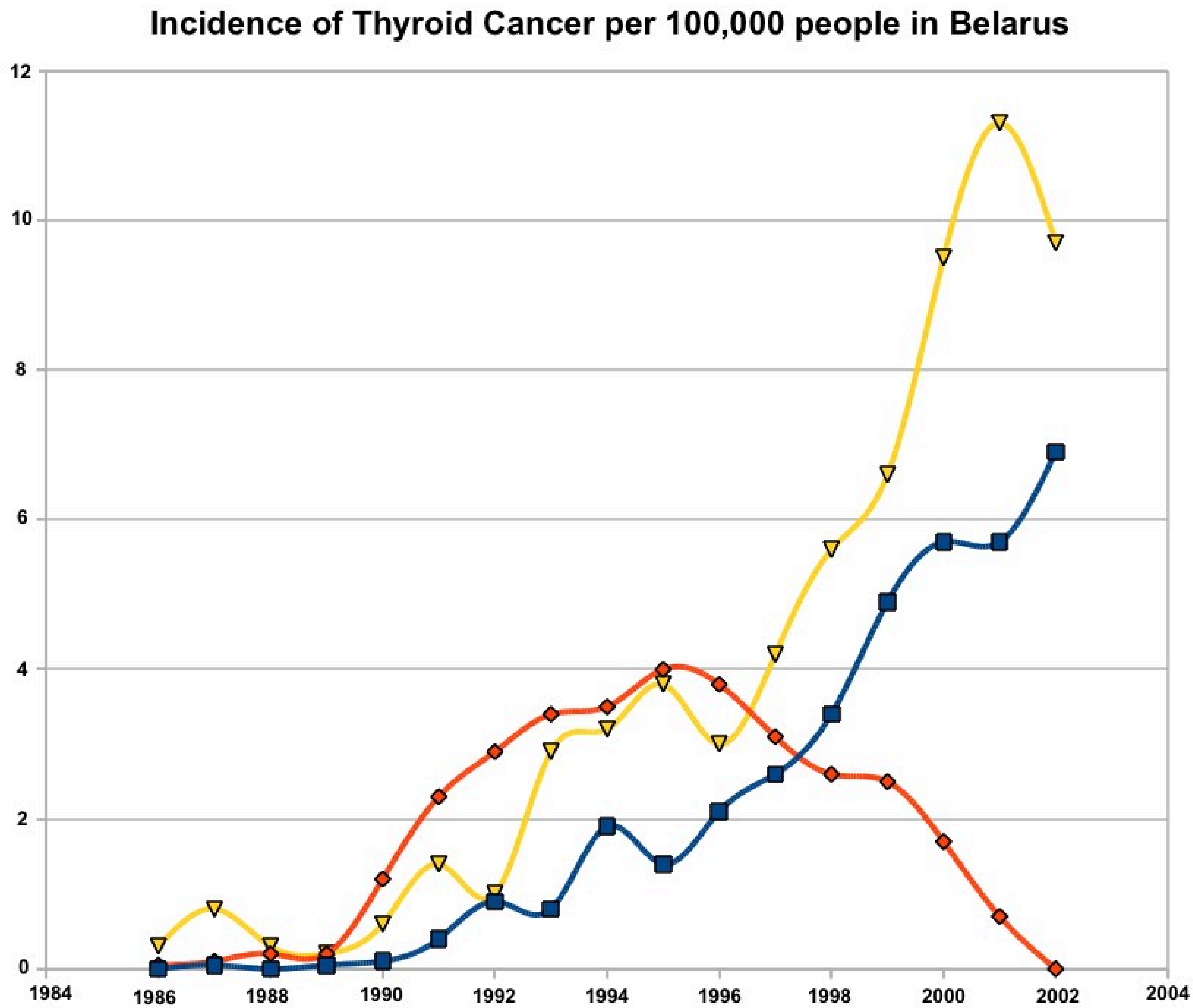


Figure 5. Incidence of Thyroid Cancer in Belarus after the Chernobyl Disaster.
After the Chernobyl Nuclear Disaster, rates of thyroid cancer increased within exposed communities.
Yellow: Adults (19–34),
Blue: Adolescents (15–18),
Red: Children (0–14)
Courtesy of Ceiocaciaca. Public Domain.

The city of Pripyat prior to the reactor explosion was home to 49,400 people. The levels of radiation were so high in the area surrounding the power plant that it became completely unlivable. Within a few days the entire population was forced to relocate.[10] Pripyat is now a ghost town. People still cannot live near Chernobyl and will not be able to settle the area for hundreds of years.

In conclusion, the Chernobyl disaster altered the lives of many different animals, plants, and humans living in the area. Although, some animals in the area are thriving, primarily the grey wolf, the delicate balance of the ecosystem will forever be marred by the radioactive material. The disaster serves as a grim reminder of the terrible effects that radiation can have on human populations. May the abandoned city of Pripyat always serve as a reminder of the consequences of a nuclear disaster.

References

1. Scherman. (2010) Chernobyl Nuclear Power Plant Explosion. Web.
2. Milhaud, G. (1991). The Lesson of the Chernobyl Disaster. Biomedicine & Pharmacotherapy. 45.6:219-220.
3. Dallas, C.E. (2012). Medical Lessons Learned from Chernobyl Relative to Nuclear Detonations and Failed Nuclear Reactors. Disaster Medicine, 6,4:330-334.
4. Moller, Barnier, Mousseau. (2012). Ecosystems Effects 25 Years After Chernobyl: Pollinators, Fruit Set and Recruitment. Oecoiogia, 170,4:1155-1165.
5. Pelevina, I.I. et al. (2011). The Molecular and Cellular Consequences of the Chernobyl Accident. Biophysics, 56.3:577-583.
6. Feichtenberger, Klaus. (Director). (2011). Radioactive Wolves. [Media]. USA: Public Broadcasting Service Nature.
7. Hoffmann, W. (2001). Fallout from the Chernobyl Nuclear Disaster and Congenital Malformations in Europe. Archives of Environmental Health. 56.6.
8. Gnepp. (1994). Pediatric Thyroid Ancer after Chernoybl Disaster. Oxford Journals. 74.2:748-766.
9. Williams, D. (2002). Health Consequences of the Chernobyl Accident in the First 15 Years. Nature Reviews Cancer. 2:543-549.
10. Marples, D.R. (1987). The Chernobyl Disaster. Current History. 86.522.
11. Monto, Tiia. (2013). [Photograph of Reactor 4 in Chernobyl Nuclear Power Plant in Ukraine]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
12. CIA Factbook. (1996). Chernobyl radiation map from CIA handbook. Retrieved from Wikimedia Commons. CC BY-SA 2.5.
13. Ries, Gunnar. (2007). European Wolves, Canis lupus lupus [Photograph]. Retrieved from Wikimedia Commons. CC BY-SA 2.5.
14. Ceiocaciaca. [Graph of Thyroid Cancer Incidence in Belarus after Chernobyl Nuclear Disaster]. Retrieved from Wikimedia Commons. Public Domain.

3.5 Ogallala Aquifer & Nebraskan SandHills Potentially Threatened by the Keystone XL Pipeline

Lee Seitz

The transcontinental Keystone XL Pipeline has the potential to contaminate a large Nebraskan water supply. What are the available alternatives to the pipeline that could prevent this possible contamination?

Figure 1. The Sandhills of Nebraska are considered their own unique ecoregion. The region is characterized by a mixed-grass prairie on grass-stabilized sand dunes.
Photograph from Ammodramus, 2010. Public Domain.

The United States' addiction to oil methodically follows a narrow-minded and myopic focus in the pursuit of the most advantageous route to obtaining "black gold". The environment and national security are often victims in the procurement of oil by the United States. The Keystone XL Pipeline has great potential to be another chapter in oil production's detrimental relationship toward nature. If completed, the pipeline will stretch 2,735 kilometers (1,700 miles) from the Tar Sands in Alberta, Canada to refineries in Houston, Texas.[1] Some proposals for completing the pipeline put it directly over an important and fragile aquifer in Nebraska. This aquifer provides water for a large portion of the agriculturally rich Midwestern state.[2] Routing the pipeline over the Nebraskan aquifer would endanger the water supply through its construction over the shallow groundwater and potential for oil leakage. In 2013, Nebraska Governor, Dave Heineman, approved a reroute around the aquifer that was proposed by the pipeline developer TransCanada.[3] Searching for energy alternatives to oil is important for the survival of both the Ogallala Aquifer and a myriad of other vulnerable regions.

The expanse of the Ogallala Aquifer in Nebraska is contained within a greater water table called the High Plains Aquifer. The High Plains Aquifer stretches into Kansas, Oklahoma, Texas and small parts of South Dakota, Wyoming, Colorado, and New Mexico (Figure 2). The Ogallala Aquifer is named for resting atop of the Ogallala Formation of the Miocene Age, which is considered the principal geological unit of the aquifer. The Ogallala Formation consists of a heterogeneous sequence of clay, silt, sand, and gravel.[4] Because this aquifer is located within the larger High Plains Aquifer, the possibility of contamination is especially significant. Additionally, depletion of the water level in the Ogallala Aquifer will increase the concentration of contaminants in the water table.[12] The Nebraska portion of the Ogallala Aquifer represents an important "hydrologic unit" within the greater aquifer and contains some of the aquifer's highest saturation levels.[4] Covering 27 percent of the irrigated land in the U.S., the High Plains Aquifer provides 30 percent of the nation's ground water used for irrigation while also supplying drinking water to 82 percent of people living within the aquifer's boundary.[2] Furthermore, the Nebraska Quaternary Deposits, the valley-fill alluvium, and the Ogallala Formation comprise the most widely used hydrogeological units in the aquifer, as measured by water use and percentage of irrigation area.[4] Considering the expanse and use of this aquifer, any contamination would have a negative influence on not only the surrounding area but also the section of aquifer that rests atop of the Ogallala Formation, with the potential to compromise the greater High Plains Aquifer.

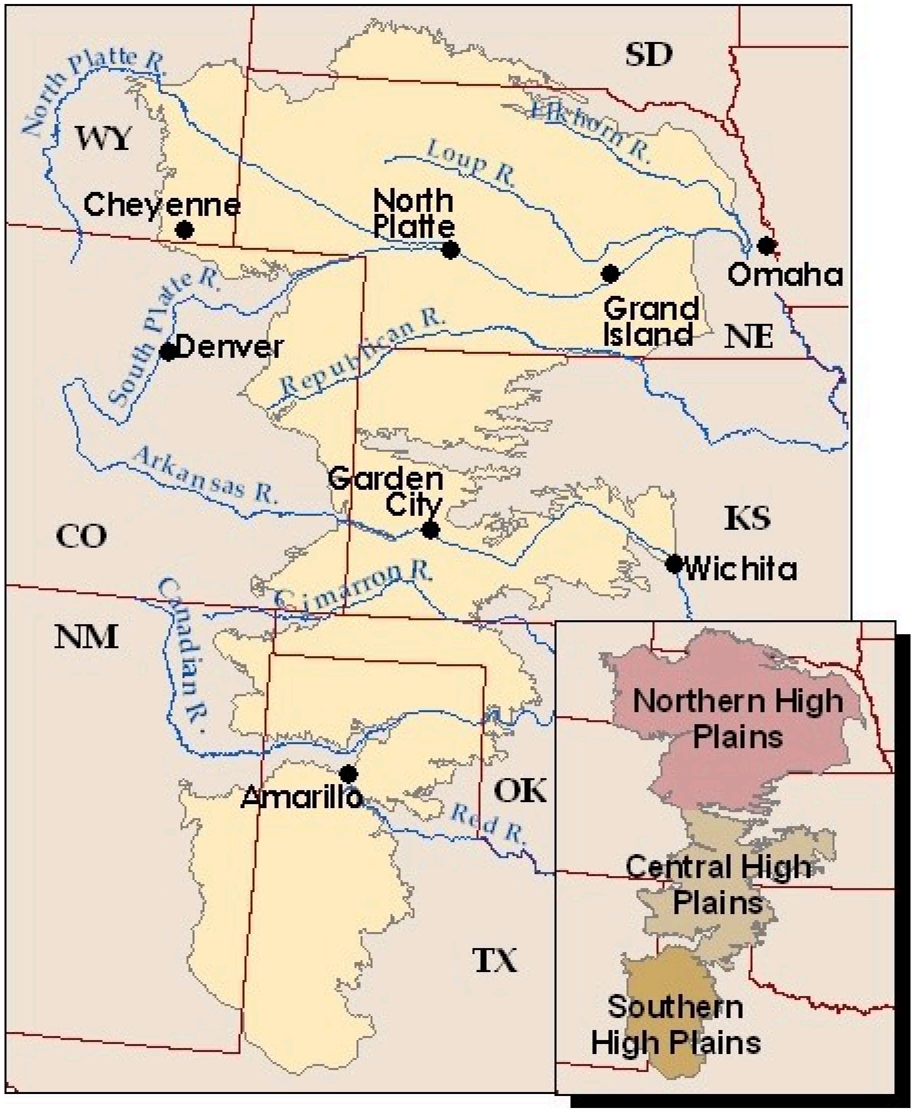


Figure 2. The High Plains Aquifer underlies eight states and provides irrigation and drinking water for millions of people.
Courtesy of K. F. Dennehy, 2013.

The premise of an underground pipeline sounds containable and controllable against negative effects to the environment. However, two main problems arise when considering to build the pipeline over the Ogallala Aquifer: 1) construction of the pipeline could harm the aquifer, and 2) once the pipeline is completed, possible leakage creates an environmental concern. These problems are amplified in this region because of the Ogallala Aquifer and the Sandhills region of Nebraska, which is the region above the aquifer. The Sandhills region atop the Ogallala Aquifer is aptly named. Consisting of mainly coarse sand and gravel, the region's soil composition is incredibly porous and acts as a giant sponge that quickly absorbs precipitation, which helps to recharge the Ogallala Aquifer.[7] Soil composed of mainly sand and gravel is very fragile, and pipeline construction would disturb this sensitive, highly vulnerable, and agriculturally undeveloped land.[5] Grassland covering 95% of the Sandhills region protect the area from wind erosion.[7]

The Tar Sands oil transported by the Keystone XL Pipeline makes potential leakage a grave concern for the Ogallala Aquifer and the Sandhills region. Tar Sands oil is more corrosive than standard oil which makes the Keystone XL pipeline more likely to rupture due to pipeline corrosion.[6] Pipe cracking occurs from a combination of stress and corrosion.[10] Pipeline failure will typically occur by a stress-oriented, hydrogen-induced cracking mechanism.[11] Leakage into the aquifer is particularly troubling because oil will seep through the porous Sandhills Region as easily as rainwater.[7]

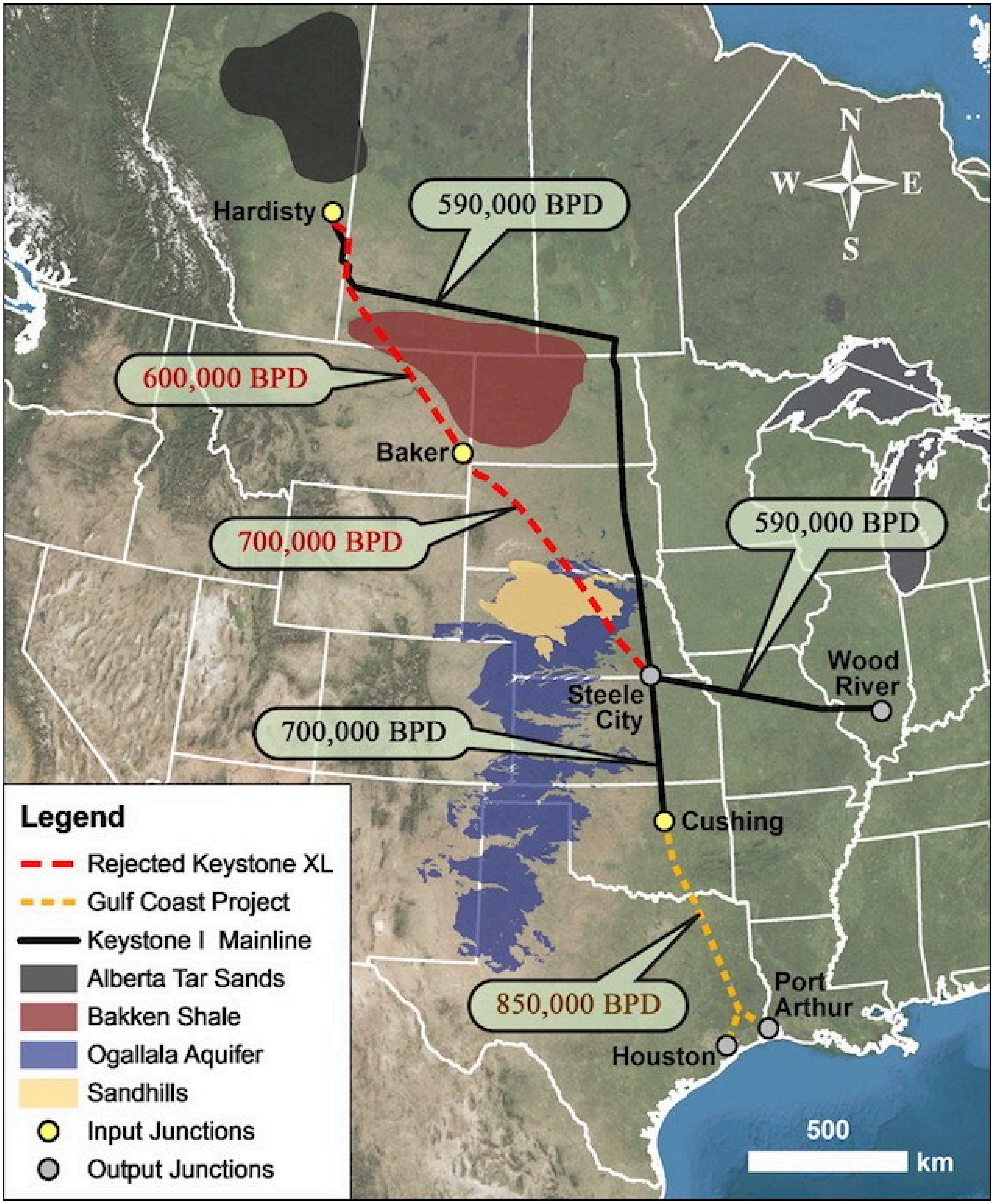


Figure 3a. Proposed Routes for the Keystone XL Pipeline
Estimated throughput volumes in Barrels Per Day (BPD).
Used by permission from R. F. Spalding and A. J. Hirsh, 2012.

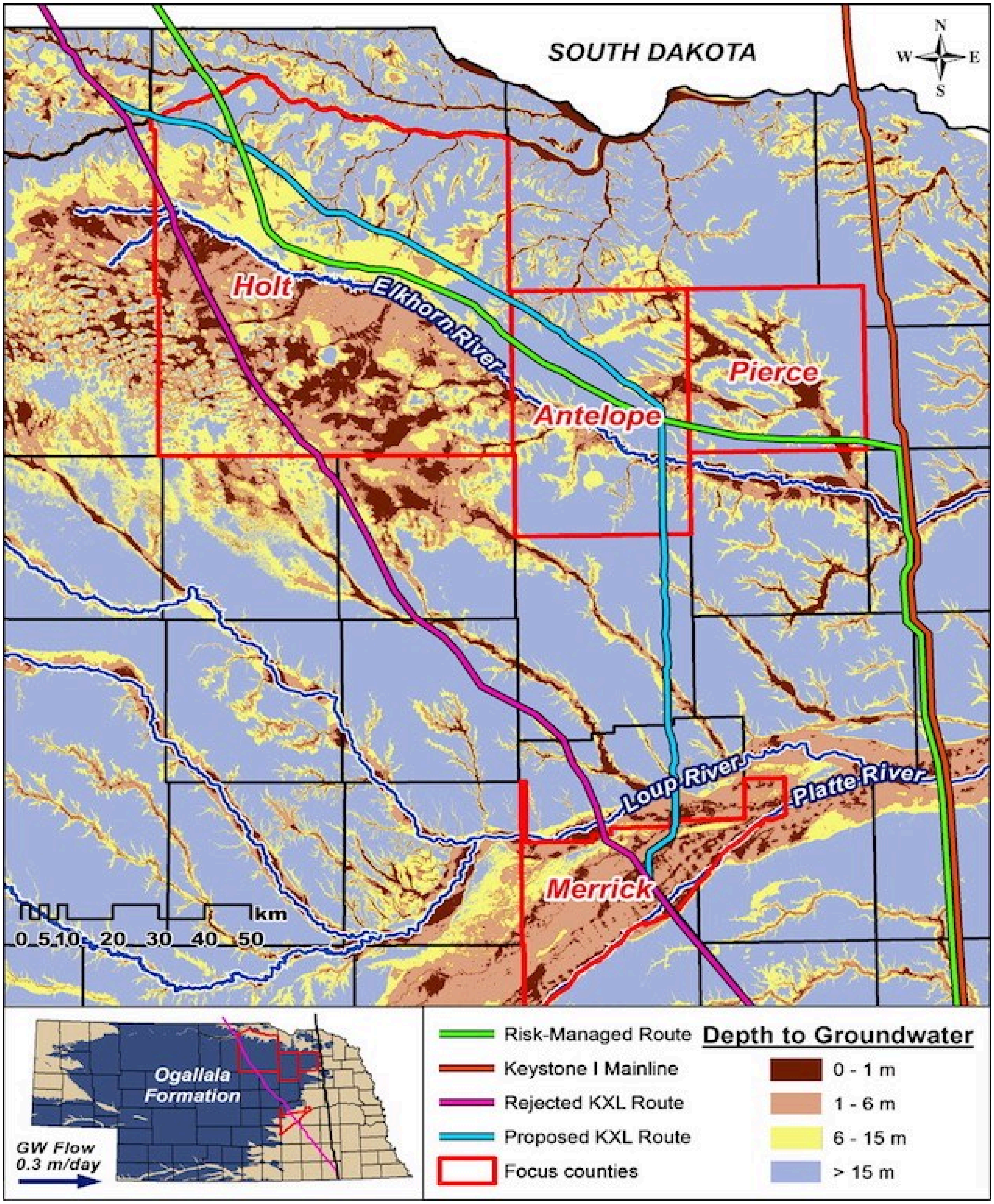


Figure 3b. Proposed pipeline routes overlaying the depth to groundwater . The closer the groundwater is to the surface, the more potential there is for contamination.
Used by permission from R. F. Spalding and A. J. Hirsh, 2012.

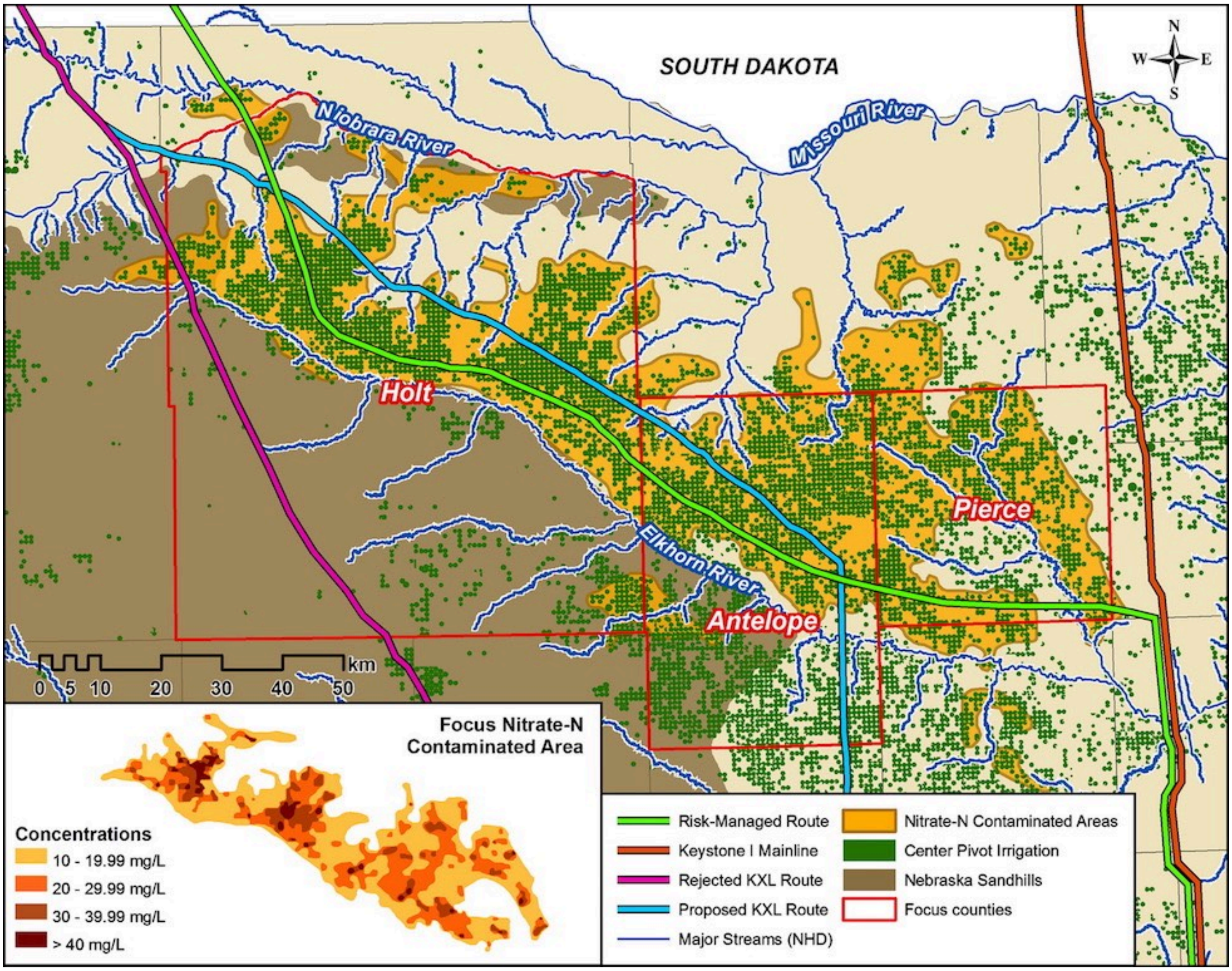


Figure 3c. Agricultural activity often contaminates groundwater with nutrients, pesticides, and petroleum. Some argue that the Keystone XL Pipeline should pass through areas that have already been negatively impacted. Used by permission from R. F. Spalding and A. J. Hirsh, 2012.

Advancements in renewable energy technology have the ability to eliminate the need for a transcontinental pipeline and can significantly reduce the U.S.'s dependence on oil. However, advancement of renewable energy is a gradual process and the economic pressure to transport Canadian oil to market is immediate. The next most popular alternative to the Keystone XL Pipeline is the use of rail transport (Figure 4). While the current pipeline proposal through the U.S. faces innumerable permitting obstacles, a pipeline that traverses either the east or west coat ofCanada would have similar permitting difficulties. Conversely, rail transport provides a quicker solution than the pipeline because rail does not require the same permits. Rail transport alternatives do have drawbacks. Transporting a barrel of oil would cost $15-$20 by rail, whereas pipeline transport costs only $7-$11 per barrel.[8] Profit margins still exist for the oil companies because they are currently ordering train cars and constructing train terminals as a secondary option to the pipeline. Gary Doer, the Canadian ambassador to the US, stated quite bluntly that "oil is going to get to market,"[8] either through a pipeline or by rail. Oil will be transported from Canada, North Dakota, and Montana to southern refineries. Transport via rail also negatively impacts the environment. Capitalist markets have put a high price on oil; and until other viable alternative energy sources exist, oil will be a powerful and environmentally damaging commodity.

Figure 4. An alternative to constructing the Keystone XL Pipeline would be to transport oil by freight train. Photograph by Anonymous, 2010. Public Domain.

The most feasible alternative is to reroute the pipeline around the Ogallala Aquifer and Sandhills region. One reroute proposal is called the "Risked-Managed Route (RMR)." This route "avoids the sensitive, highly vulnerable, and agriculturally undeveloped land" (Figure 3).[5] With the possibility of oil leakage the primary concern, the RMR traverses more agriculturally developed land. In more agriculturally developed land, the pipeline will be more accessible to vehicles for construction. Furthermore, the soil and irrigation wells in this agriculturally developed land have a history of spray irrigation. Oil is designed to drip down the pump shaft of irrigation wells to increase lubrication, but not all of this oil is caught by the well screen, and subsequently some oil leaks into the aquifer. The wells' previous acclimation to oil has likely promoted the evolution of local bacteria to degrade the harmful property of petroleum hydrocarbons (PHC).[5] In January 2013, Nebraska Governor, Dave Heineman, approved a route similar to the RMR proposal. The governor had previously advised President Obama and Secretary of State Clinton to reject the originally proposed route in the interests of the Nebraska Sandhills region and Ogallala Aquifer.[9] Nebraska has faced passionate debate over the pipeline's environmental impact, and proponents of the pipeline view approval in Nebraska as a major advancement toward the completion of the pipeline.

Figure 5. Those concerned with the negative environmental effects of the Keystone XL Pipeline protest outside the Whitehouse in Washington, D.C.
Photograph by Josh Lopez, 2011. CC BY 2.0.

Nebraska's Ogallala Aquifer and Sandhills region are an integral part of the Midwest ecosystem. The soil composition of the Sandhills region enables it to supply water to the Ogallala Aquifer. Conversely, the benefits of quicker and more constant transport of oil through a pipeline are beneficial for national security by means of U.S. liberation from foreign oil. The reroute of the pipeline allows for the preservation of the Sandhills region and Ogallala Aquifer while also allowing for the transport of oil. This may be a necessary compromise between the competing interests of oil companies and environmental interests. Unfortunately, there will be pervasive environmental concerns regardless of the Keystone XL Pipeline's final route.

References

1. Bearden, T. (10 October 2011). Keystone Oil Pipeline Project Divides Nebraska Residents. PBS.org. Online. http://www.pbs.org/newshour/rundown/keystone-xl-pipeline-divides-nebraska-residents/
2. Dennehy, K.F. (2013). High Plains Regional Ground-Water Study. USGS Fact Sheet: 091-00
3. Schulte, G. (23 January 2013). Nebraska governor OKs rerouted Keystone XL pipeline. Denver Post. Online. http://www.denverpost.com/ci_22428969/nebraska-governor-oks-rerouted-keystone-xl-pipeline
4. Dennehy, K.H., et al. (2002). The High Plains Aquifer, USA: groundwater development and sustainability, Geological Society, London, Special Publications, v.193
5. Spalding R.F., & Hirsh, A.J. (2012). Risk-Managed Approach for Routing Petroleum Pipelines: Keystone XL Pipeline, Nebraska. Environmental Science Technology, 46:12754–12758
6. Mark, J. (26 June 2012). Victory in the Pipeline. The Progressive. Pages 26-29.
7. Parfomak, P.W., et al. (2013). Keystone XL pipeline project: Key issues. Washington, DC: Congressional Research Service.
8. Mufson, S. & Eilperin, J. (2 March 2013). Rail Emerges as Alternative to Keystone Pipeline for Moving Canadian Oil. The Washington Post. Online. http://www.washingtonpost.com.proxy.lib.ohio-state.edu/
9. Broder, J.M. (2013 Jan. 13). Governor of Nebraska Backs Route for Pipeline. New York Times. Online. http://www.nytimes.com/2013/01/23/science/earth/keystone-pipeline-route-approved-by-nebraska-governor.html?_r=0
10. Hasan, F., et al. (2006). Stress Corrosion failure of high-pressure gas pipeline. Science Direct. Engineering Failure Analysis 14 (2007) 801-809.
11. Azevedo, C (2007). Failure analysis of a crude oil pipeline. Science Direct. Engineering Analysis 14 (2007) 978-994
12. Edwards, J., et al. (2012). Building a Simple Genernal Model of Municipal Water Conservation Policy for Communities Overlying the Ogallala Aquifer. HeinOnline. 52 Natural Resources Journal, 135.
13. Bureau of Oceans and International Environmental and Scientific Affairs (January 2014). Final Supplemental Environmental Impact Statement for the Keystone XL Project Executive Summary. U.S. Department of State.
14. Ammodramus. (2010). Nebraska Sandhills in Hooker County, Nebraska, seen from Nebraska Highway 97 south of the Dismal River [Photograph]. Retrieved from Wikimedia Commons. Public Domain.
15. Anonymous. (2010). Union Pacific Railroad's Overland Route in Hershey, Nebraska. Retrieved from Wikimedia Commons. Public Domain.
16. Lopez, Josh. (2011). Keystone XL Demonstration. [Photograph]. Retrieved from WikiCommons. CC BY 2.0.

POLLUTION

epSos.de, 2011. CC BY 2.0.

4.1 The Burning River- Aquatic Pollution in America's Rust Belt

Benjamin W. Schumann

The former center of heavy industry in the United States, the Rust Belt, continues struggle with the effects of pollution. Negligent regulations on the waste produced by factories and non-point source pollution from agricultural field runoff have had dramatic effects on the surrounding environment. The fire on Cleveland's Cuyahoga River was the culminating event that helped shape environmental protection in the United States.

Figure 1. Cleveland's Cuyahoga River has reportedly caught on fire over a dozen times. One of the largest fires, pictured here occurred in 1952.
Photograph by James Thomas, 1952. Public Domain.

Cleveland, Ohio was once one of the premier manufacturing and industrial centers in United States. Cleveland, one of the largest U.S. cities, is located on the southern coast of Lake Erie and divided by the Cuyahoga River (Figure 2). The city has been affected by substantial amounts of airborne and aquatic pollution, mostly created by factory production during the 20th century.[1] The externalities of factories in Cleveland are not the sole contributors to this pollution. Pesticides from agricultural runoff and waste from sewers were also major sources of pollutants.[2] Lake Erie began to experience eutrophication, which increased algae content and decreased available oxygen for other aquatic life.[2] The pollution of northeastern Ohio waterways culminated with the Cuyahoga River catching fire in 1969[2] (Figure 1). This event brought national attention to the lack of environmental responsibility in the industrial Midwest. As a result, groups such as the U.S. Environmental Protection Agency were formed to control the situation. This "burning river" phenomenon has helped inform both the public and researchers on the effects of runoff pollution and waste accumulation. However, pollution of aquatic ecosystems continues to be a major threat in the Rust Belt.

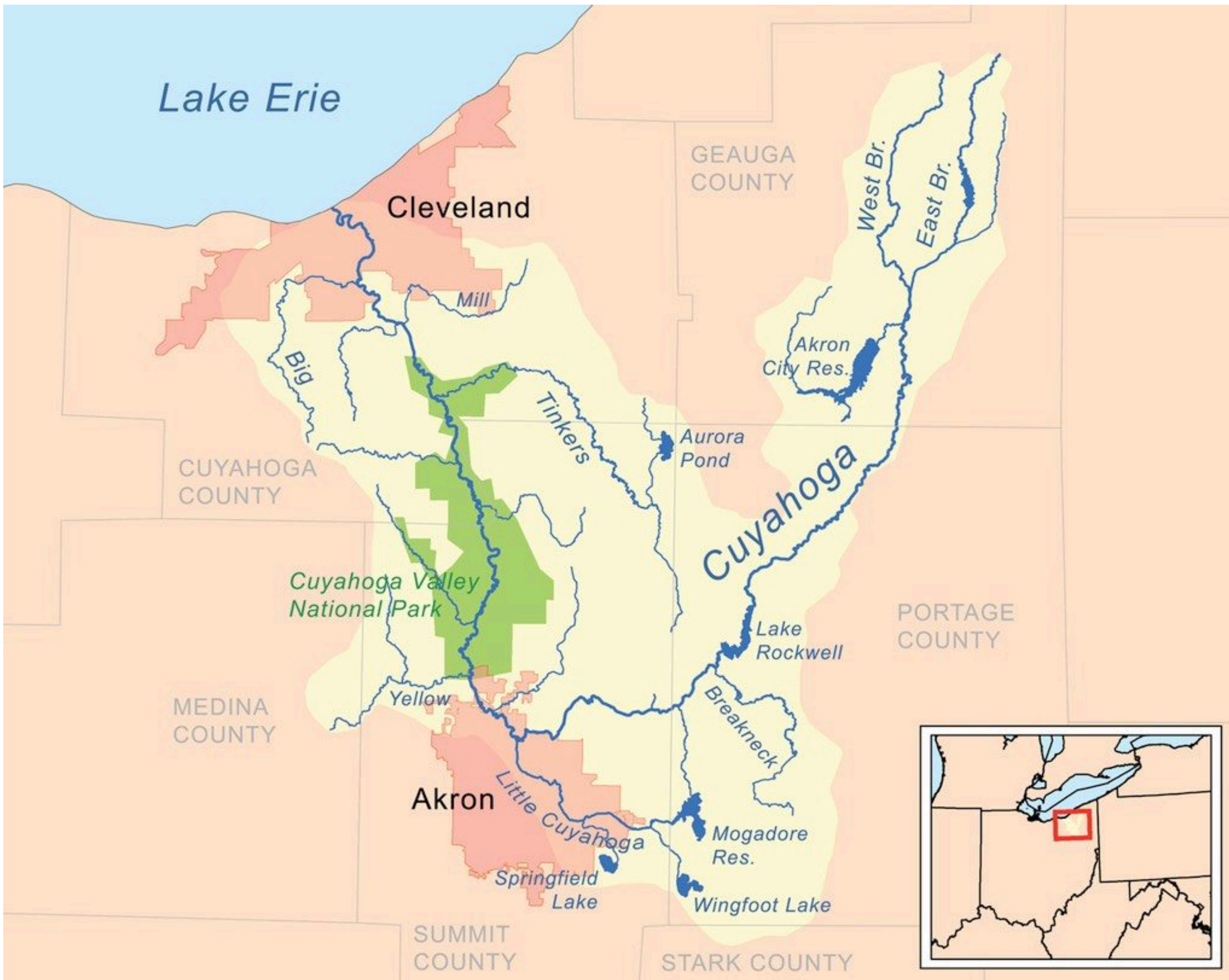


Figure 2. The Cuyahoga River Watershed is located in northeast Ohio and flows through Cleveland into Lake Erie Courtesy of Kmusser, 2011. CC BY-SA 3.0.

It is clear that anthropogenic activity has changed the water quality of Lake Erie and the Cuyahoga River.[1] Human activity has led to eutrophication in the Great Lakes since the mid-20th century.

Pharmaceutical runoff in Lake Michigan from fellow industrial powerhouse cities such as Milwaukee, Wisconsin and Chicago, Illinois, continue to put water quality at risk throughout the American Midwest.[3] Studies conclude that the water quality of the Great Lakes, represented by the fecal indicator bacteria (FIB) or coliform bacteria content, continues to be compromised near urban areas such as Cleveland.[4] Similarly, alkylphenol levels, a marker for industrial pollution, remain elevated in the Cuyahoga River's carp population.[5] Water pollutants threaten biodiversity and the quality of drinking water available to nearly 30,000,000 Americans and a large portion of Canadians.[6]

The Great Lakes are still suffering from environmental irresponsibility. Fortunately, there is evidence that controls on phosphate use and disposal have helped Rust Belt waters to partially recover.[1]

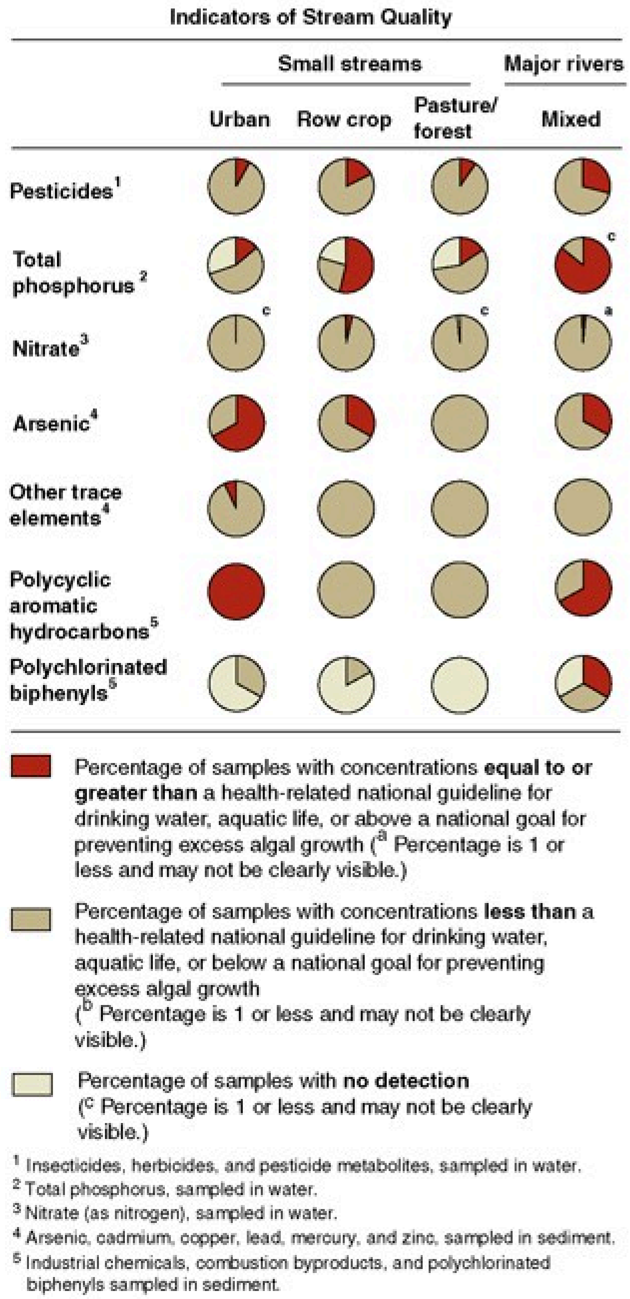


Figure 3. By testing for the presence of various indicators, researchers can better understand the source of water pollution. Data taken from the Erie Watershed (1996-1998). *Courtesy D. N. Myers et al.*, 2000. *Public Domain.*

Public awareness over the misuse of America's waterways has created outrage among many citizens. Consequently, policies have been adjusted to set controls on heavy manufacturing and refineries. For instance, the Clean Water Act of 1972 was passed to maintain and improve the condition of U.S. waterways.[2,6] Unfortunately, there is an exception in this policy that allows companies to violate this provision if they can prove increased pollution creates a significant economic or social benefit.[6] The Clean Water Act offers little protection against the contamination of aquifers, which is increasing relevant with the emergence of fracking, a technique for retrieving natural gases prevalent in some Rust Belt states.[7] In 2007, one deposit of flame retardant-substances accounted for 37% of all wet deposition loadings in the 2000s, further demonstrating the inadequacies of the Clean Water Act.[8]

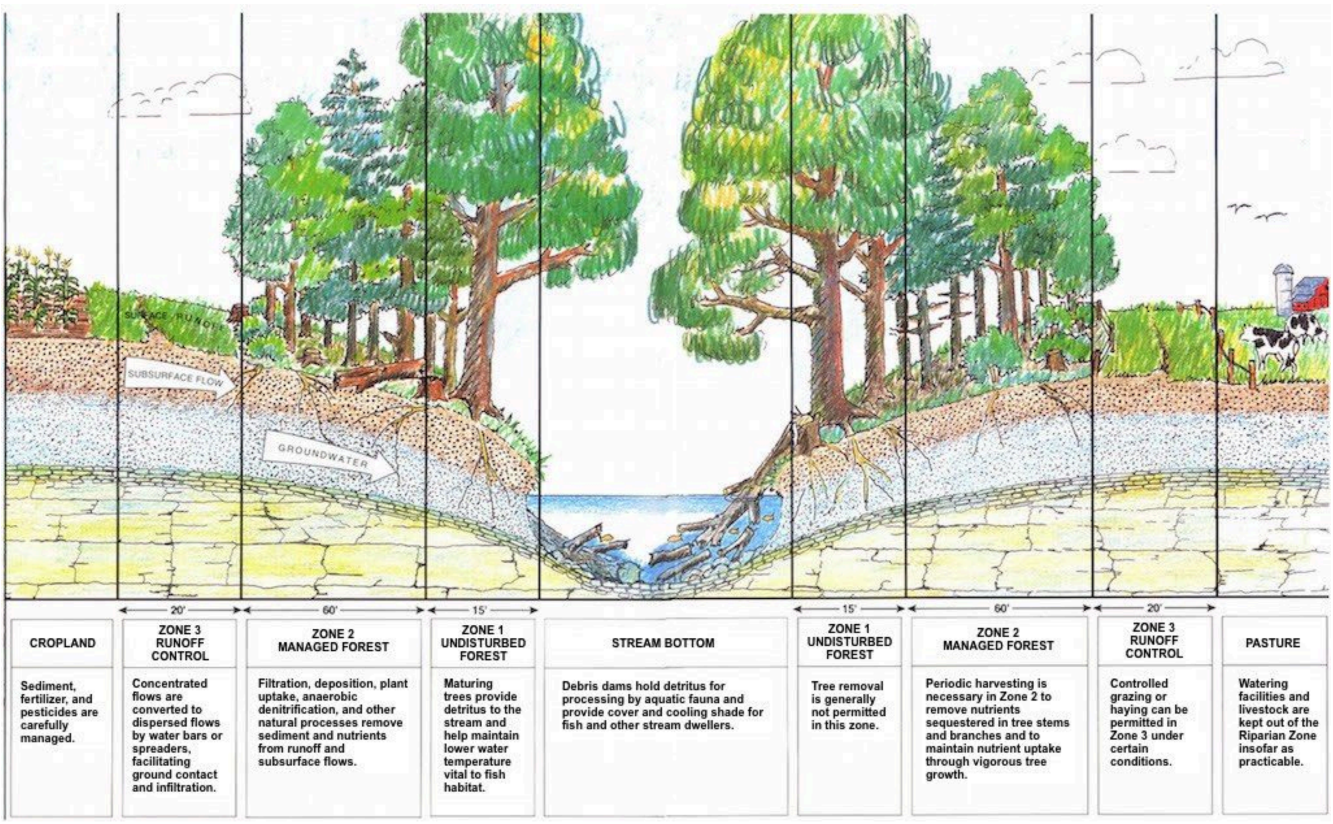


Figure 4. Riparian areas protect water quality and provide habitat for wildlife. However, they also take land out of agricultural production, reducing yields for farmers.
Courtesy of D. J. Welsch, 1991. Public Domain.

In spite of these lapses, the establishment of the Clean Water Act and the Environmental Protection Agency has helped correct many water quality impairments.[1] However, many of these policies have become outdated and must be revamped to address the growing diversity of water quality problems.

Agriculture is a major part of Ohio's economy, however agricultural fertilizer use contributes to the majority of runoff pollution in the state. One possible solution to curb runoff pollution is the creation of riparian areas (Figure 4). Riparian areas consist of trees or other obstacles that serve as buffers between agricultural fields and water bodies. These buffers help prevent chemicals from entering the water system. One problem with riparian areas is that they occupy precious farmland, which makes any farm that installs these environmentally conscious runoff controls, a less competitive business. In addition, since agricultural field runoff is considered to be non-point source pollution, accountability remains an issue. Lake Erie is also warm and shallow, which creates perfect conditions for eutrophication (Figure 5). Phosphorus levels in the Great Lakes have decreased since the passage of the Clean Water Act, but large outbreaks of eutrophication continue to occur in the region.[1,9] Water pollution continues to be a difficult to control problem in the Rust Belt. The United States has made great progress towards increasing environmental oversight in the Rust Belt, however policies must be strictly enforced and revised in order to reestablish a sustainable future for America's waterways.

Figure 5. Toxic Algal Blooms are a result of eutrophication or the enrichment of a water body with nutrients. This 2011 algal bloom in Lake Erie could easily be seen from space.
Photograph by Jesse Allen and Robert Simmon, 2011. Public Domain.

References

1. Allinger, L.E., & Reavie, E.D., (2013). The ecological history of Lake Erie as recorded by the phytoplankton community. Journal of Great Lakes Research 39,3:365-383.
2. Rotman, Michael. Lake Erie. Cleveland Historical. Accessed 14 Jan. 2014 from http://clevelandhistorical.org/items/show/58
3. Blair, B.B., et al., (2013). Pharmaceuticals and personal care products found in the Great Lakes above concentrations of environmental concern. Chemosphere 93:2116- 2123.
4. Haack, S.K., et al., (2013). Geographic Setting Influences Great Lakes Beach Microbiological Water Quality. Environmental Science & Technology 47:12054- 12063.
5. Rice, C.P., et al., (2003). Alkylphenol and Alkylphenol-Ethoxylates in Carp, Water, and Sediment from the Cuyahoga River, Ohio. Environmental Science & Technology, 37:3747-3754.
6. Environmental Protection: Muddy waters. (6 Sep 2007). The Economist. Retrieved from http://www.economist.com/node/9767825?zid=298&ah=0bc99f9da8f185b2964b6cef412227be
7. J.P., (25 Jun 2013). Fracking: Fire water. The Economist. Retrieved from http://www.economist.com/blogs/babbage/2013/06/fracking
8. Robson, M., et al., (2013). Wet deposition of brominated flame retardants to the Great Lakes basin – Status and trends. Environmental Pollution 182:299-306.
9. Borre, Lisa. (24 Apr. 2013). Harmful Algae Blooms Play Lake Erie Again. National Geographic. Retrieved from http://voices.nationalgeographic.com/2013/04/24/harmful-algae-blooms-plague-lake-erie-again/
10. Thomas, James. (1952). [Photograph of the Cuyahoga River on Fire on November 3, 1952]. Retrieved from The Cleveland Press Collection at Cleveland State University Library. Public Domain.
11. Kmusser. (2011). [Map of the Cuyahoga River drainage basin]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
12. Myers, D.N., et al., (2000). Water Quality in the Lake Erie-Lake Saint Clair Drainages Michigan, Ohio, Indiana, New York, and Pennsylvania, 1996–98. U.S. Geological Survey Circular 1203:35. Retrieved from http://pubs.water.usgs.gov/circ1203/. Public Domain.
13. Welsch, DJ. (1991). Riparian Forest Buffer: Function and Design for Protection and Enhancement of Water Resources. USDA Forest Service. Retrieved from http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/part7.htm. Public Domain.
14. Allen, Jesse & Simmon, Robert. (NASA Earth Observatory). (2011). [Photograph of a toxic algal bloom in Lake Erie]. Retrieved from Wikimedia Commons. Public Domain.

4.2 Causes and Consequences of Air Pollution in Beijing, China

Mason F. Ye

Beijing, China suffers from some of the worst air pollution worldwide. What is the source of this air pollution? How has the poor air quality affected the people and the surrounding environment?

Figure 1. A woman in China wears a face mask to protect herself from air pollution. Photograph by Nicolò Lazzati, 2009. CC BY 2.0.

China is notorious for being a major polluter. Its economic growth in the past three decades has been the fastest among major nations, which is the main factor in why China has extensive air pollution. Of the twenty cities with the worst air pollution worldwide, 16 are located in China, including Beijing.[1,2,3] Due to this extensive air pollution, China's Environmental Sustainability Index is ranked near the bottom among countries worldwide.[2]

The causes of Beijing's widespread air pollution can be attributed to a number of factors: an enormous economic boom, a surge in the number of motorized vehicles, population growth, output from manufacturing, and natural reasons which include the city's surrounding topography and seasonal weather. China has also experienced major economic growth with a drastic rise in Gross Domestic Product (GDP). This increase in wealth can be correlated with an increase in pollution.

Figure 2. Google Map of Beijing, China.
Beijing, the capital of China, is located in the northeast corner of the country.
Map data ©2015 Google. Public Domain.

Click Here to Explore Beijing, China in Google Maps

With this amplified wealth, individuals are more capable of affording motor vehicles.[1,4,5,6] The number of motor vehicles on Beijing's roads has doubled to 3.3 million with nearly 1200 added each day. Emissions from motorized vehicles contribute to nearly 70% of the city's air pollution.

The four most dangerous pollutants that are emitted include: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter (e.g. PM10).[3] Newly introduced vehicles have lower emission standards, and thereby emit more of these pollutants into the atmosphere than their older counterparts. Motorized vehicles are only one contributor to air pollution. Population growth in China and Beijing contributes to extensive pollution. Beijing's population has swelled from 11 million to 16 million in just 7 years, and has doubled over the past century.[1,3]

Coal burning factories also contribute to the smog present in Beijing. These factories rely on outdated and inefficient technologies. The factories are located on the outskirts of Beijing and the nearby cities of Harbin and Hebei.[1] Beijing is a victim of its own topography because it is surrounded by mountains, ensuring that pollution remains trapped within the city limits.[5] Air quality worsens in spring and summer when temperature and humidity levels rise, and winds contribute to the smog by carrying pollutants from industrialized southern regions.[3] There are a variety of consequences of air pollution in Beijing. Along with health consequences, high levels of harmful emissions have led to hundreds of flight cancellations and frequent road closures due to low visibility levels.[7] Air pollution has increased substantially over the years, resulting in thick smog that often engulfs the entire city[6] (Figure 3).

Figure 3. These side by side images show the severity of air pollution in Beijing.
(Left) Beijing on a clear day.
(Right) Beijing in February, 2013 from the same view when Beijing was experiencing dangerously poor air quality.
Photograph by Bill Bishop, 2013. CC BY-NC 2.0.

Air pollution is measured by the Air Quality Index (AQI), which scales pollution levels from 0 to 500 and assigns a color to different number levels to measure how hazardous the air quality is on any given day (Figure 4). Levels of 100 or below are known as “Blue Sky Days”, when smog is not easily visible.[3,5,7] However, levels now reach up to 755, as measured by the United States Embassy in Beijing, which employs its own pollution reading device. This is the highest level of air pollution since recording began in 2008, and was appropriately deemed “Beyond Index”. The World Health Organization suggests that scores near 500 contain more than twenty times the safe level of particulate matter in the air.[5]

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	51 to 100	Air quality is acceptable; however, for some people pollutants there may be a moderate health concern for a very small number of people who are usually sensitive to air pollution
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public in not likely to be affected
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious healh effects
Very Unhealthy	201 to 300	Health warnings of emergency conditions. The entire population is more likely to be affected
Hazardous	301 to 500	Health alert: everyone may experience more serious health effects

Figure 4. The Air Quality Index (AQI) is used by the U.S. Environmental Protection Agency to report daily air quality. The AQI value takes the five major air pollutants regulated by the Clean Air Act into consideration (ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide.
Adapted from U.S. Environmental Protection Agency, 2015. Public Domain.

Emissions and contaminants may also be carried across the Pacific Ocean to the Western United States by powerful global winds called Westerlies. Though this pollution is created by Chinese manufacturing and export of goods, it is demand for these goods in the United that fuels production. The United States is ironically causing its own environmental degradation through trade with China.[1,8]

The shorter lifespans of Beijing's citizens has been connected to high pollution levels.[7,8] Compared to citizens living in southern China, the average life span for Beijing's citizens is five to six years shorter. The air pollution in Beijing causes lower birth rates and higher adult mortality from respiratory related diseases. Lung cancer rates have risen over 60% in the past decade, although the smoking rate has not increased.[1]

In 2003, the Chinese Academy for Environmental Planning determined that air pollution was responsible for 411,000 premature deaths across China.[3] The 2008 Olympic Summer Games in Beijing was the catalyst leading to many new policies to address air pollution. Emergency measures were enacted depending on the pollution levels, but the most important factor in curbing air pollution is the implementation of new laws and reformation of old laws. The Olympics were crucial in raising awareness about reform of environmental regulations. Many factories, industries, and manufacturing plants were shut down for the duration of the games and driving restrictions were imposed on millions of vehicles.[1,9] Although this was a temporary solution for the Olympics, city officials promised to spend over $12 billion dollars on improving the environment. City officials converted coal furnaces in tens of thousands of homes to natural gas and relocated factories to other provinces in China.[3]

Emergency measures have also been enacted in Beijing. Mandatory factory closures and bans on motor vehicles entering the city are implemented on days of heavy air pollution. In 2013, the Heavy Air Pollution Contingency Plan was passed.[10] This plan consists of four warning levels based on air pollution levels. Depending on the warning level, different actions are executed, which include school closures, removing 80% of government vehicles from the road, allowing certain private cars on the roads based on registration plate numbers and day of the week, barring freight and construction vehicles from the roads, utilizing watering carts and sprinkler trucks, shutting factories down, halting construction sites, and even forbidding barbecues and fireworks.[10] To most effectively address air pollution would require reform in government laws and behavior.

The State Environmental Protection Administration (SEPA) was established in 1998. The organization has the difficult task of reforming environmental laws that are often ignored by leaders. Another problem of environmental laws is the fines are so minuscule that offending corporations would rather pay the penalty, rather than change their business practices.[1] Openness in reporting true pollution levels by municipal governments would also lend clarity to the condition of air quality.[2] The government only reports AQI numbers up to 500. The Chinese government also prefers to release information only on PM10 particles and not larger PM particles. These larger PM particles may be more dangerous than PM10 particles. The United States Embassy did release such information, but was asked by the Chinese government to limit the release of information to Americans.[7]

Beijing's air pollution affects the health of its citizens and threatens to limit the future success and expansion of the city. Though the contamination is extensive, there are possible solutions which can address the problem. By analyzing the sources of pollution, studying its consequences, and by reforming inadequate regulations and laws, Beijing can salvage its environment and create a healthier atmosphere for future generations.

References

1. Liu, J. & Diamond, J. (2005). China's Environment in a Globalizing World. Nature, 435:1179-1186.
2. Liu. J., & Diamond, J. (2008). Revolutionizing China's Environmental Protection. Science, 319:37-38.
3. Stone, R. (2008). Beijing's Marathon Run to Clean Foul Air Nears Finish Line. Science, 321:636-637.
4. Betts, K. S. (2002). China's Pollution Progress Slows. Environmental Science & Technology, 36,15:308A-309A.
5. Wong, E. (2013, January 13). On Scale of 0 to 500, Beijing's Air Quality Tops 'Crazy Bad' at 755. The New York Times, pp. A16.
6. Wu, Y., et. al. (2010). On-Road Vehicle Emission Control in Beijing: Past, Present, and Future. Environmental Science & Technology, 45,1:147-153
7. Lim, L. (2011, December 07). Clean Air a 'Luxury' in Beijing's Pollution Zone. National Public Radio. Retrieved from http://www.npr.org/
8. Wong, E. (2014, January 21). China is Also an Exporter of Pollution to the Western U.S., Study Finds. The New York Times, pp. A6.
9. Lubick, N. (2008). Will the Dragon Stay Green? China After the Beijing Olympics. Environmental Science & Technology, 42,14:5037-5040.
10. Armstrong, P., & Ke, F. (2013, October 23). Beijing Announces Emergency Measure Amid Fog of Pollution. Cable News Network. Retrieved from http://www.cnn.com/
11. Lazzati, Nicolò. (2009). [Photograph of woman in China wearing a protective face mask]. Retrieved from FlickrCommons. CC BY 2.0.
12. Bishop, Bill. (2013). [Side by side photographs of Beijing, China on a clear day and with severe air pollution]. Retrieved from The Washington Post. CC BY-NC 2.0.
13. United States Environmental Protection Agency. (2015). Air Quality Index (AQI) Basics. Retrieved from http://airnow.gov/index.cfm?action=aqibasics.aqi.

4.3 Proper Management of Phosphorus for Future Food Security

Alyssa M. Zearley

Phosphorus is an important nutrient in fertilizers used in agricultural systems. Excess phosphorus from field runoff, storm water, and wastewater has led to harmful algal blooms in rivers, lakes, and other bodies of water. What are methods to curb phosphorus related pollution? Phosphorus is also quickly becoming a scarce resource worldwide. With an increasing global demand and reserves dwindling, will alternative sources of phosphorus be discovered?

Figure 1. Phosphate mine near Flaming Gorge National Recreation Area, Utah. Photograph by Jason Parker-Burlingham, 2008. CC BY 2.0.

Phosphorous is an essential plant nutrient. Along with nitrogen (N) and potassium (K), phosphorus (P) is one of the three plant macronutrients. Phosphorus is used by plants in seed and fruit production, energy transfer, root growth, and maturation. A deficiency in phosphorus can lead to small fruit, reduced plant growth, and delayed maturity. Phosphorus is also critical for growth and development in animals. Animals use phosphorus in assimilating DNA, development of skeletal tissue, and for energy transferences. Understanding the phosphorus cycle is necessary to see how phosphorus moves through an ecosystem. Inorganic phosphorus is released by rock erosion and plants take up this phosphorus and transform it into organic phosphorus. Animals gain organic phosphorous by consuming plants or other animals. Phosphorus is returned to the soil by animal excretion or decomposition, and then it is either absorbed by plants or leached into waterways (Figure 2). Humans have altered the phosphorus cycle by adding phosphorus for crop production and removing phosphorus through soil management practices, which leads to erosion and leaching. Human manipulation of the phosphorus cycle negatively impacts the environment and future food production by removing phosphorus from ecosystems.

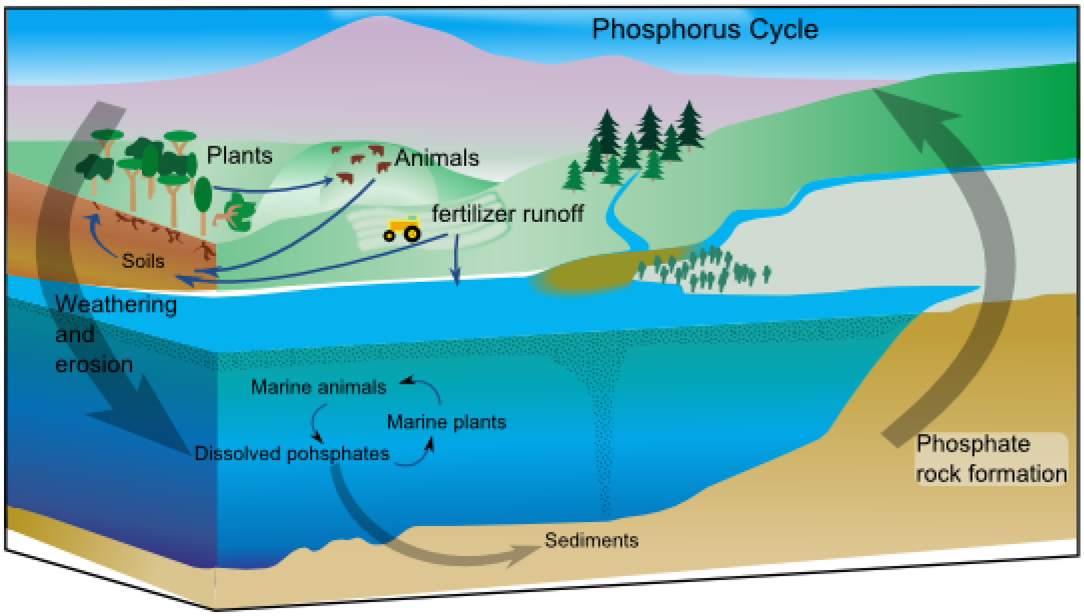


Figure 2. The Phosphorus Cycle.
Courtesy of Bonniemf Incorporates work by NASA Earth Science Enterprise, 2013. CC BY-SA 3.0.

The first phosphorus fertilizer was manure, which has been used to enrich soil since animals were domesticated. Synthetic, inorganic phosphorus fertilizers were introduced in the mid 1800's. As the technology improved, synthetic fertilizers increased crop yields and were less expensive than alternatives. While the application of manure from on-site farm animals did not significantly alter the phosphorus cycle, the addition of synthetic fertilizers increased phosphorus levels in ecosystems. Annual cropping systems result in the majority of the plant being removed after harvest, instead of decomposing and returning nutrients to the soil. However, the largest source of phosphorus loss derives from soil management practices that lead to leaching. Improper manure or fertilizer application, broadcasting fertilizers, no-till production, and erosion can cause phosphorus to leach into runoff, which then enters the waterways.[1,2,3] This excess phosphorus travels from the soil to aquatic ecosystems in which phosphorus is a limiting nutrient. The introduction of phosphorus from synthetic fertilizers, excess manure, and sewage effluent contribute to eutrophication, which triggers algal blooms (Figure 3). Excess phosphorus creates ideal conditions for algae to flourish. Many algae produce toxins that are harmful to both humans and wildlife.[4] Algal blooms also deplete oxygen in waterways and suffocate other organisms in a phenomenon known as hypoxia.[5]

Figure 3. Phosphorus enrichment in waterways leads to algae blooms like this one on the Santa Fe River in Florida.
Photograph by John Moran, 2012. Public Domain.

In addition to the negative effects associated with excess phosphorus, the production of synthetic fertilizers also has adverse environmental impacts. Phosphorus mining is the fifth largest mining industry in the United States, with the largest mines in Florida, North Carolina, Tennessee, and Idaho (Figure 1). There are two processes for extracting phosphorus from ore: the wet-acid process and the thermal process. The wet-acid process creates calcium sulfate as a byproduct, which is known as phosphogypsum. This material has no practical uses and it is stored in enormous stacks which can cover several hectares and be nearly 60 meters high. Phosphate slag is the waste product created from the thermal process, and it can be used in construction, but much of it is also stored in stacks. The production process concentrates the radioactive isotopes naturally found in phosphate ores, and as a result the waste materials often have high concentrations of radium, uranium, and thorium.

Phosphogypsum is a byproduct of the wet-acid method of producing fertilizer from phosphate rock:

Ca5(PO4)3X + 5 H2SO4 + 10 H2O →
3 H3PO4 + 5 CaSO4 · 2 H2O + HX
where X may include OH, F, Cl, or Br

Due to its weak radioactivity, phosphogypsum is considered a waste product and is placed into storage indefinitely.

Phosphorus is a nonrenewable and finite resource, yet the global agricultural industry depends on phosphorus fertilizers to improve crop yields. It has been estimated that 30-50% of yields can be directly attributed to phosphorus fertilizers, and it would take only a small drop in production to cause major problems in the food system.

Phosphorus is becoming less abundant and more expensive as global demand increases. While phosphorus is found throughout the earth's crust, it is not economical to extract it from anything but phosphate rock, which is a considerably rarer resource. Ninety percent of phosphate rock reserves are concentrated in just five countries: Morocco, South Africa, Jordan, China, and the United States.[6] These reserves have been depleted by the extraction of the high quality ores. Increased production costs associated with extraction of inferior ores has caused fertilizer prices to rise. Reserves may become completely exhausted within 50-100 years. Some estimates put peak phosphorus, the point at which production peaks, as early as 2030.[6] Demand for phosphorus and other fertilizers will increase tremendously as the world struggles to feed an increasing population.

To meet the demands of a burgeoning population, the phosphorus cycle will have to be closed. Once phosphorus reaches an ocean, it is essentially lost (Figure 2). It often takes millions of years for phosphorus deposited into ocean sediment to return to the surface.[7] Phosphorus inputs must be decreased, maintained in the soil, and recaptured. Proper manure applications and soil management practices that decrease erosion can lessen the need for synthetic fertilizers. Increasing organic matter in agricultural soils decreases runoff and provides phosphorus to plants. Homeowners can reduce their phosphorus pollution by using products such as lawn fertilizers and detergents that do not contain phosphorus.

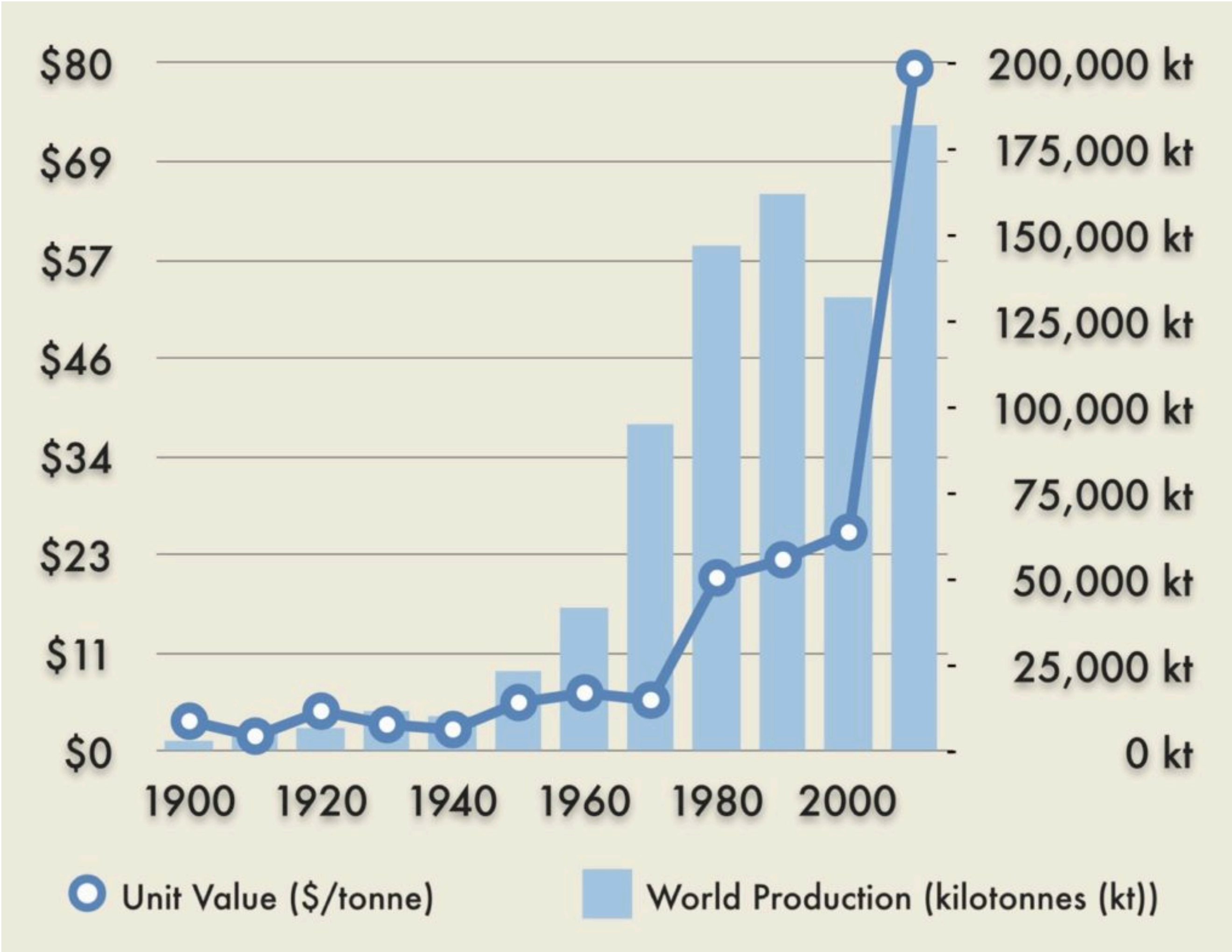


Figure 4. Decadal World Phosphate Rock Production and Unit Value.
Data from U.S. Geological Survey, 2014. Public Domain.

There is ongoing research to discover solutions to the phosphorus problem. Alternative sources of phosphorus, such as animal carcasses, algae grown on animal manure, and sewage sludge have proved to be promising alternatives to phosphate rock.[8,9,10] Utilizing these methods for phosphorus production would also provide alternate solutions for the pollution problems caused by these commonly unusable wastes. Although these research efforts are promising, countries are unable to recognize the impending phosphorus shortage. The efforts to find alternative phosphorus sources must be vastly increased to protect the environment and ensure sufficient phosphorus to feed future generations.

References

1. Kleinman, P. J. et al. (2002). Journal of Environmental Quality, 31:2026-2033.
2. Eghball, B., & Gilley, J. E. (1999). Journal of Environmental Quality, 28(4):1201-1210. doi:10.2134/jeq1999.00472425002800040022x
3. McDowell, L. L., & McGregor, K. C. (1980). Transactions of the ASAE, 23(3): 643-648.
4. Pitois, S., et al. (2001). Journal of Environmental Health, 64(5): 25-33
5. Michalaka, A. M., et al. (2013). Proceedings of the National Academy of Sciences of the United States of America, 110(16):6448-6452.
6. Cordell, D., et al. (2008). Global Environmental Change, 19:292-305.
7. Paytan, A & McLaughlin, K. (2007). Chemical Reviews, 107(2): 563-576.
8. Ma, Y. L. & Matsunaka, T. (2013). Soil Science and Plant Nutrition, 59(4): 628:641
9. Mulbry et al. (2006). Journal of Vegetable Science, 12:107-125
10. Gambus, F. (1998) Acta AGraria et Silvestria/ Agraria, 36:23-35.
11. Parker-Burlingham, Jason. (2008). [Photograph of Phosphate Mine near Flaming Gorge NRA, UT]. Retrieved from Wikimedia Commons. CC BY 2.0.
12. Bonniemf Incorporates work by NASA Earth Science Entersprise. (2013). [Diagram of the Phosphorus Cycle]. Retireved from Wikimedia Commons. CC BY-SA 3.0.
13. Moran, John. (2012). [Photograph of a canoeist's paddle scooping up algae on Santa Fe River]. Retrieved from Wikimedia Commons. Public Domain.
14. U.S. Geological Survey. (2014). Phosphate Rock Statistics. Retrieved from http://minerals.usgs.gov/minerals/pubs/historical-statistics/ds140-phosp.pdf

4.4 The Use and Effects of Agent Orange in Vietnam

Cain W. Crouse

Herbicides were sprayed by military forces of the United States during the Vietnam War (1961-1971). A debate has been waged since the early 70's as to whether the use herbicides are associated with diabetes, cancer, birth defects, and other serious ailments. While this association has been denied, the effects of herbicide use in Vietnam linger.

Figure 1. A U.S. Military helicopter spraying Agent Orange in Vietnam. Courtesy of the U.S. Army. Public Domain.

The Vietnam War began in 1961 and lasted until April of 1975. Between 1961 and 1971, mixtures of herbicides were utilized by the U.S. military against the Republic of Vietnam forces[1] (Figure 1). The most infamous of these herbicides, Agent Orange, was used to deprive Vietnamese forces of crops to eat and forest canopy in which to hide.[2] An estimated 49.3 million liters were sprayed over 2.6 million acres during the war.[3] Within days of application, plant and animal life for kilometers were completely devastated. Agent Orange has had adverse effects on Vietnam's foliage and animal life. However, the debate continues as to whether humans that were exposed are at higher risks for certain ailments.

Dioxins are an extremely prevalent and dangerous environmental pollutant.[4] They are typically manufactured as products of industrial processes and incinerations.[4] Agent Orange is composed of 2,4-dichloro-phenoxyacetic acid, 2,4,5-trichlorophenoxyacetic acid and contains traces of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)[5] (Figure 2). Some reports have shown that approximately 3 parts per million of TCDD can be found in Agent Orange.[6] This poses a concern for people that were exposed to Agent Orange because dioxins may accumulate in fatty tissue.[4] After accumulating, dioxins can disrupt the endocrine system by forming unusual enzyme complexes that act as an intermediary in the breakdown of steroid-hormone receptors.[4] Numerous studies have been conducted since the late 1960s to connect dioxin-contaminated Agent Orange to multiple illnesses such as diabetes, birth defects, and cancers.[5] While some researchers argue that "environmental dissipation, low bioavailability, the protection of overhead canopy, the properties of the herbicides, and the circumstances of application" would lead to a low chance of exposure for troops, others found statistical associations between the herbicide and the aforementioned ailments.[7] Surprisingly, a fair portion of these studies have rendered inconclusive results when considering human impairments.

Chemical components of Agent Orange are composed of two primary compounds with trace elements of TCDD (Figure 2).[13]

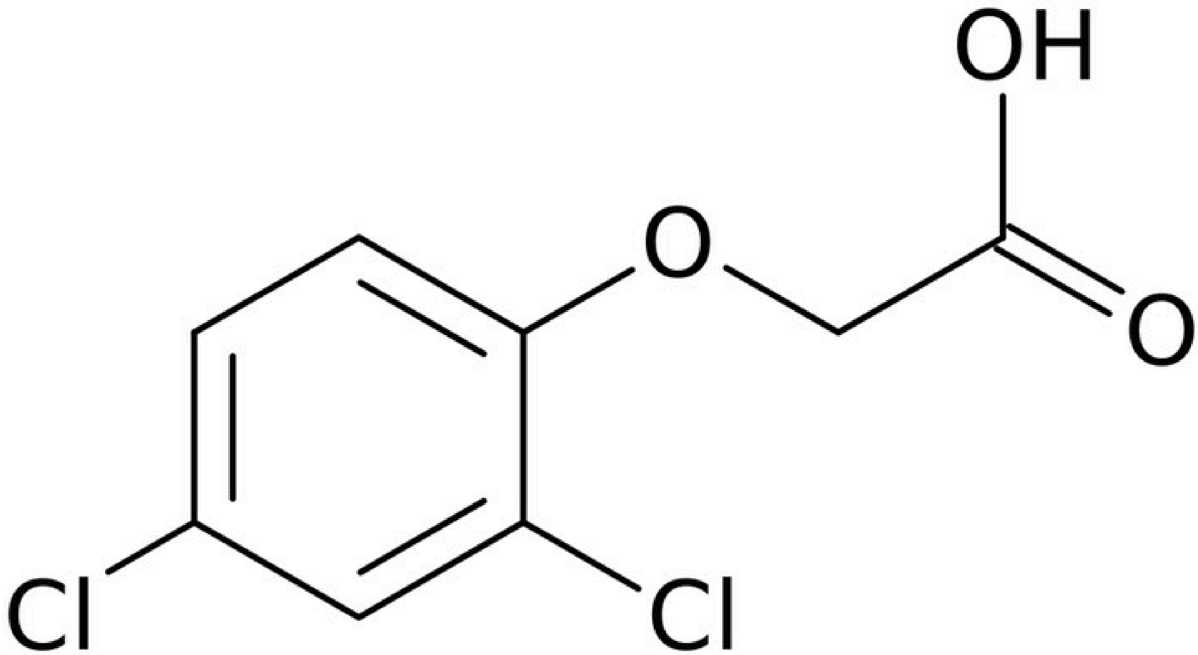


Figure 2a. Molecular structure of 2,4-dichloro-phenoxyacetic acid. Courtesy of Wikimedia Commons. Public Domain.

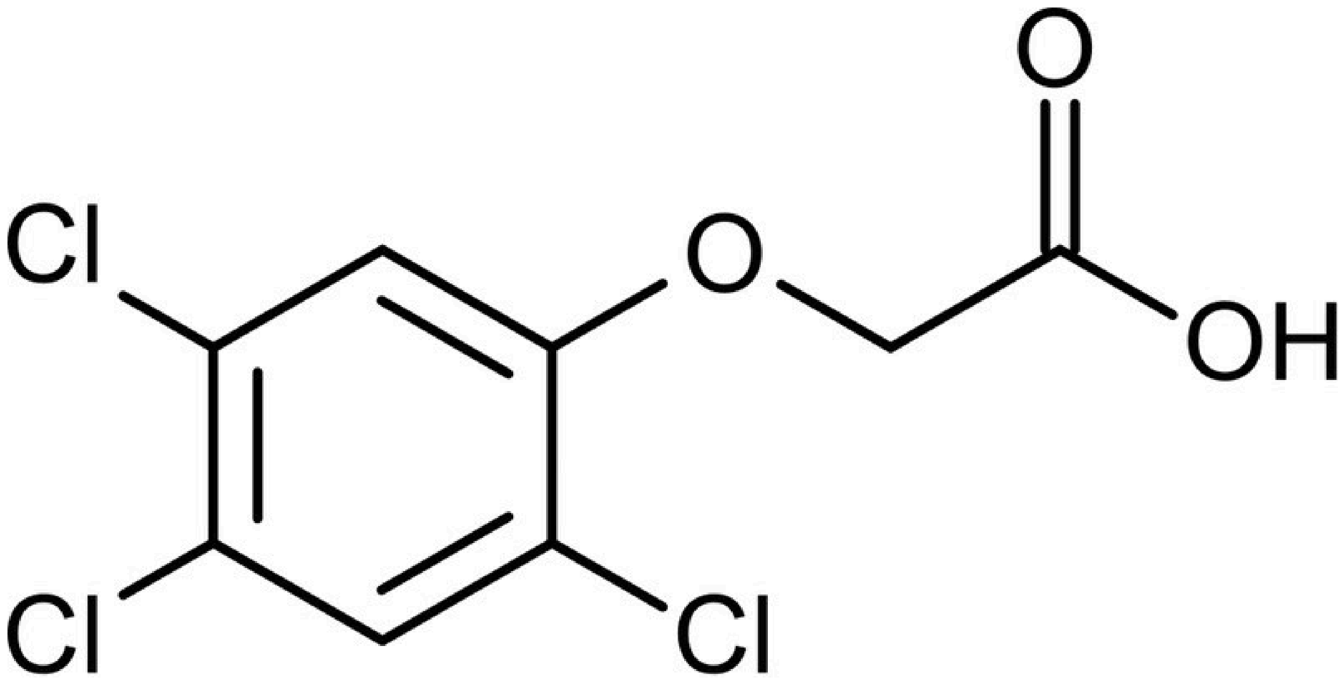


Figure 2b. Molecular structure of 2,4,5-trichlorophenoxyacetic acid.
Courtesy of Wikimedia Commons. Public Domain.

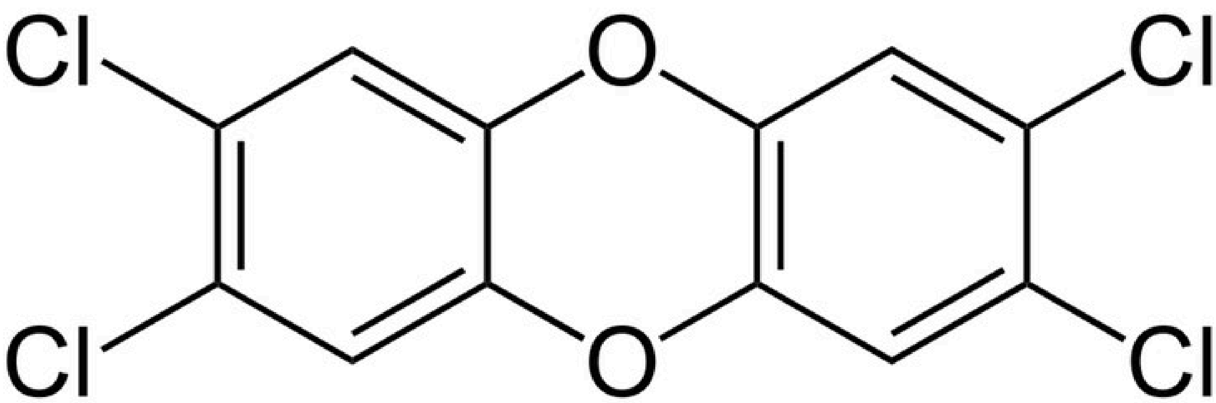


Figure 2c. Molecular structure of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) or Dioxin.
Courtesy of Wikimedia Commons. Public Domain.

In the late 1960s, evidence linking dioxins to birth defects in mice and reports of birth defects in Vietnam began to arise.[2] On October 31 of 1971, the U.S. ceased tactical herbicide missions in Vietnam.[7] One year prior to this cessation, Congress had urged the Department of Defense to work in unison with the National Academy of Sciences to conduct a study on possible effects of Agent Orange exposure.[3] This study found an association between dioxin and birth defects, but the link was deemed statistically insignificant.[3] These results did not suppress interest in Agent Orange. Between 1979 and 1990, federal departments and agencies in the U.S. helped sponsor over 50 studies focused on the herbicide[7] (Figure 3). Although all of these research programs failed at yielding a definitive assessment, many found modest associations between illnesses and Agent Orange.

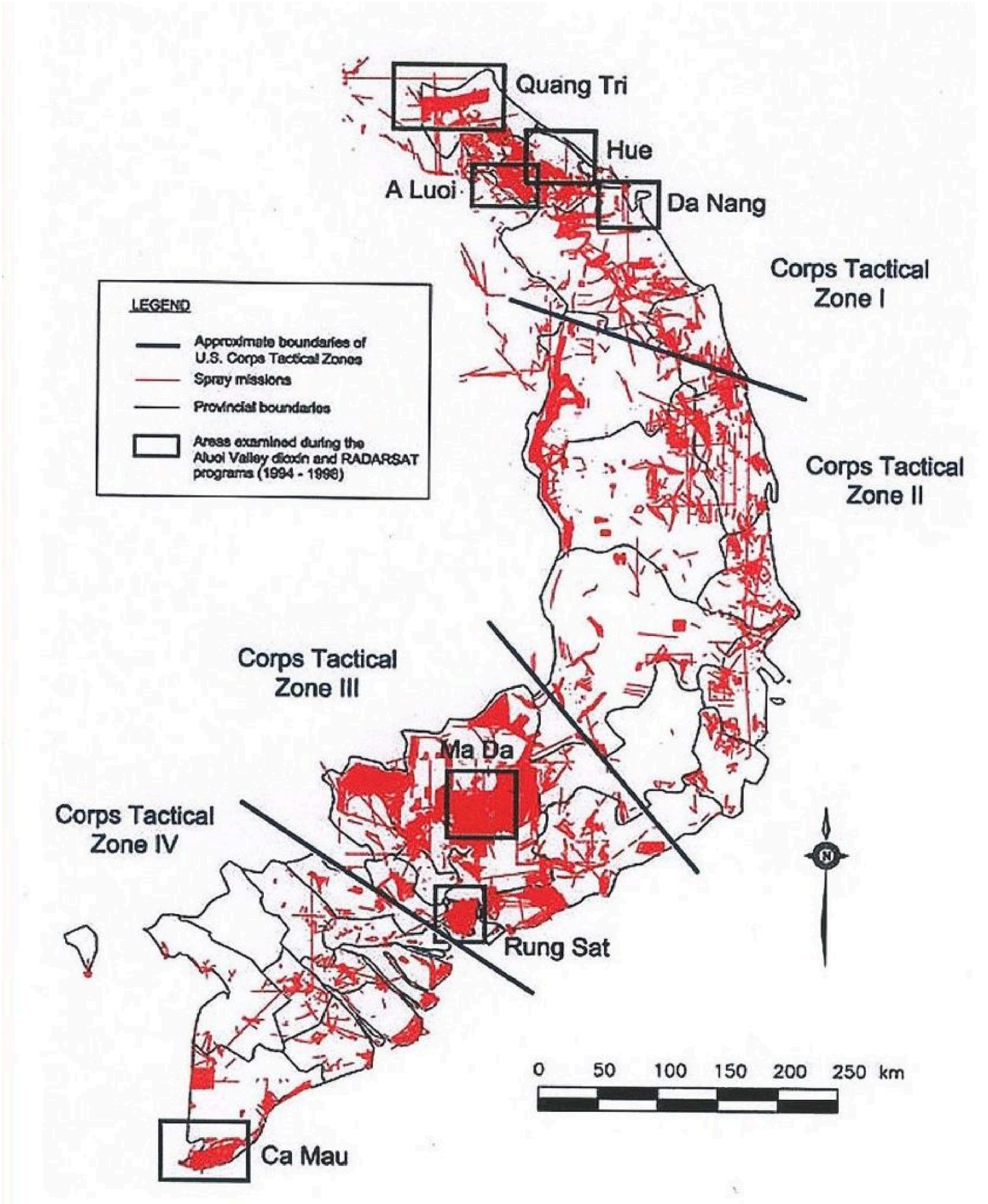


Figure 3. Aerial herbicide spray missions in southern Vietnam between 1965 and 1971. Courtesy of the U.S. Army, 2011. Public Domain.

In 1991, Congress passed legislation that directed the Secretary of the Department of Veterans Affairs to work with the National Academy of Sciences, Institute of Medicine, to research Agent Orange.[7] Researchers at the Institute of Medicine found statistical associations between dioxin exposure and type 2 diabetes, many types of leukemia, Hodgkin's disease, non-Hodgkin's lymphoma, prostate and respiratory cancers, heart disease, Parkinson's disease, and birth defects among other ailments.[7] A noteworthy study conducted in 2006 combined data from 22 other studies to conclude Agent Orange exposure is linked to increased risks of birth defects[3] (Figure 4). Two researchers from Texas also found a correlation among dioxins, diabetes, and cancer in Ranch Hand veterans after they adjusted for calendar period, days of spraying, and time spent in Asia.[5] These studies demonstrate the many harmful effects of Agent Orange. However, there remains a degree of uncertainty concerning the herbicide that has had policy implications and environmental impacts.

Figure 4. A Vietnamese mother holds her son who has been physically and mentally handicapped since birth due to her exposure to Agent Orange.
Photograph by Alexis Duclos, 2004. CC BY-SA 3.0.

As of 2014, the U.S. government has spent billions of dollars on the health care of American soldiers exposed to Agent Orange. U.S. military forces were not the only people affected by the herbicide. In Vietnam, an estimated 4.8 million people came into contact with Agent Orange.[3]

Yet, the U.S. government has been slow to funnel aid to the Vietnamese. During President George W. Bush's second term, Congress began distributing several million dollars to fund a cleanup project in Da Nang, Vietnam, which is expected to be completed by 2016.[8,9] Da Nang has exceedingly high levels of dioxin, shrubs and weeds still cannot grow there.[6] Aside from this cleanup, the U.S. government has refused to acknowledge their responsibility for the health effects Agent Orange has had on the Vietnamese. Benefits enjoyed by U.S. veterans have yet to be extended to civilians living in the dioxin saturated areas of Vietnam.[9] Many U.S. veterans, irritated with government inaction have moved to Vietnam to help cleanup efforts.[10] One veteran quipped, "We get more support from the government of Norway" in a recent interview.[10] Some find hope for U.S. reparation to Vietnam in the rise of China as an international global competitor. The U.S. and Vietnam have a mutual interest in balancing Chinese hegemony.[10] President Obama has hinted at shifting from wars in Iraq and Afghanistan to Asia, in order to profit from the region's rising economic prosperity while maintaining a watch on China's military forces.[8] This foreign policy adjustment has the potential to improve U.S.-Vietnamese relations.

The former Secretary General of the United Nations, Kofi Annan, was quoted saying, "As long as wars have existed, the environment and natural resources have been their silent victims".[11] In the same address, Annan expressed contempt for delayed responses by many to curb the harsh effects of prolonged wars on the environment, citing the United States and its use of Agent Orange.[11] The U.S. government maintains an inconsistent position on the issue of Agent Orange. Through allocation of resources to Da Nang, and the coverage of health care costs of U.S. veterans, the U.S. government has acknowledged the adverse environmental and health effects of Agent Orange. Despite these efforts, little monetary support is given to Vietnamese veterans and areas outside Da Nang.

Research suggests Agent Orange has affected not only the physical and biological environment of the 60s and 70s, but also subsequent generations of Vietnam War veterans, the civilian population, and the current environment. Forty years of research has suggested that the environment may not be the only silent victim of the Vietnam War. The U.S. government should disperse more humanitarian aid to Vietnam to alleviate the detrimental effects of Agent Orange and to improve its international reputation. History demonstrates trust amongst nations emerges from successful, cooperative engagements that overcome disagreements. Funding a large-scale cleanup project would serve as a tremendous step in the right direction for the health of the Vietnamese people and the diminishing reputation of the United States as a global leader in humanitarian efforts.

References

1. Stellman, J.M., et al. (2003). The Extent and Patterns of Usage of Agent Orange and Other Herbicides in Vietnam. Nature 422:681-87
2. Stone, R. (2007). Agent Orange's Bitter Harvest. Science 315:176-79
3. Ngo, A.D., et al. (2006). Association between Agent Orange and Birth Defects: Systematic Review and Meta-Analysis. International Journal of Epidemiology 35.5: 220-30.
4. Harper, J.W. (2007). Chemical Biology: A Degrading Solution to Pollution. Nature 446:499-500.
5. Michalek, J.E., & Pavuk, M. (2008). Diabetes and Cancer in Veterans of Operation Ranch Hand after Adjustment for Calendar Period, Days of Spraying, and Time Spent in Southeast Asia.

Journal of Occupational and Environmental Medicine 50.3:330-40
6. Stone, R. (2007). Chemical Clearance. Science.
7. Young, A. (2011). Agent Orange Exposure and Attributed Health Effects in Vietnam Veterans. Military Medicine 176:29-34.
8. Coll, Steve. (12 April 2012). America's Debt to Vietnam. The New Yorker.
9. Fuller, Thomas. (9 Aug. 2012). 4 Decades on, U.S. Starts Cleanup of Agent Orange in Vietnam. The New York Times
10. Stein, Jeff. (2 Dec. 2013). In Return to Vietnam, Vets Tackle Mess They Left Behind. Newsweek
11. Annan, Kofi. (11 Jan 2004). No Conflict Is Too Remote to Affect Local Environment, Secretary – General Says in Message to Mark International Day to Prevent Exploitation. United Nations.
12. U.S. Army. (Undated). [Photograph of a U.S. Huey helicopter spraying Agent Orange over Vietnam]. Retrieved from Wikimedia Commons. Public Domain.
13. [Molecular diagram of Agent Orange compounds]. Retrieved from Wikimedia Commons. Public Domain.
14. U.S. Department of the Army. (2011). [Map showing locations of U.S. Army aerial herbicide spray missions in south Vietnam from 1965 to 1971]. Retrieved from Wikimedia Commons. Public Domain.
15. Duclos, Alexis. (2004). [Photograph of two Vietnamese pose in front of a billboard]. Retrieved from Wikimedia Commons.CC BY-SA 3.0.

POPULATION ECOLOGY

Photograph by Neil Herbert, 2014. CC BY 2.0.

5.1 Africa's Vanishing Predator The African Wild Dog

Allyson E. Loparo

The African wild dog has become one of the most critically endangered species in Africa. Once nearly 500,000 wild dogs roamed Africa, however now there is only an estimated 3,000 to 5,000. With greatly reduced numbers from the encroachment on farmer and rancher lands, there is a lack of genetic variation and a new strand of canine distemper threatens the species with further decline.

Figure 1. A pack of African wild dogs hunting in Kruger National Park, South Africa.
African wild dogs are efficient hunters, with a hunt success rate of almost 80%. This makes them the third most productive hunter in the wild.
Photograph by Bart Swanson, 2007. CC BY-SA 3.0.

The African wild dog, Lycaon pictus, is one of Africa's premier hunters.[1,2] African wild dogs (Figure 1) are one of the top three most efficient hunting animals in Africa and are found on most of the continent aside from the drier deserts in the north, and the denser forests of the southern tip. As some of the most social and vocal animals roaming the earth today, the African wild dog is an essential species to maintaining biodiversity in the African plains, but sadly their numbers are decreasing daily. The African wild dog has been listed as an endangered species since 1990, and the species may soon be listed as critically endangered.[3,4,5] The population of African wild dogs was nearly 600,000 two decades ago, but now their numbers have dwindled to fewer than 5,000 individuals (Figure 2).

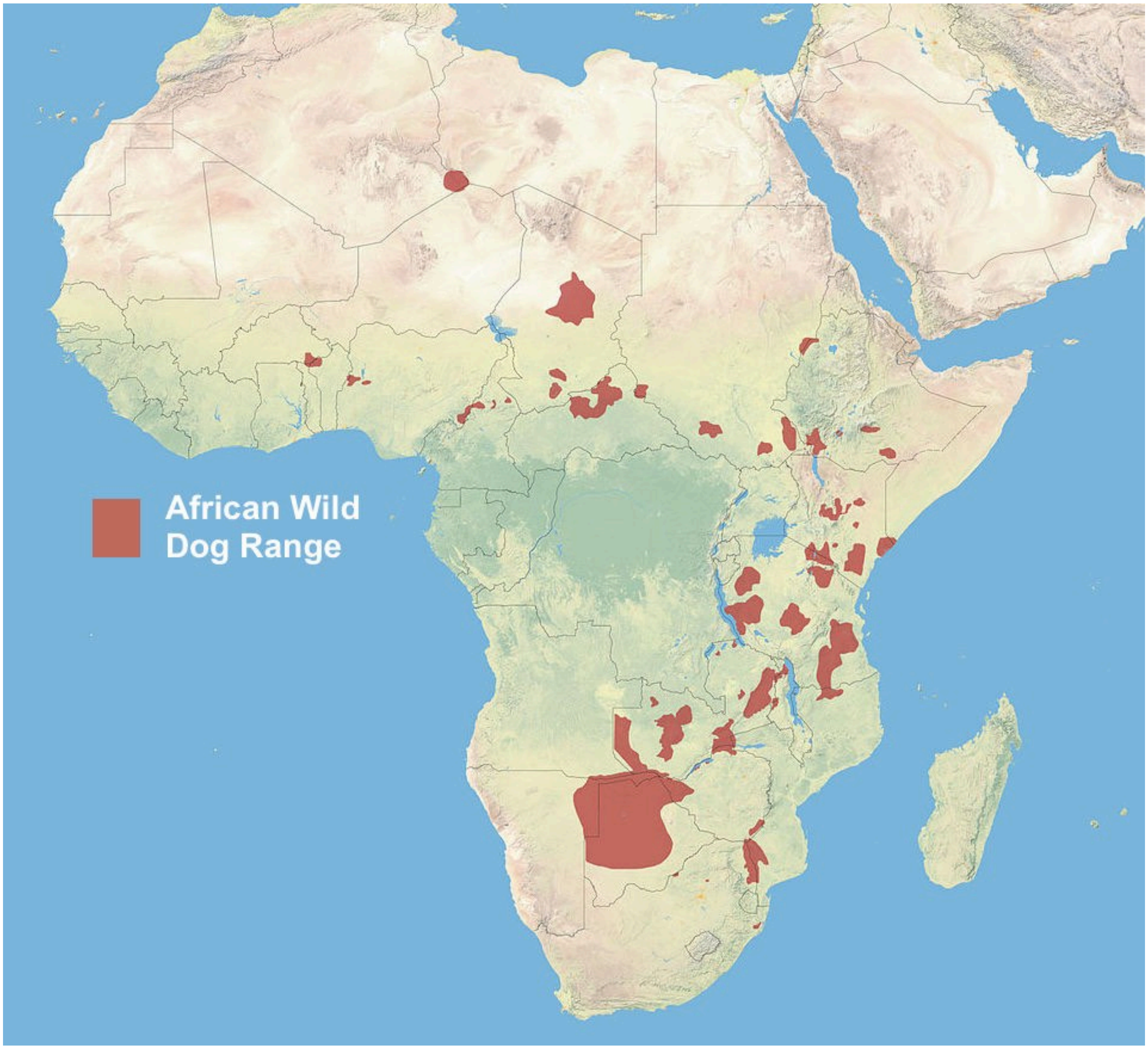


Figure 2. The range of the African wild dog, as described by the International Union for Conservation of Nature, is shrinking daily as humans attain more land and are pushing the animals into smaller, less desirable territories.
Modified from Nrg800, 2011. CC BY-SA 3.0.

Lycaon pictus translates directly to "painted wolf" in Greek, which is exactly what the animals resemble.[6] No two wild dogs are born with the same coloration and markings, which allows for easy identification by researchers (Figure 3). African wild dogs are the second largest wild canid, other than the grey wolf, and usually weigh between 18-36 kilograms (40-80 pounds) at maturity.[6] Males and females are similar in size and shape with males only weighing between 3-7% more than females.[6] Their large round ears aid in body heat release and differentiate them from their wolf ancestors.

Figure 3. The African wild dog's unique coat pattern differences make it easy to decipher individual members of the pack.
Photograph by Mosztics Attila, 2008. Public Domain.

One of the major factors contributing to the decline of these animals is their proximity to humans. Humans are responsible for the majority of accidental and intentional deaths of African wild dogs. Some animals are killed accidentally by road accidents or snare trappings, but others are killed to protect livestock and game populations. African wild dogs have learned that corralled animals make easy prey and farmers and ranchers across Africa admit to killing the dogs to protect their assets and livelihood by means of lethal control, such as shooting and the use of poison.[7] Since the African wild dog is not on any "no kill" lists, they are legal to kill while on the farmer or rancher's property. Habitat loss is driving the species away from protected sanctuaries and into private property. In previous years, each dog had on average 130 square kilometers (80 square miles) of hunting territory, but now the wild dogs are down to only 15.6 square kilometers (9.7 square miles).[8] African wild dogs need extensive hunting and roaming territory, and most African sanctuaries are not large enough, thus the dogs are forced to go to unprotected areas where they are constantly at risk.[7]

Packs of mostly related males and a few females create a unique social structure. Packs consist of 10-15 animals and contain females that have not reached breeding maturity.[2,9] Females will leave their birth packs near 30 months of age when they reach sexual maturity and search for a pack with insufficient females. This differs from most other pack animals in which females are relatives and the males wander to find packs of females. In a typical pack, the ratio of males to females is 8:1, which contributes to their lack of numbers. Only the alpha female and male will breed once a year to produce 2-19 pups, with an average litter of 10[4] (Figure 3). At one time, this was an evolutionary advantage to the packs to not strain themselves by having too many pups to take care of at one time. However, now wild dogs are not producing enough offspring to keep up with their declining numbers. Studies have shown that if the alpha female dies, the remaining females in the pack do not always reach sexual maturity, and the pack may split up.

A disease called canine distemper is also ravaging the species (Figure 4). Canine distemper is a viral disease transmitted to other pack mates through aerosol, and it affects the nervous and lymphatic tissues. Research of one pack indicates that none of the members had detectable antibodies to fight canine distemper, which is similar to the human flu but with a mortality rate of 38%.[10] Some researchers have begun to vaccinate wild dogs with the same vaccine that we give to domestic dogs to protect against canine distemper, and it has proven to be almost 100% effective.[5,9]

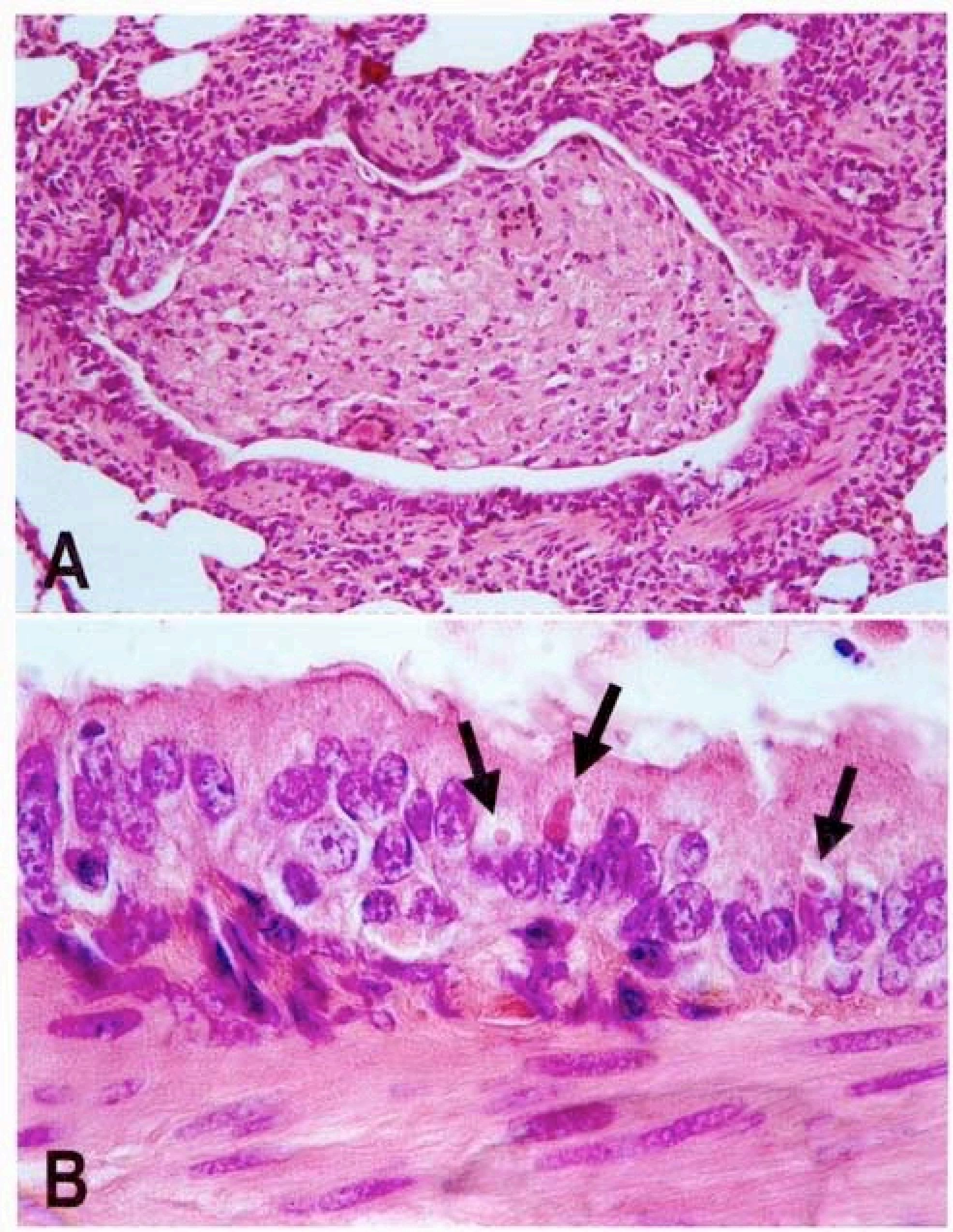


Figure 4. Microscopy images of African wild dog lung tissue infected with the canine distemper virus. A) Bronchioles, small passageways by which air passes through in the lung, are obstructed by inflamed and damaged cells. B) A detail of image A showing multiple viral inclusion bodies.
Courtesy of M. W. Van de Bildt et al., 2002. Public Domain.

The African wild dog is similar to most species in Africa in its need for increased land and reservations for protection. Large hunting ranges force packs out of the reserves, which puts them in contact with the dangers associated with human establishments. Creating more space and increasing the number of park rangers would greatly benefit the survival of many African species of wildlife. Education of farmers and ranchers on the use of non-lethal means to fend off wild dogs, such as higher fences or rubber darts instead of bullets, will aid in increased survival rates for the species. To combat canine distemper, more researchers will need to trap and vaccinate the animals. Also, attaching trackers on to the wild dogs will allow researchers to study hunting ranges and search for a solution to protect the species from accidental and intentional deaths outsides their protected sanctuaries. With the combined efforts of researchers, citizens, farmers, and ranchers the wild dog will recover and thrive in Africa once again.

References

1. Davies-Mostert, H.T., et al. (2013). Hard boundaries influence African wild dogs' diet and prey selection. Journal of Applied Ecology, 50:1358–1366.
2. Alexander, K.A., & Appel, M.G. (1994). African Wild Dogs (Lycon-Pictus) Endangered by a Canine-Distemper Epizootic Among Domestic Dogs near the Masai-Mara National Reserve, Kenya. Journal of Wildlife Diseases, 30:81-85.
3. Kruger, S.C., et al. (1999). Diet Choice and Capture Success of Wild Dog (Lycaon Pictus) in Hluhluwe-Umfolozi Park, South Africa. Journal of Zoology, 4:543-551.
4. Groom, R., et al. (2012). Diet of Four Sympatric Carnivores in Savé Valley Conservancy, Zimbabwe: Implications for Conservation of the African Wild Dog (Lycaon Pictus). South African Journal of Wildlife Research, 42:94-103.
5. Woodroffe, R., et al. (2005). Livestock Predation by Endangered African Wild Dogs (Lycaon Pictus) in Northern Kenya. Biological Conservation, 124:225-234.
6. Creel, S. (1995). Communal Hunting and Pack Size in African Wild Dogs, Lycaon Pictus. Animal Behaviour, 50:1325-339.
7. Marsden, C.D., et al. (2009). Highly Endangered African Wild Dogs (Lycaon Pictus) Lack Variation at the Major Histocompatibility Complex. Journal of Heredity, 100:54-65.
8. Davies, H.T., & Du Toit, J.T. (2004). Anthropogenic Factors Affecting Wild Dog Lycaon Pictus Reintroductions: A Case Study in Zimbabwe. Oryx, 38:32-39.
9. Carbone, C., et al. (1999). Feeding Success of African Wild Dogs (Lycaon Pictus) in the Serengeti: The Effects of Group Size and Kleptoparasitism. Journal of Zoology, 266:153-161.
10. Romañach, S.S., & Lindsey, P.A. (2008). Conservation Implications of Prey Responses to Wild Dogs Lycaon Pictus during the Denning Season on Wildlife Ranches. Animal Conservation, 11:111-117.
11. Swanson, Bart. (2007). [Photograph of Wild Dogs in Kruger National Park, South Africa]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
12. Nrg800. (2011). [Diagram of the distribution of the African Wild Dog, according to the IUCN]. Retrieved from Wikimedia Commons. CC BY-SA 3.0. Modifications: Cropped and added key.
13. Attila, Mosztics. (2008). [Photograph of African Wild Dog Pups]. Retrieved fromWikimedia Commons. Public Domain.
14. Van de Bildt, M.W., et al. (2002). Distemper outbreak and its effect on African wild dog conservation. Emerging Infectious Diseases. 8(2):212-213. Retrieved from Wikimedia

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5.2 Saving Juvenile Hawaiian Monk Seals-Status and Challenges

Rika L. Bailey

The Hawaiian Monk Seal is an ancient seal species indigenous to the Hawaiian Islands. Human interference, coupled with difficult pup rearing, is causing their population to decrease by 4% annually. Human attempts to revitalize the Hawaiian Monk Seal population could determine if the species will survive.

Figure 1. An adult Hawaiian Monk Seal sleeps on a beach.
Photograph by Geordie Mott, 2010. CC BY-ND 2.0.

The Hawaiian Monk Seal (Monachus schauinslandi) is considered an ancient seal species, and it is indigenous to the Northwestern Hawaiian Islands (Figure 1). Often referred to as a "living fossil", they are one of only two monk seal species remaining, and their population continues to dwindle at a rate of near 4% annually.[1] Their population is estimated to be 1000-1500 in number, with the largest percentage living in the French Frigate Shoals, the largest atoll of the Northwestern Hawaiian Islands (Figure 2). Much like the buffalo population of North America, the Hawaiian Monk Seal was hunted to near extinction by expeditions during the mid-1800s.[1]

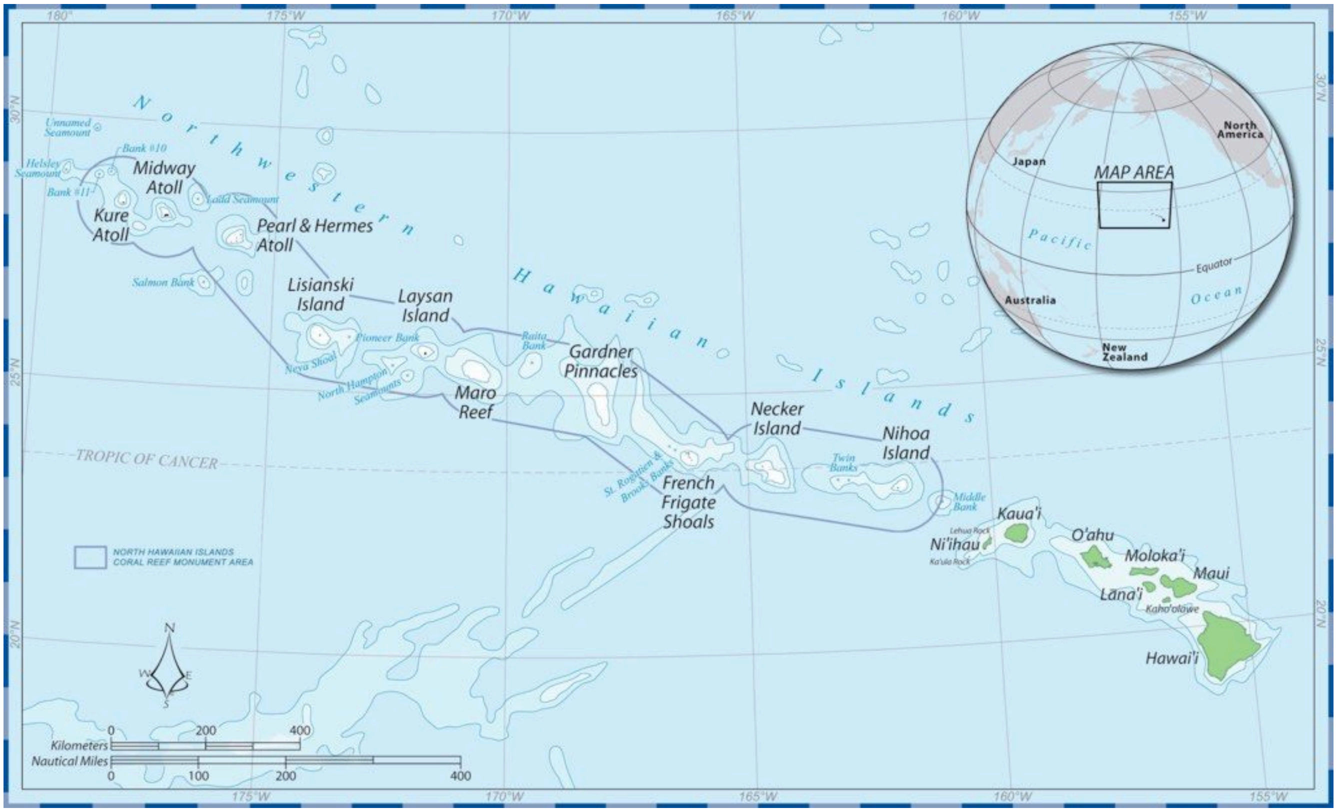

Figure 2. In 2006, the Northwestern Hawaiian Islands were designated as a National Monument making it the largest Marine Protected Area in the world. The Papahānaumokuākea Marine National Monument is home to over 7,000 species, many of which are endangered, threatened, or endemic to the area.
Courtesy of the U.S. National Oceanic and Atmospheric Administration, 2006. Public Domain.

Burgeoning threats to the Hawaiian Monk Seal population include increasing amounts of marine debris in their habitat, aggressive mating practices, lack of genetic diversity due to low population size, increased presence of disease, environmental contaminants, human interference (including bycatch practices), foraging issues, and general human encroachment onto their habitat.[1] Perhaps the greatest threat to the Hawaiian Monk Seal population is the inability of juvenile seals to survive (Figure 3). Only one in five pups born will live to reproductive age.[1,2] Juvenile foraging practices and the role that monk seal mothers play in fostering these practices, yields insight into the development of seal pups and their high mortality rate.

Though the population is decreasing at a dramatic rate, concentrated attempts to salvage and facilitate the growth of young Hawaiian Monk Seals may determine the survival of the species.

Threat	Most Vulnerable Age-Class	Frequency of Threat Occurring	Certainty of Impact	Relative Impact to Recovery
Food Limitation	Pups & Juveniles	High	High	Crucial
Entanglement	Pups & Juveniles	High	High	Crucial
Shark Predation	Pups	High	High	Crucial
Infectious Disease	All Age-classes	Low	Low	Serious
Habitat Loss	All Age-classes	High	High	Serious
Fishery Interaction	All Age-classes	Medium	High	Serious
Male Aggression	Immature & Adult Females	Low	High	Serious
Human Interaction	All Age-classes	Medium	High	Serious
Biotoxins	All Age-classes	Low	Low	Moderate
Vessel Groundings	All Age-classes	Low	Low	Moderate
Contaminants	All Age-classes	Low	Low	Moderate

Figure 3. Threats to the Recovery of the Hawaiian Monk Seal.
The top three threats to the Hawaiian Monk Seal (Food Limitation, Entanglement, and Shark Predation) most seriously affect seal pups and juveniles. Addressing the low survival rate of young Hawaiian Monk Seals is crucial to the recovery of the species.
Table modified from the National Marine Fisheries Service, 2007.

Female Hawaiian Monk Seals do not breed as consistently as other seal species, although this does not cause much disparity in the amount of pups being born.[2] Rather, the female's inability to identify her own pup alongside the pup of another female causes many juveniles to become orphaned. However, the rate of fostering within this species is so high that orphaned juveniles tend to find another female to take care of them.[2] This occurs because either a female has lost her own pup, or is willing to take up the orphaned pup in addition to her own. Oftentimes, the density of the breeding population is low and females will have aggressive encounters in which they end up switching offspring.[3] Fostering practices have little impact on the weight of the seal pup, which is often the largest determining factor into whether the seal pup will survive its first year.[4] The mother will only lactate for the seal pup for slightly over a month and during this time she is not eating. After this lactation period, the seal pup will have to fend for itself. It is during this weaning period that a seal pup must learn to forage for benthic organisms, the primary prey of Hawaiian Seal Monks. Seal pups tend to stay closer to shore where they are protected from predators, but where prey is harder to catch. Limited availability of prey and their smaller size makes pups more susceptible to starvation, predation, and increased risk of developing diseases.[4] Juvenile pups are also harassed by aggressive male seals. Other than elevated testosterone levels, the reason for this behavior is relatively unknown.[5]

Female Hawaiian Sea Monks are often the victims of mobbing, in which more than one male seal tries to mate with a single female at once. Mobbing often results in injury and may kill the female.[2] Despite the mobbing behavior, females are often injured during mating due to the method in which the male mounts the female. Male monk seals hold onto the female's back with their teeth, which can lead to gashes and subsequent infection.[2]

Human interference has greatly influenced Hawaiian Monk Seal populations. Hawaiian Monk Seals primarily live in the protected Marine National Monument (Figure 2), but prior to its establishment in 21st century, the Northwestern Hawaiian Islands were home to various United States Coast Guard and Navy activities and bases.[6] Hawaiian Monk Seals were no longer able to 'haul out' onto optimal shore areas (shallow and protected by reefs) to undergo parturition because of human interference. The seals were forced to go to less productive areas that were more exposed to predators including sharks, or deeper areas where pups faced the possibilities of drowning.[2] Once a noticeable decline in the population of Hawaiian Monk Seals was discovered, human activity on or near the military bases became more regulated, and the population recovered. Hawaiian Monk Seals have also been affected by the amount of human debris washing onto the shores of the Northwestern Hawaiian Islands, which includes fishery nets that can entangle seals and cause drowning (Figure 4). Efforts to minimize beach debris have not significantly reduced the waste.[6]

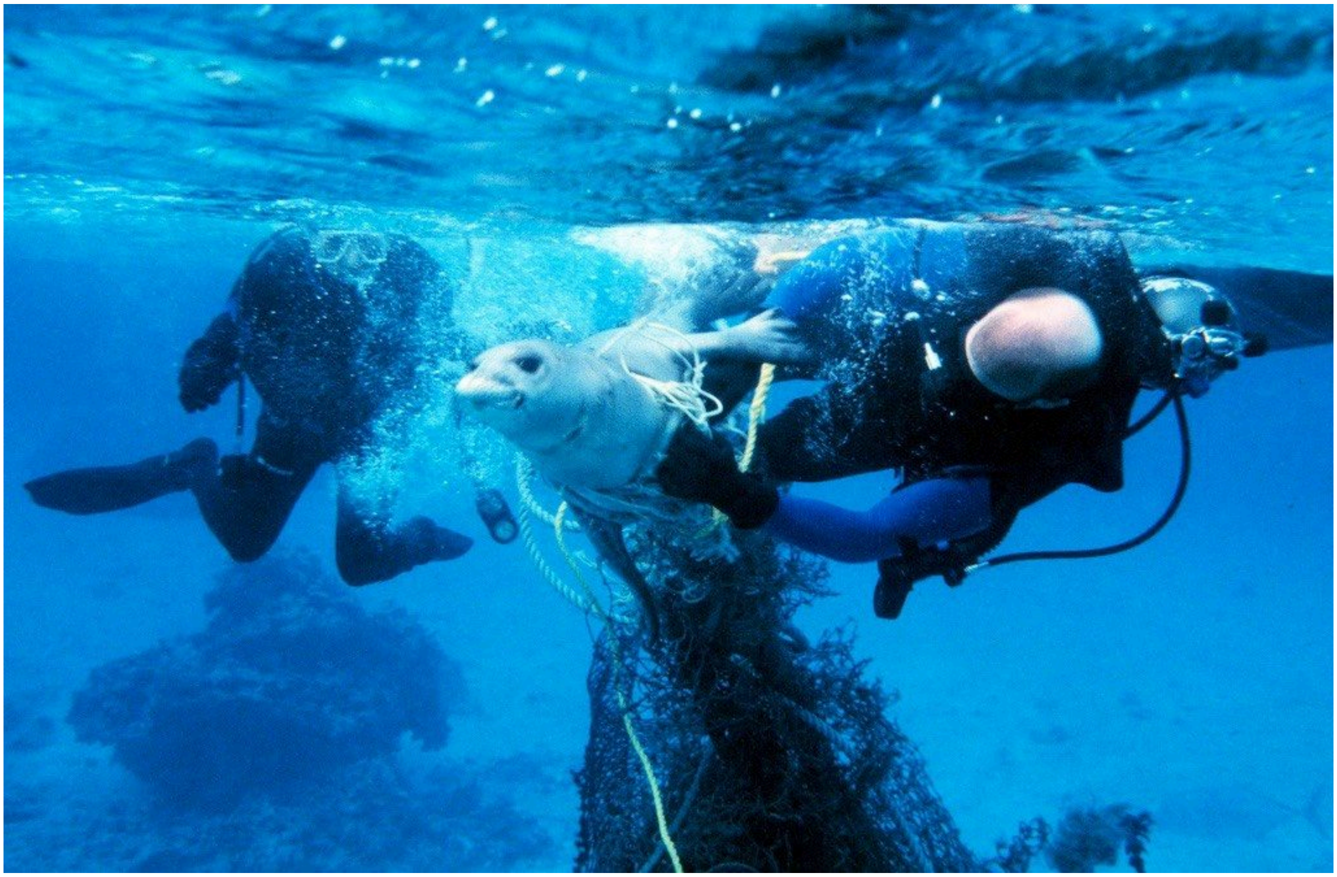

Figure 4. Lieutenant Commander Marc Pickett and Lieutenant Mark Sarmek wrestle to free an entangled Hawaiian Monk Seal at French Frigate Shoals, Northwestern Hawaiian Islands, during a marine debris survey and removal cruise. Entanglement is one of the leading causes of mortality in Hawaiian Monk Seals. Photograph by Ray Boland, 2010. CC BY 2.0.

Human efforts at rehabilitating the Hawaiian Monk Seal population have had limited success, because protected marine areas are not enough to sustain the population. Programs have been established to foster healthy female pups until they are of reproductive age and then return them to their original nesting site to ensure the best chance of survival and reproduction. However, it is difficult to determine whether the rehabilitated females are producing surviving offspring because of the high rate of displacement among pups.[7] Although the overall population of the Hawaiian Monk Seal continues to decline, monk seals populations on the Main Hawaiian Islands (versus the Northwestern Hawaiian Islands) are growing. Also, these main island populations have more reproductive females that are necessary for the survival of the species.[5]

With the advent of new technology, monitoring Hawaiian Monk Seal behavior (particularly pup behavior) is becoming easier and more efficient. Video-monitoring devices such as the CritterCam are providing new possibilities for observation that were previously unavailable.[8] Observation technology may provide critical insight on Hawaiian Monk Seal behavior, foraging practices, environment, and social interactions.[8] More research is needed on the low survival rates of juvenile Hawaiian Monk Seals to determine the best methods to support species growth and reverse the population decline.

References

1. Seal Conservation Society. (2011 August). Hawaiian Monk Seal. Retrieved from http://www.pinnipeds.org/seal-information/species-information-pages/the-phocid-seals/hawaiian-monk-seal
2. Johanos, T.C. et al. (1994). Annual Reproductive Cycle of the Female Hawaiian Monk Seal (Monachus Schauinslandi). Marine Mammal Science, 10:13-30.
3. Boness, D.J. (1990). Fostering Behavior In Hawaiian Monk Seals: is there a Reproductive Cost?. Behavioral Ecology and Sociobiology, 27:113-122.
4. Craig, M.P. & Ragen, T.J. (1999). Body size, survival, and decline of juvenile Hawaiian Monk Seals, Monachus schauinslandi. Marine Mammal Science, 15:786-809.
5. National Oceanic and Atmospheric Administration. (2013 February 17), Hawaiian Monk Seal (Monachus Schauinslandi). Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/pinnipeds/hawaiianmonkseal.htm
6. Gerrodette, T. & Gilmartin, W.G. (1990). Demographic Consequences of Changed Pupping and Hauling Sites of the Hawaiian Monk Seal. Conservation Biology, 4:423-430.
7. Gilmartin, W.G., et al. (2011). Rehabilitation and Relocation of Young Hawaiian Monk Seals (Monachus Schauinslandi). Aquatic Mammals, 37:332-341.
8. Marshall, G.J. (1998). CRITTERCAM: An animal borne imaging and data logging system. Marine Technology Society Journal, 32:11-17.
9. Mott, Geordie. (2010). [Photograph of a Hawai'ian Monk Seal sleeping on a beach]. Retrieved from FlickrCommons. CC BY-ND 2.0.
10. National Oceanic and Atmospheric Administration. (2006). [Map of The Papahānaumokuākea Marine National Monument in Hawai'i]. Retrieved from Wikimedia Commons. Public Domain.
11. National Marine Fisheries Service. (2007). Hawaiian Monk Seal (Monachus schauinslandi) 5-Year Review: Summary and Evaluation. Retrieved from http://www.fisheries.noaa.gov/pr/pdfs/species/hawaiianmonkseal_5year.pdf
12. Boland, Ray. (2010). [Photograph of two divers freeing a Hawaiian Monk Seal from a commercial fishing net]. Retrieved from FlickrCommons. © U.S. National Oceanic and Atmospheric Administration. CC BY 2.0.

5.3 Elephant Contraception- Possible Solution for South Africa's "Elephant Problem"?

Emily C. Mills

Although the African Elephant is a vulnerable species, South African national parks and reserves have started exceeding their elephant carrying capacities. Management techniques of the elephant population are required to maintain the delicate balance of the savannah ecosystem. Many different options are available, one of which is elephant contraception. But is this management option the most efficient and least damaging?

Figure 1. A mother and calf African elephant in Samburu National Reserve, Kenya. Photograph by Peter Steward, 2013. CC BY-NC 2.0.

The African elephant, Loxodonta africana, is the largest terrestrial mammal in the world and can live up to 90 years (Figure 1). Elephants are highly intelligent animals and display complex social and emotional responses, which include grieving for their dead. Their social hierarchies depend upon a matriarch elephant which leads, protects, and teaches younger females how to raise their young. Elephant communication systems are considered to be more extensive than humans can understand. They exhibit a broad range of acoustic emissions including trumpeting, braying, and a deep rumbling. In addition to their excellent auditory abilities, their feet have sensitive receptors that allow them to pick up vibrations through the ground.[1]

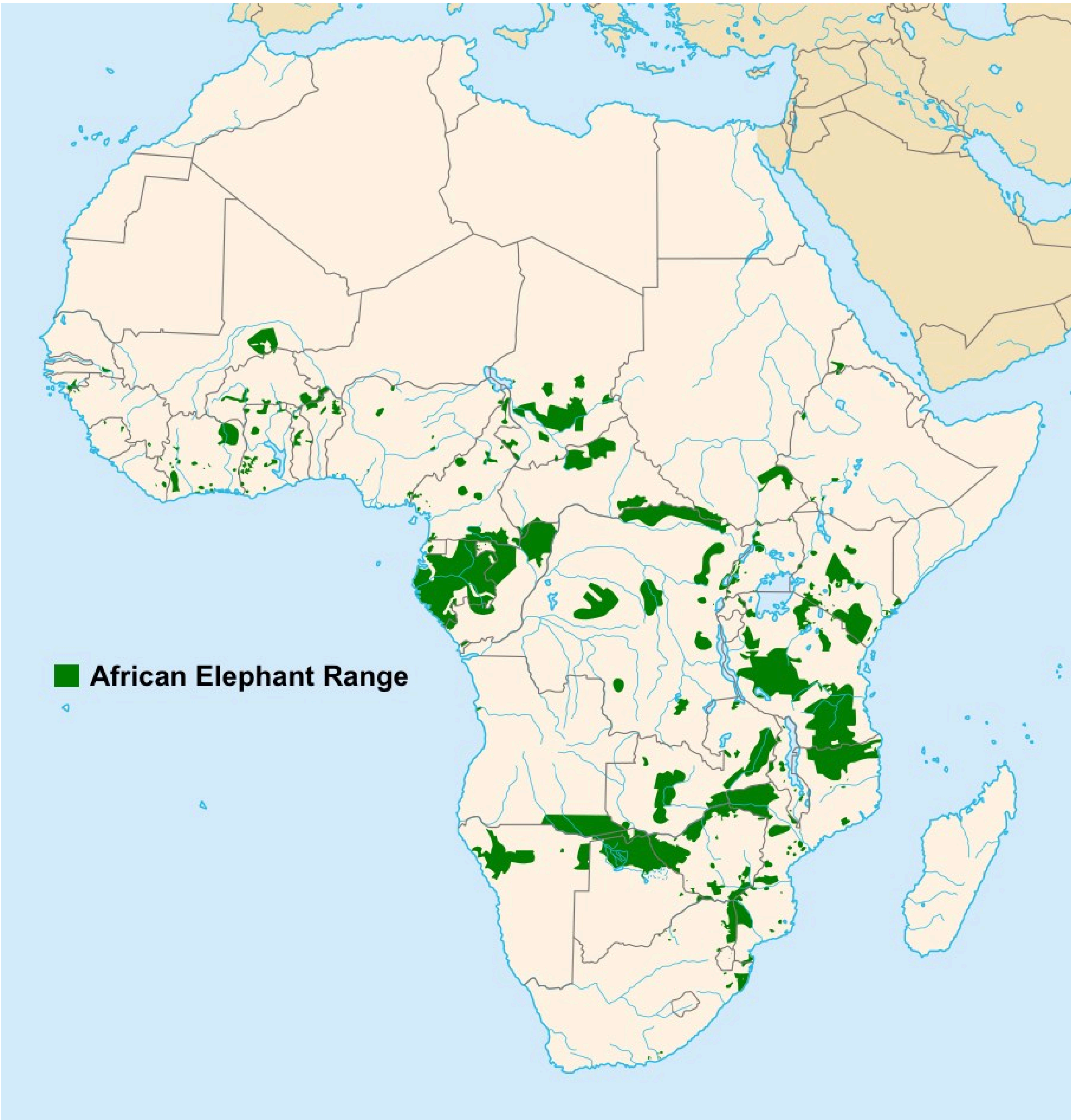

Figure 2. The distribution of the African Elephant has been significantly diminished over the past century due to harvesting of the species for their valued ivory tusks. This map includes the distribution of both African Elephant subspecies (the Savanna Elephant (Loxodonta africana) and the Forest Elephant (Loxodonta cyclotis)) and is based on data from the African Data Status Report from the International Union for Conservation of Nature. Courtesy of Bamse, 2007. CC BY-SA 3.0.

The elephant's most prominent feature is their ivory tusks, which can grow to immense lengths if they mature to adulthood. Ivory has become a commodity, especially in locations in East Asia where ivory sculptures and fine crafts are considered status symbols (Figure 3). Asian demand helps drive the illegal ivory trade and has been a major factor in the African Elephant's dwindling numbers over the past century.[1,2] There were once abundant numbers of elephants roaming the continent of Africa, but in modern times, their range has been greatly diminished[2] (Figure 2). Poaching of elephants in the twentieth century is a primary focus of African wildlife conservation. Poachers brutally kill elephants with machine guns and then hack their skulls open with machetes to gain access to their ivory tusks.[3] The demand and monetary reward is so high for ivory, poachers are willing to kill young adolescents and females, whose tusks are much smaller than that of adult bull elephants. Consequently, poaching has led to many infant elephants being orphaned. For the first few years of their life, baby elephants depend on their mothers for breast milk and protection. Infant mortality is likely if their mother is killed.[4] Although some African governments are rife with corruption and commonly ignore or even facilitate poaching, there has been an increasing effort to support anti-poaching teams and laws. This is especially true in highly regulated areas such as national parks and reserves.[2]

Figure 3. Confiscated ivory ornaments, made from elephant tusks, are displayed in a warehouse before being destroyed by the U.S. Fish and Wildlife Service.
Photograph by Kate Miyamoto, 2013. CC BY 2.0.

Fortunately, elephants are an extremely resilient species. A study conducted by Foley and Faust focusing on the recovering elephant population in Tarangire National Park in Tanzania suggests that elephant populations can display extremely rapid growth over long time periods if they are protected and given sufficient land area and resources[5] (Figure 4). South Africa's protected areas have also become a refuge and stronghold for the African elephant. As a result, many reserves in South Africa are experiencing a boom in elephant populations, which could become an "elephant problem".[6] Elephants can cause major environmental damage by uprooting trees and eating tons of foliage, thus overpopulation threatens the balance of the surrounding ecosystem.[7,8] While this population increase may be a positive trend in terms of the poaching activity across Africa, it poses a challenge for fenced-in areas such as national parks and reserves where populations must be carefully monitored due to the limited space and resources.

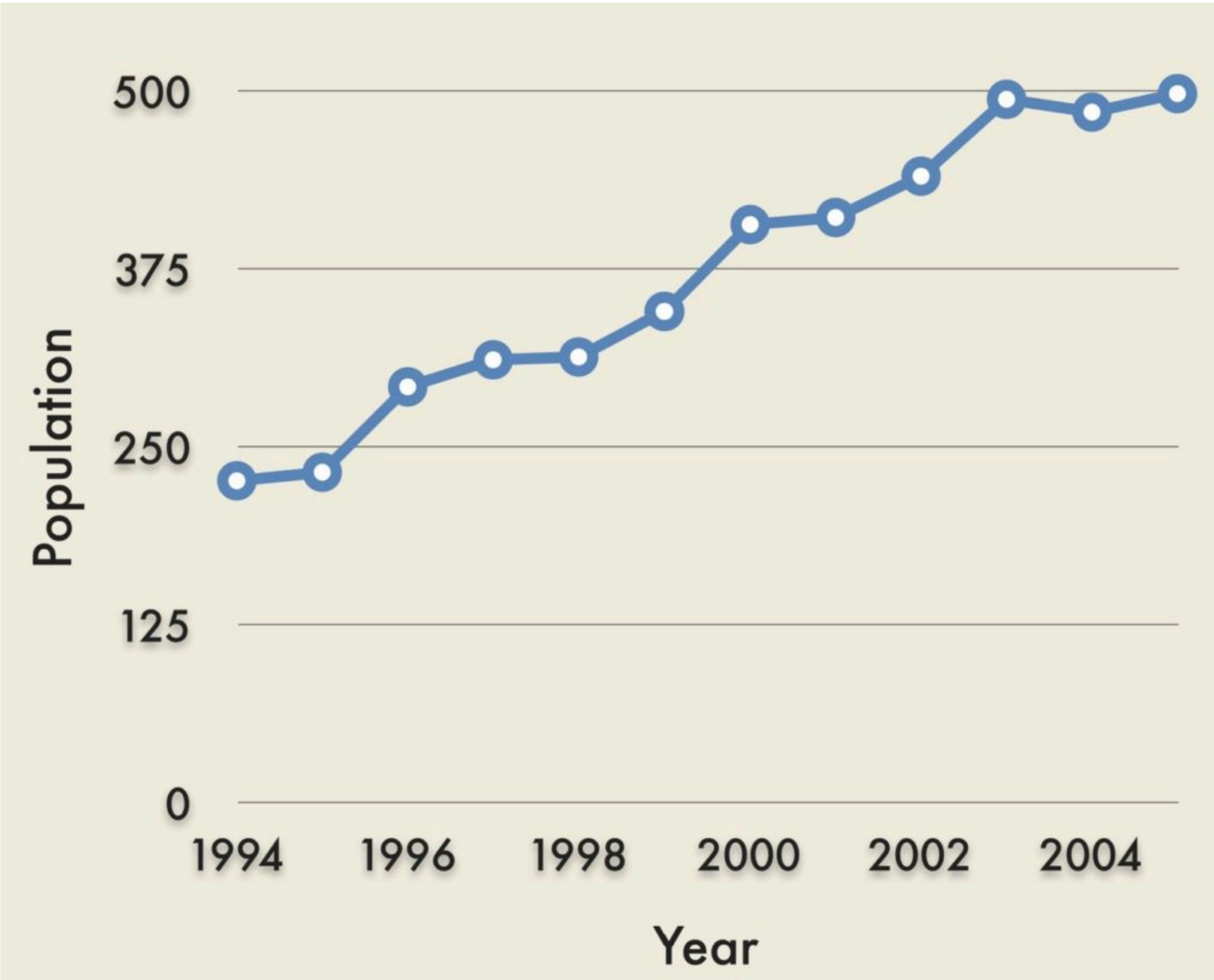

Figure 4. African Elephant Population in Tarangire National Park, Tanzania.
African elephants find refuge within Africa's National Parks where they are more protected from poaching. Research by Foley and Faust (2010) found that elephant populations are able to recover if given protection and resources.
Data from C. A. H. Foley and L. J. Faust, 2010.

Managers of the national parks and reserves must now institute elephant population management techniques. Some of these approaches include culling, translocation, or contraception.[3] In the past, culling was seen as a negative strategy for management, because it requires park rangers to gun down entire herds of elephants with automatic weapons from a helicopter. The rangers target entire herds because killing only some of the members would cause turmoil in the herd, causing infants to die, and the remaining females may scatter.[3] Another option is translocation, or moving elephants from an area of higher population density to one of lower population density. This is a timely and costly venture as elephants are difficult to immobilize and transport. In addition, bulls have been known to trample over fence lines and travel hundreds of miles just to get back to where they came from, rendering translocation completely useless.[9] Also, research suggests that interfering with social interactions and introducing foreign elephants into an area can cause significant increases in defensive behavior and social turmoil.[10]

Contraception is an increasingly enticing option for conservationists trying to control elephant populations and maintain a balanced savannah ecosystem. The most viable option is referred to as immunocontraception, a form of reducing births via vaccination of female elephants using porcine zona pellucida (pZP).[11] However, concerns exist about the side effects of the vaccine and how it could affect mating behavior and herd structure.[12] There is also a heavy cost involved with immunocontraception, as conservation managers must acquire the vaccines as well as the means to dispense them. Conservation managers must have access to helicopters, dart guns, and crew to properly administer the vaccines.[13] Despite the logistics involved, contraception is extremely effective. The population growth is expected to be reduced to near 50%.[7] A 2007 study conducted in the Greater Makalali Private Game Reserve in South Africa concluded that immunocontraception was a realistic, cost-effective management strategy for the African elephant population. Immunocontraception also minimized stress on the elephants.[9] Another recent study demonstrated that immunocontraception was effective in reducing the number of calf births, and did not cause any significant behavioral, social, spatial, or resource changes over an 11-year study period.[14]

Figure 5. Elephants travel in family units of around 10 closely related females and their calves. All the members of the parade, or herd of elephants, help to raise the young, allowing each female to give birth as often as every two years.
Photograph by Charles Peterson, 2013. CC BY-NC-ND 2.0.

In conclusion, contraception that targets female elephants seems like the most viable option for controlling the elephant populations. Alternating treatments in certain females would be necessary to maximize genetic diversity while still decreasing elephant birth rates. Unfortunately, humans have had a detrimental effect on African wildlife by pushing them out of their habitats and limiting their space and resources. The next best option to giving back the elephants' roaming ground is to help control their population growth by the least invasive and most humane way possible.[11] Immunocontraception is arguably the best option we have for addressing this issue in the most cost-effective and least-damaging manner to elephants and their environment. Further research is necessary to improve this management strategy and ensure it is being conducted with minimal detrimental effects on the African Elephant population.

References

1. World Wildlife Foundation. (2011). African Elephants. WWF. Retrieved from http://wwf.panda.org/
2. Blanc, J. (2008). Loxodonta Africana. IUCN 2013. IUCN Red List of Threatened Species Version 2013.2. Retrieved from http://www.iucnredlist.org/
3. Eveleth, R. (2011, December 22). The Elephant in the Room: How Contraception Could Save Future Elephants from Culling. Scientific American. Retrieved from http://www.scientificamerican.com/article/the-elephant-in-the-room/
4. Siebert, C. (2011, September). Elephant Poaching in Samburu. National Geographic. Retrieved

from http://ngm.nationalgeographic.com/2011/09/orphan-elephants/poaching-update
5. Foley, C.A.H. & Faust L.J. (2010). Rapid population growth in an elephant Loxodonta africana population recovering from poaching in Tarangire National Park, Tanzania. Oryx, 44(02): 205-212.
6. The International Union for the Conservation of Nature. (2014). The Elephant Database. Retrieved from http://www.elephantdatabase.org/preview_report/2013_africa/Loxodonta_africana/2012/Africa
7. Mackey, R.L., et al. (2009). Modelling the effectiveness of contraception for controlling introduced populations of elephant in South Africa. African Journal of Ecology, 47(4): 747-755.
8. Scheiter, S., & Higgins, S.I. (2012). How many elephants can you fit into a conservation area. Conservation Letters, 5(3):176-185.
9. Delsink, A. K., et al. (2007). Implementing immunocontraception in free-ranging African elephants at makalali conservancy. Journal of the South African Veterinary Association, 178(1): 25-30.
10. Shannon, G., et al. (2013). Effects of social disruption in elephants persist decades after culling. Frontiers in Zoology, 10(63).
11. Barber, M.R. & Fayrer-Hosken R.A. (2000). Possible mechanisms of mammalian immunocontraception. Journal of Reproductive Immunology, 46(2):103-124.
12. Kerley, G.I.H., & Shrader, A.M. (2007). Elephant contraception: Silver bullet or a potentially bitter pill? South African Journal of Science, 103(5-6):181-182.
13. Plaut, M. (2012, October 30). Will elephant contraception work in South Africa? BBC News. Retrieved from http://www.bbc.co.uk/news/world-africa-19990483
14. Delsink, A. K., et al. (2013). Lack of spatial and behavioral responses to immunocontraception application in African elephants (Loxodonta africana). Journal of Zoo and Wildlife Medicine, 44(4 Suppl.): S52-74.
15. Steward, Peter. (2013). [Photograph of a mother and calf African elephant in Samburu National Reserve, Kenya]. Retrieved from FlickrCommons. CC BY-NC 2.0.
16. Bamse. (2007). [Range Map of the African Elephant]. Retrieved from Wikimedia Commons. CC BY-SA 3.0. Modifications: Cropped and added key.
17. Miyamoto, Kate. (2013). [Photograph of ivory ornaments]. Retrieved from FlickrCommons. © U.S. Fish and Wildlife Service. CC BY 2.0.
18. Peterson, Charles. (2013). [Photograph of an elephant family in South Africa]. Retrieved from FlickrCommons. CC BY-NC-ND 2.0.

5.4 The Mysterious Case of Colony Collapse Disorder

Andrew T. Wood

Colony Collapse Disorder or CCD has decimated the honeybee population. Most scientists agree that it is caused by a combination of factors ranging from the environment, climate change, unknown viruses, and other pathogens. If CCD is not resolved, it will severely damage a multi-billion dollar food industry.

Figure 1. A European Honeybee (Apis mellifera) gathers nectar from a flower. Photograph by James Petts, 2014. CC BY-SA 2.0.

Since 2009, the population of Apis mellifera, or the honeybee (Figure 1), has been in continuous decline. Scientists are unsure of what is causing the decline, called Colony Collapse Disorder (CCD), but many researchers hypothesize it stems from numerous factors ranging from the misuse of pesticides to RNA viruses.[1,2,3,4,5,6] Diminished populations of honeybees can have a large impact on the quantity of crops produced and the global economy.[1,3,4,6,7] While there are many possible causes of CCD, microbes, pollutants, and stress factors are the three biggest influences that have contributed to the decline of honeybees.

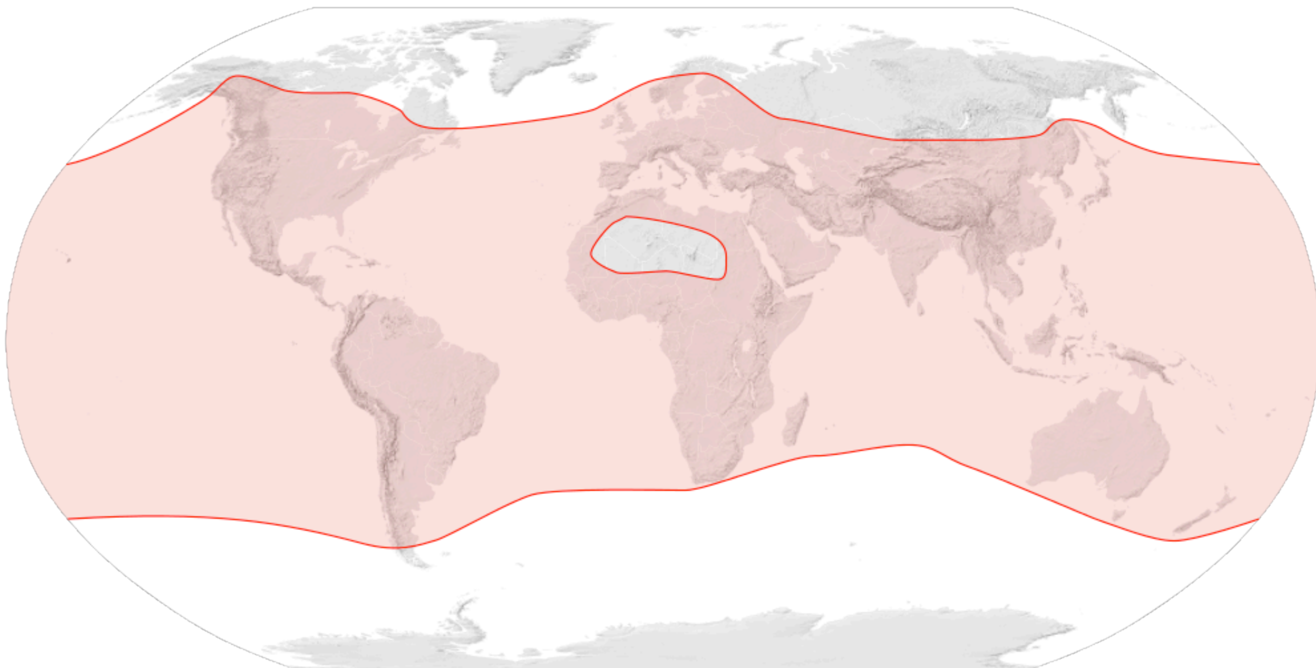

Figure 2. Distribution of the honeybee (Apis melifera).
While native to Europe, Asia, and Africa, the European Honeybee can now be found around the world.

Scientists are searching for possible causes of CCD on a microbial level due to the lack of clear indicators on a larger magnitude scale. While CCD only explains a small proportion of losses, it is prevalent in numerous independent populations. The three most researched groups of microbes are viruses, bacteria, and fungi.[8] Viruses can change honeybees at the cellular level by altering DNA and RNA strands. Scientists have documented around twenty positive RNA viruses, and these viruses can "affect the morphology, physiology, and behavior of bees and have been widely associated with weak and dying colonies both historically and recently".[8] As a result, it is possible an unknown virus has affected the bees' cognitive function and inhibited them from returning to the hive.[9] Healthy bees also attempt to save the hive by removing the infected bees.[8]

Bacteria have the advantage of being highly infectious and target the weak and young bees.[8] Well known diseases such as the American and European foul brood disease infect and kill the larvae, but are less hindering towards adults.[4] Tests have concluded that adults carry lower levels of these infectious bacteria.[8] A bacterial infection would explain the quick spread of disease within a colony. Lastly, infected bees do not return to the hive, thus an infection would be undetected in the healthy bees.

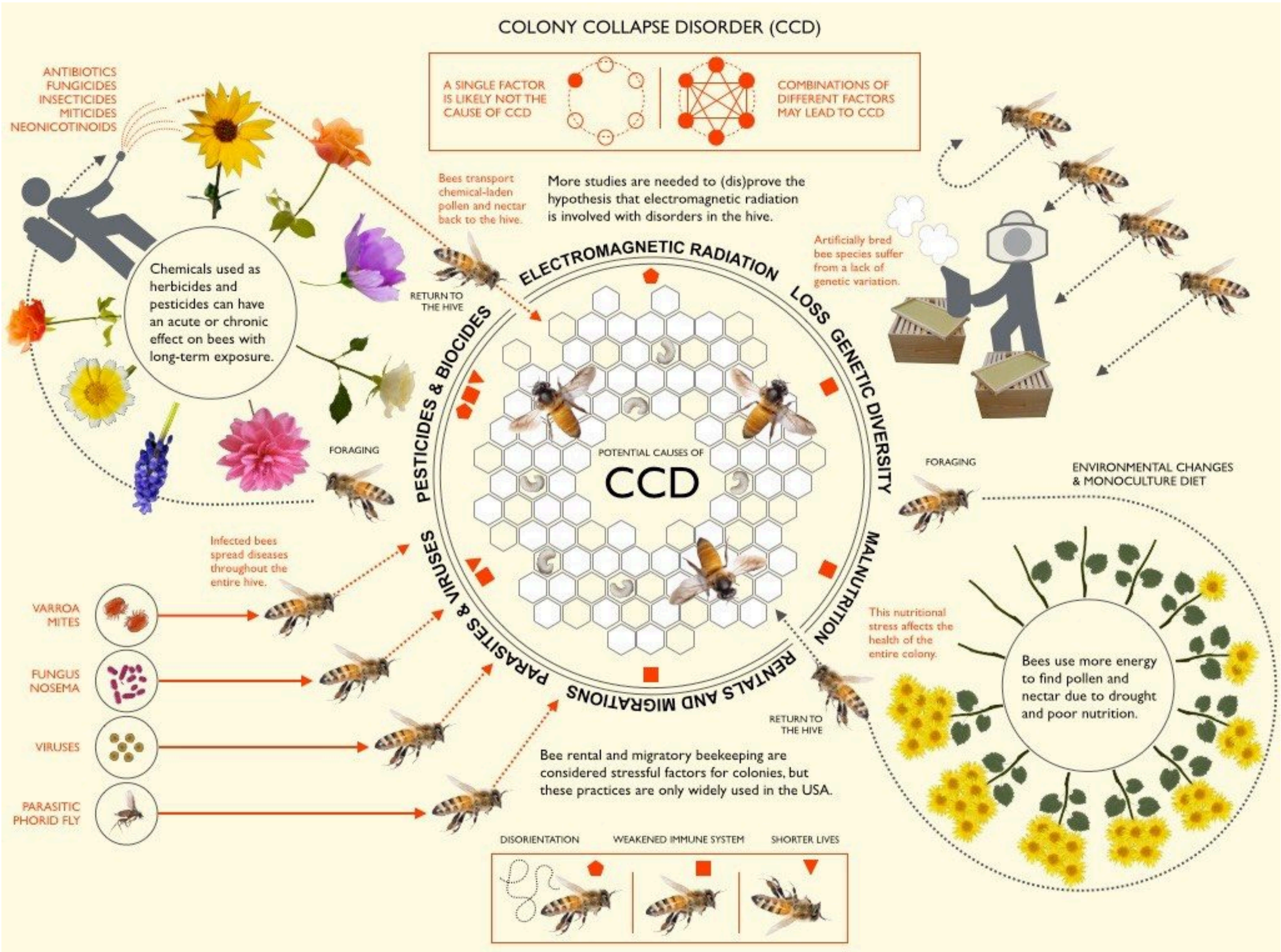

Figure 3.
Image courtesy of Giulia De Rossi, 2014. CC BY-SA 4.0.
Sunflower photo by Stan Shebs, 2008. CC BY-SA 3.0.
Peach rose photo by Scott Wylie, 2009. CC BY 2.0.
Cosmos photo by Magnus Manse, 2013. CC BY 2.0.
White rose photo by Scott Wylie, 2009. CC BY 2.0.
Yellow tidy tips photo by Alan Vernon, 2010. CC BY 2.0.
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Phorid fly photo by Inna Strazhnik, 2014. CC BY 2.0.
Honey bee photo by Karunakar Rayker, 2010. CC BY 2.0.

Fungi also have many ways of spreading around the colony and killing larvae.[8] Fungi can spread both vertically and horizontally. Vertically would be the queen passing it her brood during reproduction, whereas horizontally, hive mates transfer the fungi to each other by their close approximations within the hive. Bees have evolved to try to combat this spread, but their methods may sometimes cause more harm than good. For example, hives can produce special worker bees that "recognize larvae infected with chalkbrood fungus earlier in the disease process than workers from typical colonies, and subsequently remove the larvae before spore maturation".[8] Other less specialized workers remove the dead from the hive or eat them in an attempt to rid the colony of pathogens.[8] This is problematic because diseases can spread from the dead to the living when the worker bees eat them or come into contact with them. One possible reason why bees leave the hive is because workers detect the sickness and send them away to die. However, the queen is rarely sick and that may point to a horizontal disease path.[2]

Other stressors have also been known to affect bee health. Scientists are becoming more interested in the interaction of the environmental factors which include habitat loss and climate change. Climate change may impact organization levels of bee hierarchy by "changing the temporal activity of bees".[7] Plant biodiversity in many regions of the world has changed due to the introduction of foreign plants, pathogens, and other species of insects.[7] Some foreign plants were introduced to provide better resources for the bees. Other plants and bees have been introduced into the region and have caused new pathogens to come into contact with native honeybees.[7] Transplanted bees have an extremely difficult time adjusting to their new environment. Bees have to constantly move from location to location to pollinate crops around the United States, and as more colonies die, the healthy colonies must work harder to pollinate[8] (Figure 4). Lastly, the interaction of the foreign objects with the indigenous species can cause diseases to pass and mutate.

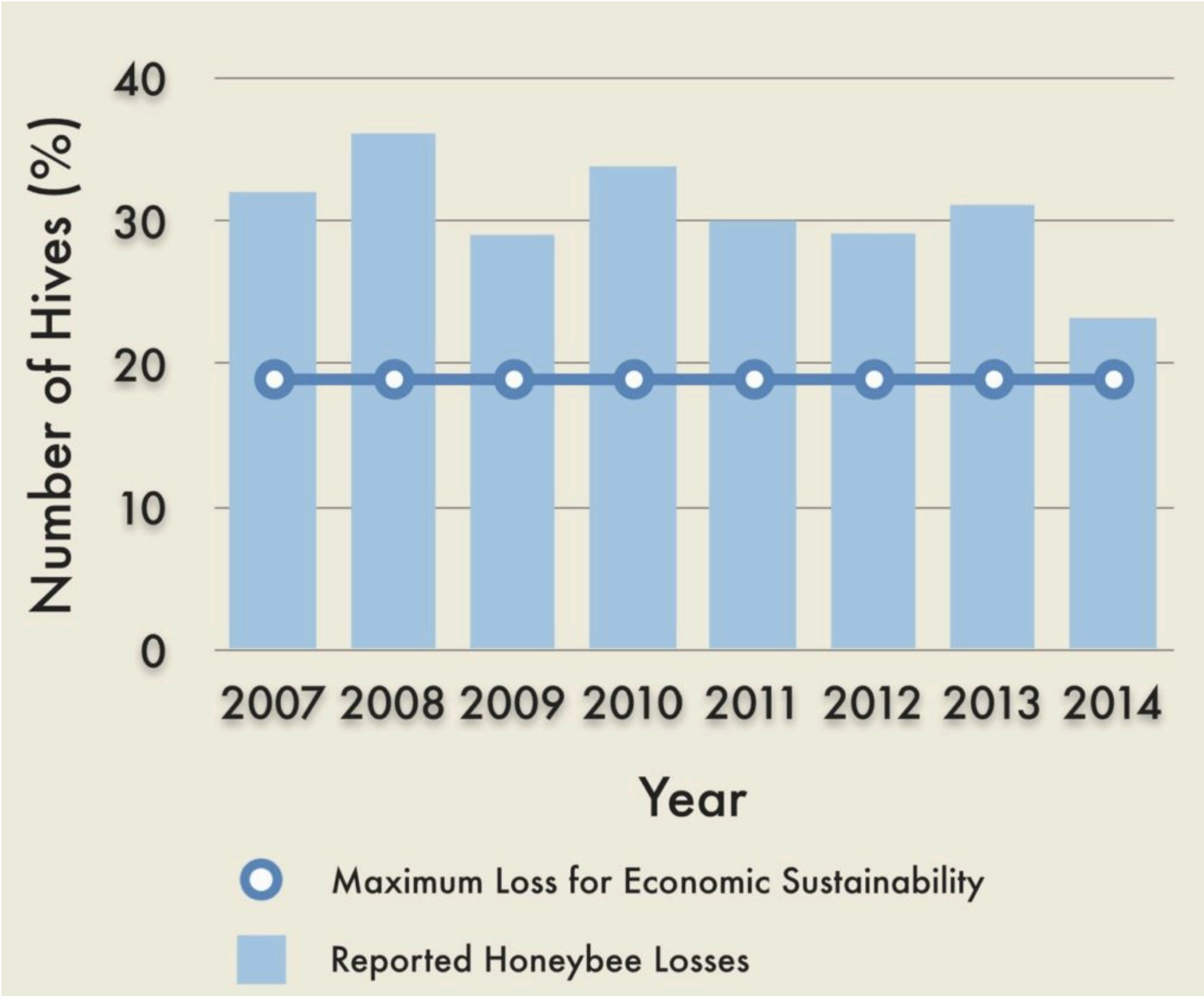

Figure 4. Reported Annual Honeybee Losses in the U.S.
Annual surveys conducted by the U.S. Department of Agriculture and collaborators show that since the winter of 2006/2007, honeybee mortality has remained above the level that beekeepers consider economically sustainable (18.9%).
Data from Kim Kaplan, 2006-2014.

Human made chemicals are also detrimental to the health of honeybees.[3,4,6,10] The Environmental Protection Agency (EPA) has tested the active ingredients in nearly all chemical compounds and they have deemed these compounds safe for use in mass application. Many of the benign chemicals in insecticides may not be entirely harmless. This is because they are considered non-active and do not face the same rigors of testing by the EPA. These 'inactive' chemicals may harm honeybees as well as other insects. They may also "alter honeybee gene expression for detoxification pathways and may down-regulate gene products"[10] and "alter physiological functions, immune responses, and detoxification functions in the host bees rendering them more susceptible to pathogens and pesticides".[10] The physical and mental health risks involved with these chemicals can either make bees sick through pathogens or can slowly kill them, and may also lead to higher mortality rates of future generations.[10]

Researching the causes of Colony Collapse Disorder is important because bees increase the yield of 96% of the crops that require animal pollination, and 75% of all crops that require insect pollination.[7] The global annual economic value of insect pollination was estimated at 153 billion Euros in 2005[7] (190.4 billion U.S. Dollars). Without honeybees to pollinate wild plants and cultivated crops, the global food industry would have to use artificial means for pollination and this would vastly increase the price of food products.[1,3,4,7] Honeybees are essential if humans hope to continue producing cheap food and food byproducts. In conclusion, honeybees are important to the humans because they affect the success of so many products used in our daily needs. Remedying Colony Collapse Disorder is imperative to ensure honeybee survival.

Figure 5. A beekeeper inspects a honeybee hive at a cherry farm in South Wales. Honeybees are often moved from farm to farm in order to pollinate crops.
Photograph by Nick Pitsas, 2007. CC BY 3.0.

References

1. Associated Press. (20017, May). Declining Honeybees a 'threat' to Food Supply. MSNBC.
2. Dainat, B., et al. (2012). Colony collapse disorder in Europe. Environmental Microbiology Reports. 123-125
3. Holland, Jennifer (2013, May 10). The Plight of the Honeybee. National Geographic.
4. Plumer, Brad (2013, May 3). Why are bees dying? The U.S. and Europe have different theories. The Washington Post.
5. Van Engelsdorp, D., et al. (2009). Colony Collapse Disorder: A Descriptive Study. Plos One. 4.8:1-17.
6. Walsh, Bryan (2013, May 7). Beepocalypse Redux: Honeybees Are Still Dying – and We Still Don't Know Why. Time.
7. Potts, S., et al. (2010). Global pollinator declines: trends, impacts and drivers. Trends in Ecology & Evolution. 25.6:345-353.
8. Evans, J.D., & Schwarz, R.S. (2011). Bees brought to their knees: microbes affecting honey bee health. Trends in Microbiology. 19.12:614-620.
9. Bromenshenk, J., et al. (2010). Iridovirus and Microsporidian Linked to Honey Bee Colony Decline. Plos One. 5(10):1-11
10. Berry, J.A., et al. (2013). Field-Level Sublethal Effects of Approved Bee Hive Chemicals on Honey Bees (Apis mellifera L). Plos One. 8(10):1-7
11. Petts, James. (2014). [Photograph of honeybee gathering nectar]. Retrieved from Wikimedia Commons. CC BY-SA 2.0.
12. Sémhur. 2011. [Map of the distribution of Apis melifera, the European Honeybee]. Retrieved from Wikimedia Commons. © Sémhur. CC BY-SA 2.0.
13. Kaplan, Kim. (2006-2014). Annual Survey Reports on U.S. Honey Bee Losses. U.S. Department of Agriculture.
14. CSIRO (Pitsas, Nick). (2007). CSIRO ScienceImage 6807 Dr Denis Anderson of CSIRO Entomology examining in a hive at a cherry farm near Young New South Wales. [Photograph]. Retrieved from Wikimedia Commons. © CSIRO. CC BY 3.0.
15. De Rossi, Giulia. (2014). [Diagram describing possible causes of Colony Collapse Disorder]. Retrieved from Wikimedia Commons. © DensityDesign Research Lab. CC BY-SA 4.0.
16. Shebs, Stan. (2008). [Photograph of sunflower]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
17. Wylie, Scott. (2009). [Photograph of peach rose]. Retrieved from Wikimedia Commons. CC BY 2.0.
18. Manske, Magnus. (2013). [Photograph of cosmos flower]. Retrieved from Wikimedia Commons. CC BY 2.0.
19. Wylie, Scott. (2009). [Photograph of white rose]. Retrieved from Wikimedia Commons. CC BY 2.0.
20. Vernon, Alan. (2010). [Photograph of yellow coastal tidy tips flower]. Retrieved from Wikimedia Commons. CC BY 2.0.
21. Kika De La Garza Subtropical Agricultural Research Center. (2005). [Photograph of varroa mite]. Retrieved from Wikimedia Commons. Public Domain.
22. Muir, Richard. (1927). [Micrograph of microorganisms]. Retrieved from Wikimedia Commons.

CC BY 4.0.
23. Strazhnik, Inna. (2014). [Photograph of phorid fly]. Retrieved from Phorid.net. CC BY 2.0.
24. Rayker, Karunakar. (2010). Honey Bee Macro. [Photograph]. Retrieved from FlickrCommons. CC BY 2.0.

5.5 Tigers- Naked and Alone in the Disappearing Sumatran Forests

Lydia F. Bednarski

The Sumatran tiger is struggling to survive on the Indonesian islands. Deforestation caused by human activity is destroying the rainforest habitat in which the tigers live. As their habitat continues to dwindle, human-tiger conflicts increase. Is there a way to save the Sumatran tiger before they become extinct?

Figure 1. This photograph of an adult Sumatran tiger was taken as part of the Sumatran Tiger Conservation Project.
Photograph by Roger Smith, 2012. CC BY-NC 2.0.

As a species, the tiger has become a "poster child" for conservation of endangered species. Three of the eight tiger subspecies are extinct due to human activity.[1] In Indonesia, the Sumatran tiger is the only remaining subspecies after two other subspecies went extinct in the mid-twentieth century.[2] The Sumatran tiger (Panthera tigris sumatrae) is extremely rare (Figure 1 and 2). Researchers are searching for ways to revive the population, but the tiger's elusiveness makes them difficult to study. However, new mapping methods allow biologists to study the tigers in their disappearing habitat as well as their interactions with humans. Researchers have created a mapping system using motion-activated cameras deployed in grids around Sumatran national parks.[1] Expectedly, it was discovered that tigers preferred denser forests as opposed to locations in which deforestation has occurred.[3] In Riau, Sumatra, deforestation continues at a rate of 9.8% per year.[4] The Sumatran tiger's shrinking habitat has forced them towards human societies where they occasionally prey on livestock, and in some instances, attack people. Sixteen tigers were killed in a five year period due to encounters with human societies, a grave toll for a population of only a few hundred.[2] These types of deaths, coupled with their increasing habitat loss, are enough to cause extinction for the Sumatran tiger in the near future. However, if Sumatra's National Tiger Recovery Plan is successful, there may be double the number of tigers by the year 2022.[4] The National Tiger Recovery Plan was enacted in July 2010 and its long term goal is to "double the number of wild tigers by securing source populations within the largest and most viable Sumatran tiger conservation landscapes by maintaining connectivity between these protected populations".[5]

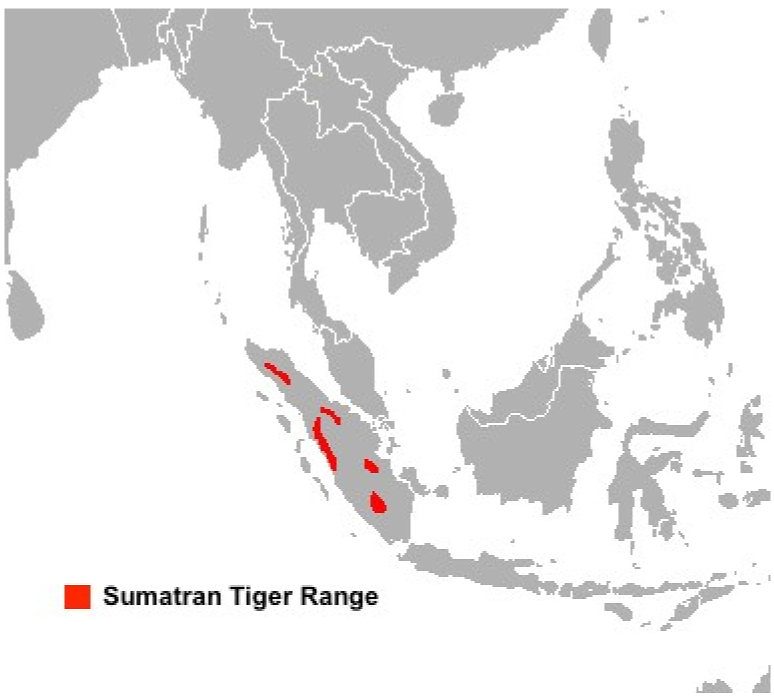

Figure 2. The Distribution of the Sumatran Tiger (Panthera tigris sumatrae).
The Sumatran tiger is only found on the island of Sumatra in western Indonesia. Its range is highly fragmented due to human encroachment and deforestation.
Modified from ToB, 2011. Public Domain.

Deforestation is the primary cause behind the Sumatran tiger's dwindling numbers (Figure 3). Since 1993, Sumatra has lost 48% of its forest cover.[6] Not only is deforestation harmful to tigers, it also accounts for 20% of the world's greenhouse gas emissions.[7] Similarly, 71% of tiger habitat in Asia is currently undergoing deforestation.[8] Rainforests are being cut down to create land for agriculture and the fell trees are used for fuelwood and timber-use products. In Sumatra, most of the logging is occurring in the lower elevation forests, which support high densities of Indonesian wildlife, including the Sumatran tiger.[4] Many of these forests are getting logged because there is little to no protection for them[9] (Figure 4). As a result, roads are built through the Sumatran forest. The roads bring high levels of human activity into the wilderness and reduce the tigers' habitat to smaller, less viable patches.[10]

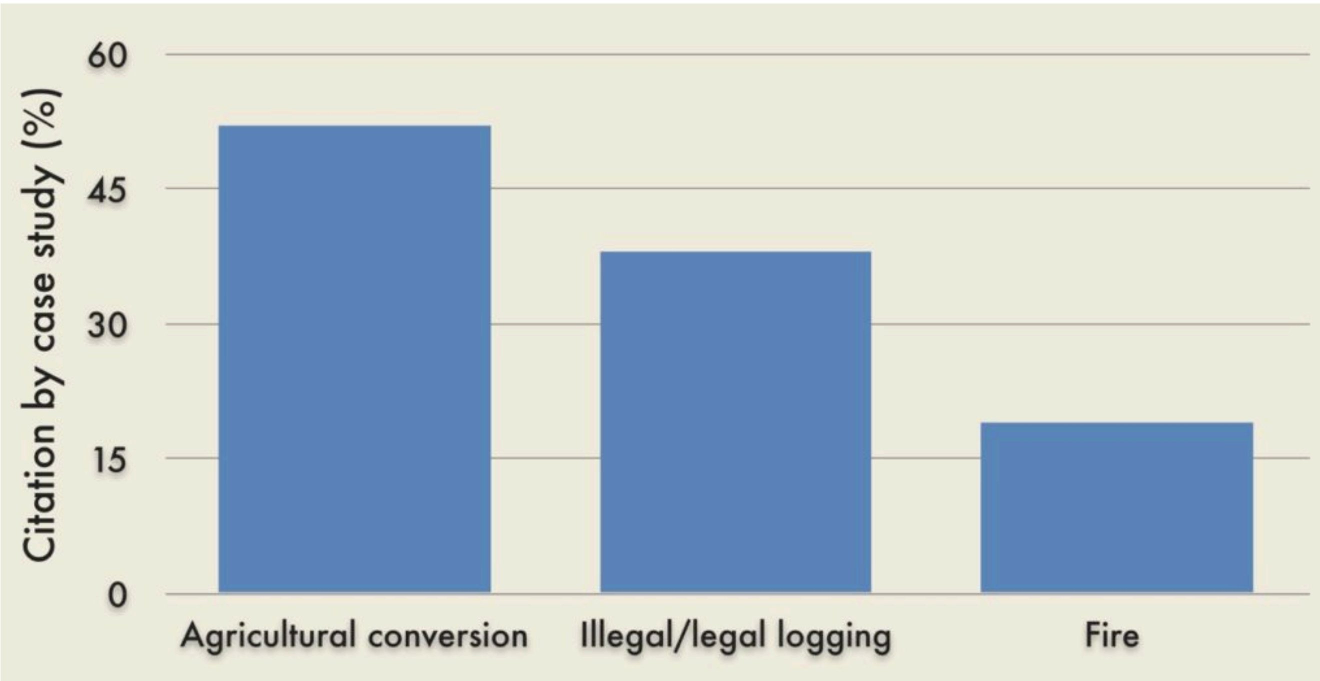

Figure 3. Causes of Deforestation and Degradation in Indonesia.
The conversion of land for agriculture is the leading cause of deforestation in Indonesia. Causes of deforestation were determined through a case study analysis.
Courtesy of P. Mondal and H. Nagendra, 2011. Public Domain.

Study Area	Average Annual Forest Loss (%)	Surveyed Area with Tiger Signs (%)
Kerinci Seblat-Batang Hari	0.8	69
Leuser-Ulu Masen	0.8	48
Southern Sumatra	1.2	41
Central Sumatra	1.9	68
Eastern Sumatra	2.2	67
Way Kambas National Park	2.3	20
Northern Riau	9.8	0

Figure 4. A summary of a Sumatra-wide field survey shows a negative correlation in deforestation rates and tiger presence. The most number of tiger signs were observed in Kerinci Seblat National Park where the forests are highly protected. Meanwhile, in Northern Riau, where deforestation is high, no tiger presence was observed. Data from Wibisono et al., 2011.

Presently, the majority of wild Sumatran tigers are located in 12 Tiger Conservation Landscapes (TCLs) covering approximately 88,000 km^2.[10] Tiger conservation is difficult because there are few options to monitor the tigers at Level 1 TCLs, and these options are not always accurate.[1] Infrared cameras provide the most exact locations of tigers and help biologists monitor the populations. When biologists conduct population counts, they deploy infrared cameras around the Sumatran rainforest. The cameras are checked every two weeks and are moved accordingly if tigers are found in other places.[3] A camera snaps photos for 20 seconds whenever a moving tiger is detected within range[11] (Figure 5). When tigers are captured on camera, biologists classify the animal by its size and stripe pattern. Tigers were often identified through these pictures. From these pictures, a map of Sumatra's tiger densities could be made. It was found that tigers preferred primary forests, which were less accessible than degraded forest sites found near logging roads. Only 29% of the tiger habitat patches are protected.[10] Distressingly, all the study sites in one experiment showed evidence of human disturbance including footprints, litter, and snare traps set for tiger prey.[1]

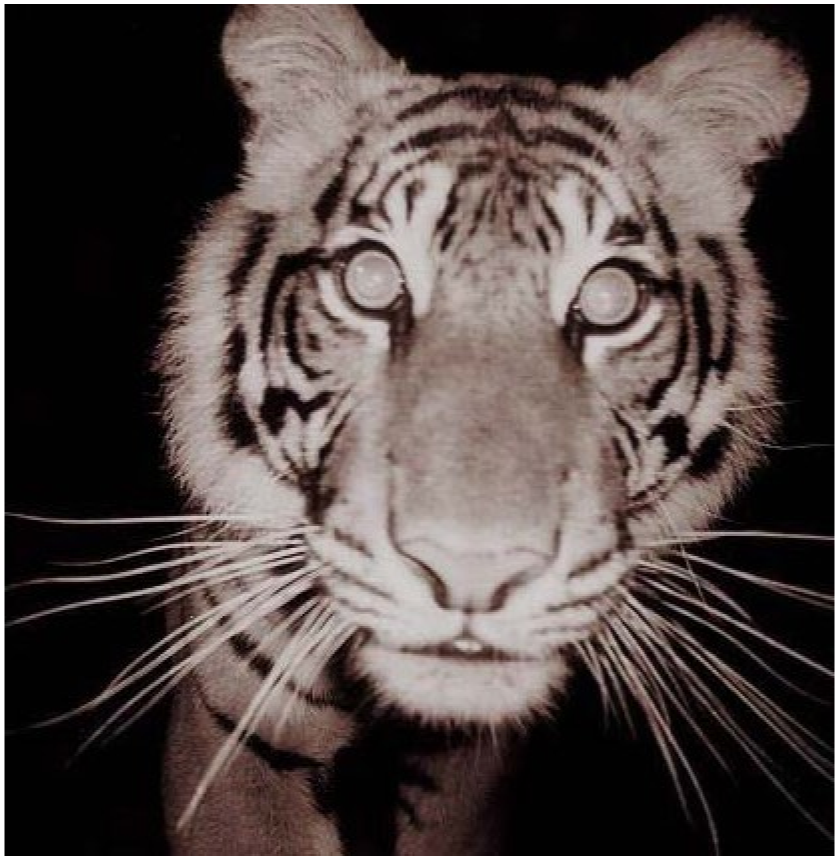

Figure 5. This photograph of a wild Sumatran tiger was captured in the Sumatran forest by a motion sensor wildlife camera.
Photograph used by permission of Jeremy Holden, 2006.

As the Sumatran tiger habitat decreases, human-tiger conflicts become more likely. Many Sumatrans are hostile towards tigers because they prey on livestock, attack humans, and cause insecurity within communities.[2] A negative local attitude towards tigers creates problems for conservationists, since community members will oppose protected tiger habitats.[2] During the years 1978-1997, tigers in Sumatra killed 146 people and wounded another 30 people.[2] A total of 870 livestock deaths by tigers were also reported during this time.[2] In response to these attacks, people illegally killed tigers, which negatively impacted the already small population. Because of the illegality of these killings, many tiger deaths caused by humans are not reported.[2] However, when Sumatran forest rangers began distributing compensation for human victims in 2003, reports more than doubled in 2004.

Kerinci Seblat National Park (KSNP) is a region of Sumatra where human-tiger conflicts are common. It is the largest protected area in Indonesia and one of the most important tiger habitats in the world.[2] Many people live in close proximity to KSNP, and therefore, close to tigers. Around 1.5 million people live in hundreds of villages situated around KSNP's 2,600 km boundary area.[2] The livestock owned by these villagers are left unsupervised to graze in open areas close to the edge of KSNP, creating easy prey for tigers.[2] Biologists are working with these villagers to move tigers away from the communities around KSNP. Disruptive stimuli such as light, audio, and chemical repellents have been used to scare tigers and their prey away from human settlements.[2] Despite these conflicts and losses, many people in Indonesia still see tigers as religious spirits, and often dedicate special ceremonies to them.[2]

The National Tiger Recovery Program was issued to implement a better protection plan for the Sumatran tiger in Indonesia.[5] The priorities of the recovery program were to create a specialized tiger law enforcement team, a management system, and a legal basis to have better reign over the endangered cats.[5] The conservation team also wants to create tiger conservation funds to ensure sustainable funding for future conservation projects.[5] It was estimated in 2010 that the total cost of fully protecting tiger natural habitat was 82 million dollars.[12]

The Sumatran tiger is one of the most endangered mammals left on Earth. Deforestation of their rainforest habitat has driven the tigers towards human communities. Attacks on humans and livestock have created tension and hostility between villages and Sumatran tigers. Although the tiger seems like a threat to human settlements, it is vital to the greater Sumatran ecosystem. The Ministry of Forestry of Indonesia created The National Tiger Recovery Plan in 2010, which is the government's response to the decreasing tiger populations in Sumatra. Although natural causes such as forest fires or erosion do cause some habitat loss, it is imperative that the Sumatran government limits deforestation due to human activity. The National Tiger Recovery Plan is Sumatra's best defense to prevent the extinction of another tiger species.

References

1. Linkie, M., et al. (2006). Assessing the viability of tiger subpopulations in a fragmented landscape. Journal of Applied Ecology, 43:576-586
2. Nugraha, R.T. & Sugardjito, J. (2009). Assessment and management options of human-tiger conflicts in Kerinci Seblat National Park, Sumatra, Indonesia. Mammal Study, 34:141-154
3. Linkie, M., et al. (2008). Conserving tigers Panthera tigris in selectively logged Sumatran forests. Biological Conservation, 141:2410-2415
4. Wibisono, H.T., et al. (2011). Population status of a cryptic top predator: An island-wide assessment of tigers in Sumatran rainforests. PLoS ONE. 6:11
5. Ministry of Forestry Republic of Indonesia. (2010). National Tiger Recovery Program INDONESIA. [PowerPoint Slides]. Retrieved from https://openparksnetwork.org/gtidocs/01F0CF6D07A72F4F887B3D1371E124DD.ppt
6. Kanter, James. (2008 October 9). Agreement Reached to Save Sumatran Forests. The New York Times.
7. Gelling, Peter. (2007 December 6). Forest loss in Sumatra Becomes a Global Issue. The New York Times, pp A14.
8. Mondal, P & Nagendra, H. (2011). Trends in Forest Dynamics in Tiger Landscapes Across Asia. Environmental Management, 48:781-794

9. Sunarto, et al. (2013). Threatened Predator on the Equator: multi-point abundance estimates of the tiger Panthera tigris in central Sumatra. Oryx, 47:211-220
10. Wibisono, H.T. & Pusparini, W. (2010). Sumatran tiger (Panthera tigris sumatrae): A review of conservation status. Integrative Zoology, 5:313-323
11. Goodman, David J. (2011 May 9). Cameras Capture Endangered Tigers in Sumatra Forest. The New York Times.
12. Guynup, Sharon. (2014 January 13). Three Thousand Wild Tigers. National Geographic.
13. Smith, Roger. (2012). [Photograph of an adult Sumatran tiger]. Retrieved from FlickrCommons. CC BY-NC 2.0.
14. ToB. (2011). [Distribution Map of Panthera tigris sumatrae]. Retrieved from Wikimedia Commons. Public Domain. Modifications: Cropped and added key.
15. Holden, Jeremy. (2006). [Photograph of a wild Sumatran tiger caught by a motion sensor wildlife camera]. Retrieved from Flickr. © Jeremy Holden/FFI. All Rights Reserves.

5.6 White-Nose Syndrome in North Americans Bats

Samantha K. Runser

In 2006, scientists discovered a disease that has the potential to devastate multiple species of hibernating bats in North America. The disease is known as white-nose syndrome and it is extremely lethal to bat populations. The loss of bat populations will have disastrous effects on many ecosystems.

Figure 1. A healthy Northern Long Eared Bat (Myotis septentrionalis). Photograph by Al Hicks, 2007. CC BY 2.0.

Bats play an integral part in many North American ecosystems, including in the eastern United States. They are responsible for keeping insect populations including mosquitos and moths under control. Some bat species also help with seed distribution and pollination of flowers and plants. Many species of bats are considered to be keystone species, and therefore are vital to their ecosystems. However, a recently discovered disease is threatening the existence of bats and may ultimately jeopardize entire ecosystems.

In 2006, scientists in New York discovered and documented a series of caves that showed evidence of white-nose syndrome. Originally, white-nose syndrome (WNS) was isolated to a few caves in New York. However, the disease has now spread to 22 states and several Canadian provinces[1,2] (Figure 2). There are seven North American bat species that are affected by WNS including the big brown bat (Epitesicus fuscus), the little brown bat (Myotis lucifugus) (Figure 3), the northern long-eared bat (Myotis septentrionalis) (Figure 1), the Indiana bat (Myotis sodalis), eastern small-footed bat (Myotis leibii), gray bat (Myotis grisescens), and the tri-colored bat (Perimyotis subflavus).[3] All these bats species hibernate.[3]

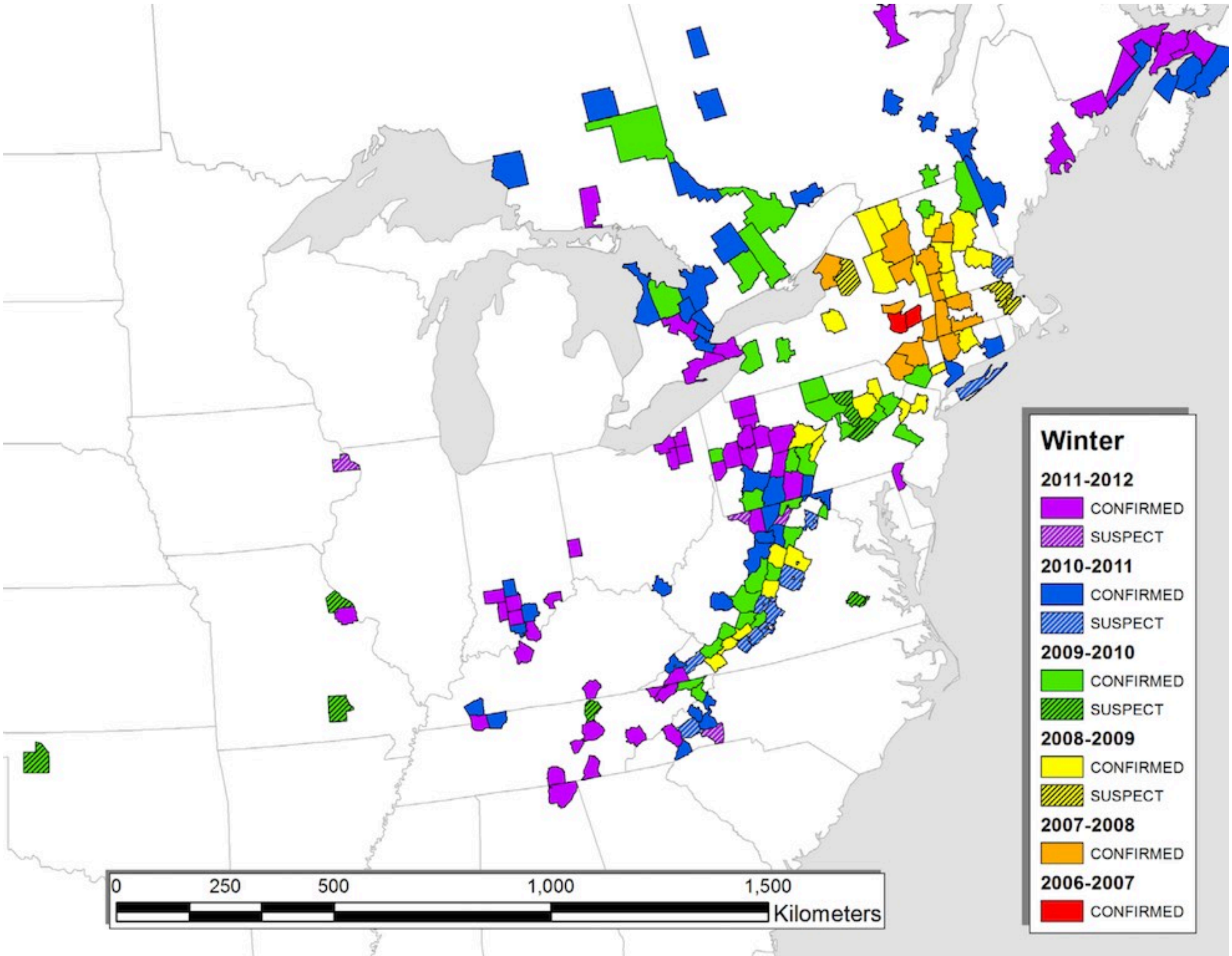

Figure 2. Confirmed and Suspected White-Nose Syndrome Presence by County.
Since the winter of 2006-2007 (red), white-nose syndrome has been confirmed in numerous Eastern U.S. states and in several Canadian territories. Histopathology analysis and PCR are used to detect the presence of WNS and the fungus that causes the disease.
Modified from P. M. Cryan et al., 2013. CC BY 2.0.

To determine if bats have been infected by WNS, scientists search for noticeable patches of skin erosion that include visible white fungal growth on the bat's muzzle, wings, and ears[4] (Figure 3). They also take tissue samples and search for significant losses in muscle tissue as well as discoloration.[4] Infected bats demonstrate irregular behavior such as flying during the day, have frequent interruptions during normal hibernation periods, and exhibit sporadic flight patterns.[4]

Scientists have debated the cause of WNS. The fungus they believe to be responsible for WNS is known as Pseudogymnoascus destructans (formerly known as Geomyces destructans)[4] (Figure 3). When the disease was first documented in 2006, several scientists hypothesized that the outbreak was caused by a genetic mutation in the fungus P. destructans. Fungal samples were taken from seven different caves in New York. The scientists grew the fungus for a year and then assembled the nucleotide sequences in the DNA. Through analysis of the DNA, the scientists discovered a repeating sequence of ten genes that were connected as a single clonal genotype in the P. destructans population.[5] The scientists suggest that the rapid spread to nearby caves was caused by the gene in the fungus that replicated very efficiently. Furthermore, data implied that the fungus was spread to other caves by natural channels such as through air, soil, and water.[5]

Figure 3. A little brown bat, one of the most common bats in North America, shows visible signs of white nose syndrome on it's muzzle, ears (Top), and wings (Right). Pseudogymnoascus destructans, the fungus that causes WNS, exhibits a gray color when grown in a laboratory (Left).
Photographs by Ryan Von Linden, 2008. CC BY 2.0 (Top and Right) and D. B. Radabaugh, 2013. CC BY-SA 3.0 (Left).

Other scientists developed an alternate hypothesis regarding the cause and spread of the fungus.

They suggest the outbreak was caused by anthropogenic means. These scientists used genetic markers to track the spread of the disease and deduced that P. destructans originated in Europe and was accidentally transported to the United State by humans. The first infected sites were popular commercial caves that saw regular tourist activity, providing further evidence of a link between the spread of WNS and humans.[6] Presently, nearly all experts believe that the spread of WNS is a combination of both hypothesizes, however more research needs to be completed to confirm these findings.

WNS has had devastating effects on hibernating bat species in North America. It is estimated that at least 5 million North American bats have perished due to WNS, with mortality rates often exceeding 90 percent.[7] To assess this dramatic loss of life, considerable bat counting experiments were performed and hazard models were created and analyzed. These experiments tested the association between mortality rates and the size of bat colonies. Population sizes ranged from less than 1000 bats to over 5000 bats.[8] Findings suggest that colonies with greater concentrations of bats had higher mortality rates than those with fewer individuals.[8] These experiments confirmed the lethality of WNS and also its effectiveness at annihilating large bat populations in a short time period.

With drastically high mortality rates from WNS, researchers are calculating if several bat species will be at risk of extinction.[7] The two bat species that are most affected by WNS are the little brown bat and the endangered Indiana bat. The Indiana bat population model suggests that in the next 20 years over 90 percent of the population will encounter WNS, and in less than 50 years the total population will decline by 69 percent.[7]

Similar trends are present in little brown bat populations. In one experiment, five different scenarios were simulated with each scenario having a different mean decline rate. At the highest decline rate of 45 percent, it was estimated that there was a 99 percent chance the species would be extinct within the next 16 years.[8] However, even if the mortality rate decreases over time, the regional population is estimated to radically change in less than 20 years.[8] Populations may decline from 6.5 million individuals to less than 65,000 individuals.[8]

Figure 4. In addition to protecting caves with bat-friendly gates, the Vermont Fish and Wildlife Department post signs warning visitors that disturbing hibernating bats may result in a fine.
Photograph by Ann Froschauer, 2012. CC BY 2.0.

If immediate action is not taken to prevent the spread of WNS, hibernating bats in North America may face extinction. If bats were to disappear completely it would have numerous negative impacts on the entire ecosystem. Insect populations left uncontrolled would consume plants and foliage at a rapid rate, leading to further problems. To help combat the spread of WNS, several states have shut down caves from public access.[9] Labs are developing vaccines and antibiotics to help save the bats.[6] It is promising for the future of North American bat populations that alleviating actions are underway, but it is vital that a definitive solution to WNS be discovered before these bats are extinct.

References

1. Blehert, D.S., et al. (2008). Bat White-Nose Syndrome: An Emerging Fungal Pathogen, Science, 328:227

2. Raudabaugh, D.B., & Miller, A.N. (2013). Nutritional capability of and substrate suitability for Pseudogymnoascus destructans, the causal agent of bat white-nose syndrome. Plos One,8:10.
3. Turner, G.G., et al. (2011). A Five-year Assessment of Mortality and Geographic Spread of White-nose Syndrome in North American Bats and a Look to the Future. Bat Research News, 52:13-27.
4. Cryan, P.M., et al. (2013). White-nose syndrome in bats: illuminating the darkness. BMC Biology, 11:47.
5. Rajkumar, S., et al. (2011). Clonal genotype of Geomyces destuctans among bats with white nose syndrome, New York, USA. Emerging Infectious Diseases, 17:1273-1276.
6. Eskew, E.A. & Todd, B.D., (2013). Parallels in Amphibian and Bat Declines from Pathogenic Fungi. Emerging Infectious Diseases. 19:379-385.
7. Thogmartin, W.E., et al. (2013). White-nose syndrome is likely to extirpate the endangered Indiana bat over large parts of its range. Biological Conservation. 160:162-172.
8. Wilder, A.P., et al. (2011). Risk factors associated with mortality from white-nose syndrome among hibernating bat colonies. Biology Letters. 7:950-953.
9. Frick, W.F., et al. (2010). An Emerging Disease Causes Regional Population Collapse of a Common North American Bat Species. Science, 329:679-682.
10. Hicks, Al. (2007). [Photograph of a healthy northern long eared bat]. Retrieved from FlickrCommons. © U.S. Fish and Wildlife Service. CC BY 2.0.
11. Cryan, P.M., et al. (2013). The spread of bat white-nose syndrome and the fungus (Geomyces destructans) that causes the disease. [Map]. Retrieved from http://www.biomedcentral.com/1741-7007/11/47 © 2013 Cryan et al; licensee BioMed Central Ltd. CC BY 2.0. Modifications: Cropped.
12. Von Linden, Ryan, New York Department of Environmental Conservation. (2008). Little brown bat; close-up of nose with fungus. [Photograph]. Retrieved from FlickrCommons. © U.S. Fish and Wildlife Service. CC BY 2.0.
13. Raudabaugh, DB. (2013). [Photograph of a Pseudogymnoascus destructans culture]. Retrieved from Wikimedia Commons. CC BY-SA 3.0.
14. Von Linden, Ryan, New York Department of Environmental Conservation. (2008). Little brown bat; fungus on wing membrane. [Photograph]. Retrieved from FlickrCommons. © U.S. Fish and Wildlife Service. CC BY 2.0.
15. Froschauer, Ann. (2012). Cave closed signs. [Photograph]. Retrieved from FlickrCommons. © U.S. Fish and Wildlife Sercive. CC BY 2.0.

Appendix

NASA, 2002. *Retrieved from Wikimedia Commons. Public Domain.*

Chapter One Image

St Louis Julie, U.S. Fish and Wildlife Service. (2013). Chenega glacier an active glacier. [Photograph]. Retrieved from Wikimedia Commons. Public Domain.

Chapter Two Image

Zimmerman, Matt. (2007). Slash and burn agriculture in the Amazon, [Photograph]. Retrieved from Flickr. CC BY 2.0.

Chapter Three Image

U.S. National Archives and Records Administration. (1972). Power Lines Pass From Nearby Hoover Dam to Southern California. [Photograph]. Retrieved from Wikimedia Commons. Public Domain.

Chapter Four Image

epSos.de. (2011). Water Pollution with Trash Disposal of Waste at the Garbage Beach. [Photograph]. Retrieved from Flickr. CC BY 2.0.

Chapter Five Image

Herbert, Neal, National Park Service. (2014). Bull elk, Blacktail Deer Plateau. [Photograph]. Retrieved from Flickr. CC BY 2.0.

Glossary

ABIOTIC
nonliving components of an ecosystem

ACCLIMATION
to become accustomed to a new climate or environment; to physically adapt

ACTIVE INGREDIENT
an ingredient that is biologically active in a formulated product

AGENT ORANGE
an herbicide used by the U.S. military to defoliate forests during the Vietnam War

AGRO-ECOSYSTEM
The area of land that is influenced by or that supports agricultural activity; land used for crops, pasture, and livestock, the adjacent uncultivated land that supports other vegetation and wildlife and the associated atmosphere, the underlying soil, ground and water, irrigation channels, and drainage networks

AIR QUALITY INDEX (AQI)
a numerical index used by government agencies to inform the public of air quality levels

ALGAL BLOOM
a rapid increase of accumulation in the population of algae (typically microscopic) in an aquatic system

ALKYLPHENOL
a commonly accepted marker of industrial and urban pollution; a family of organic compounds used in the production of detergents and other cleaning products

ALLUVIUM
a deposit of sand, mud, or other sediment formed by flowing water

ALPHA (MALE/FEMALE)
the highest ranking member of a group of animals that has reserved breeding rights and first choice of food from a kill

ANADROMOUS
a species which migrates from the sea to freshwater to reproduce

ANNUAL CROPS
crops that grow, produce seeds, and die in a year and must be replanted each season

ANTHROPOGENIC
caused by or related to human action; originating in human activity

ANTI-SCALANT
a chemical that inhibits or delays precipitation and subsequent scale formation

AQUACULTURE
Farming of aquatic organisms (plant or animal) in any water environment (ocean, pond, or river)

AQUEDUCT SYSTEM
a series of pipes, ditches, canals, tunnels, and supporting structures used to transport water from its source to its main distribution point

AQUIFER
an underground layer of permeable rock or soil that is saturated with water; a geological formation containing ground water
ARID
a region characterized by a severe lack of available water to the extent of hindering or preventing the growth and development of plant and animal life
ATMOSPHERE
the layer of gases surrounding Earth and held by Earth's gravity
ATMOSPHERIC RIVERS
regions of intense moisture over oceans that transport moisture from lower altitudes to higher altitudes
ATOLL
a region characterized by a severe lack of available water to the extent of hindering or preventing the growth and development of plant and animal life
BACTERIA
a single-celled, prokaryotic organisms that lacks a nuclei
BALLAST WATER
water taken into the haul of a shipping vessel to provide stability
BASHAR AL-ASSAD
the President of Syria since 2000
BIODIVERSITY
the variety of life on Earth or in a particular habitat or ecosystem
BIOLOGICAL CONTROL
biocontrol, a management practice that involves introducing a predator to an area to regulate the population of a pest
BIOMAGNIFICATION
the increased level of substances within the tissue of predators as a result of consuming organisms that contain bio-accumulated substances such as mercury
BIOMASS
material from plants and animals that can be used for energy
BIOTIC
the living or organic components of an ecosystem
BIRTH DEFECT
structural or functional abnormalities present at birth that cause physical or mental disability
BORNEO
island in Indonesia, east of Sumatra, which is mountainous and has extensive rainforests
BRINE
water saturated with salt; a liquid with high salinity
BROADCAST
to uniformly distribute fertilizer on a soil surface without working it into the soil
BYCATCH
a non-target organism that is caught unintentionally when harvesting a target species
CALCIUM CARBONATE

$CaCO_3$; a common chemical compound composed of three main elements calcium, carbon and oxygen

CANCER

a type of disease characterized by unregulated cell growth

CANINE DISTEMPER

a viral disease associated with canines that affects the lymphatic and nervous system

CARBON CREDITS

a permit that represents carbon removed from the atmosphere, which can be purchased by companies or governments to offset the carbon emissions they generate

CARBON SINK

a process or material in an environment that removes carbon dioxide from the atmosphere

CARCINOGENIC

cancer causing

CARRYING CAPACITY

the population size that an area can support indefinitely

CERES

a non-profit organization advocating for sustainability leadership

CESIUM-137

one of the common fission products of uranium nuclear power plants

CLEAN AIR ACT

U.S. law that authorizes the EPA to set standards for dangerous air pollutants and enforce those standards

CLEAN WATER ACT

U.S. federal legislation that regulates the release of point source pollution into surface waters and sets water quality standards for those waters

CLIMATE

long-term weather conditions in a particular region

CLIMATE CHANGE

a change in global climate patterns such as rainfall and average regional temperature

CLIMATOLOGY

the scientific study of Earth's climates, climate variability, climate change, and effects of climate on the biosphere

CNIDARIAN

an invertebrate belonging to the Cnidarian phylum; they are characterized to have radial symmetry and a saclike internal cavity

COLIFORM BACTERIA

type of bacteria that are universally found in the feces of warm blooded animals; commonly used as a water quality indicator

COLONIES

refers to individual organisms of the same species living closely together

COLONY COLLAPSE DISORDER (CCD)

a disorder in honey bees categorized by sudden loss of worker bees, lack of dead bodies, and delayed invasion from attackers

COMMODITY
a physical substance that is uniform in quality and can be bought and sold
CONDENSE
to change from a gas to a liquid
CONDUCTOR
a material which easily permits the flow of electrons, often an electric current
CONSERVATION
a political, environmental, and social movement to help protect natural resources and wildlife from exploitation
CONTAMINATION
to make something dangerous, dirty or impure by adding something harmful or undesirable to it
CONTRACEPTION
a technique used to prevent pregnancy
CORAL BLEACHING
the expulsion of the algae living within coral's tissues causing it to die
CORRELATION
a statistical relationship involving the dependence of two or more variables
CRITICALLY ENDANGERED
a species that is facing a very high risk of extinction
CRITTERCAM
a camera that is attached to a wild animal with intent to study the animal's behavior and ecology
CROP YIELD
the amount of product a crop produces per unit of land in a given time
CULLING
a method of population control that involves the killing of an entire family unit
DAMASCUS
the capital city of Syria
DEFORESTATION
removal of forest areas by humans for non-forest use, often for agriculture
DESALINATION
the removal of salt from a water source to convert it to fresh water, often used with seawater
DESERTIFICATION
the increased degradation of drought affected areas, causing them to become deserts
DIABETES
a metabolic disorder defined by high blood sugar and insulin resistance
DIOXINS
a group of chemically related compounds that are classified as environmental pollutants
DISRUPTIVE STIMULI
chemical, light, or audio repellents used to try and deter organisms
DISTILLATION
the process of separating substances in a mixture
DNA
deoxyribonucleic acid; found in all living organisms and contains genetic information

DROUGHT

an extended amount of time with little to no precipitation

ECOLOGICAL SOCIETY OF AMERICA

a nonpartisan, nonprofit organization of scientists founded to promote, conduct, and disseminate studies in the ecological sciences

ECOSYSTEM

all of the organisms in a given area interacting in a physical environment

EDNA

Environmental DNA; genetic material left behind by a species

EFFLUENT

liquid waste discharged into a body a water; outflow from a sewage treatment plant that is rich in nutrients

ELECTRIC FISH BARRIER

a tool that sends low-level electric currents into a body of water to cause discomfort in fish and cause them move away from the affected area; used to regulate the movement of fish

ELYTRA

one of the anterior wings in beetles and other insects that serve to protect the delicate posterior pair of functional wings

EMERALD ASH BORER

a green beetle that was accidentally transported from Asia to North America in the 1990s and has caused widespread destruction of ash trees in the United States and Canada

EMISSIONS

the production and discharge of a gas

ENDANGERED

a species that is threatened with extinction

ENDOCRINE DISRUPTOR

a chemical that interferes with the endocrine system, typically mimicking a hormone or preventing a hormone from having effect

ENDOCRINE SYSTEM

the system cells, glands, and tissue within an organism that is responsible for secreting hormones into the bloodstream

ENTRAINMENT

the loss of fish during water diversion often occurring when fish enter irrigation systems and become isolated when diversion ends

ENVIRONMENTAL PROTECTION AGENCY (EPA)

a federal agency in the United States tasked with implementing legislation concerning the protection of the environment

ENVIRONMENTAL SUSTAINABILITY INDEX

a measure of a country's overall progress towards environmental sustainability

ENZYME

a molecular protein that acts as a catalysts and facilitates complex biological reactions

EROSION

the process by which something is gradually worn away by natural forces (wind, water, or other natural agents)

EUROPEAN UNION

economic and political union of 28 member states that are located primarily in Europe

EUTROPHICATION

the process by which a body of water is enriched with nutrients (nitrogen and phosphorus) stimulating excessive growth of photosynthetic organisms like algae. Human activities can accelerate the process.

EXTINCTION

the complete loss of a species

EXTIRPATION

describes a species that is locally extinct in one or more areas within its historical range

FALLOUT

airborne radioactive particles that gradually fall back to Earth after a nuclear blast

FARADAY'S LAW

Faraday's Law of induction states that the flow of electricity will be induced on a conductor when it is in the presence of a varying magnetic field. this principle allows for the generation of electricity by moving magnets through coils of wire.

FECUNDITY

related to fertility; the actual reproductive rate of an organism

FIELD TRIALS

small, controlled fields of genetically modified plants used to conduct research

FLOY TAG

a small piece of plastic attached to live fish as part of scientific studies; a company which produces tags used to specifically identify live fish as part of studies

FOLSOM LAKE

a reservoir in Northern California formed by the Folsom Dam and that provides flood control, drinking water, hydroelectricity, and water for irrigation to the surrounding communities

FOOD AND DRUG ADMINISTRATION (FDA)

a federal agency of the United States government found within the Department of Health and Human Services which is responsible for protecting the public health by assuring the safety, efficacy and security of human and veterinary drugs, biological products, medical devices, food supply, cosmetics, and products that emit radiation

FOSTERING

when a female cares for and raises an orphaned juvenile in addition to her own offspring or after the death of her biological offspring

FOUL BROOD DISEASE

a disease in bees in which bacteria attack larvae and kill them before they mature

FRACKING FLUID

a combination of sand, liquids, and chemicals used in the hydraulic fracturing process which are pumped underground to break away natural gasses from permeable rock layers

FUNCTIONAL EXTINCTION

when a population becomes so reduced that it no longer plays an important role in the way an ecosystem functions

FUNGUS

a diverse group of eukaryotic single-celled or multicelled organisms that live by decomposing organic material

GAME RESERVATION

a controlled area used for wildlife conservation which sometimes allows regulated hunting

GENE

the hereditary material of an organism that direct the production of a particular protein and influence an individual's traits

GENETIC DIVERSITY

the hereditary variability among individuals of a single population or within a species

GENETIC MARKER

a gene or short sequence of DNA used to identify a chromosome or to locate other genes on a genetic map

GENETIC MUTATION

a heritable change in the DNA sequence

GENOTYPE

the complete genetic content of an organism

GHOST TOWN

a human settlement, such as a town, that has few or no remaining inhabitants

GLOBAL WARMING

a scientifically observed and ongoing rise in the biosphere's average temperature that is contributing to climate change

GMO

a genetically modified organism; an organism whose DNA has been altered with a gene from another species to produce a desired trait

GOLDEN RICE

a variety of rice that has been genetically modified to produce beta-carotene, a precursor of vitamin A

GRAPHITE MODERATOR

a nuclear reactor that uses carbon as a neutron moderator, which allows un.enriched uranium to be used as nuclear fuel

GREENHOUSE GASES

water vapor, carbon dioxide, methane, nitrous oxide, and ozone; gases that contribute the greenhouse effect and global climate change

GROSS DOMESTIC PRODUCT (GDP)

the total value of goods and services provided in a country during a one year period

GROUNDWATER

the water beneath the surface of the ground, consisting largely of surface water that seeped into the ground

HABITAT

the environment in which an animal or plant species resides

HALLIBURTON LOOPHOLE
a provision included in the U.S. Energy Policy Act of 2005 that gave natural gas drilling and extraction companies exemptions from the Safe Drinking Water Act

HAULING OUT
leaving the water to stay on land between periods of foraging

HEGEMONY
a form of government where one state or group has cultural, economic, and military dominance over all others

HERBICIDE
a substance used to exterminate or slow the growth of plants

HIBERNATION
cessation from or slowing of activity during the winter

HIGH PRESSURE RIDGE
a region where the atmosphere pressure at the surface of the planet if greater than its surrounding environment

HISTOPATHOLOGY
the study of tissue abnormalities using microscopy

HOME RANGE
the area where an organism lives and travels

HYDRAULIC FRACTURING
aka fracking; the process of breaking up subsurface rock formations through the use of high pressure liquids usually mixed with sand and chemicals to extract gas and oil

HYDROGEOLOGY
the study of the distribution and movement of water through the Earth

HYDROGRAPH
a graph showing the rate by which water flows past a specific point in a river over time, or a chart that displays a hydrologic variable over time

HYPOCHLORITE
any salt or ester of hydroclorus acid; a chemical commonly found in bleach, water purifiers, and cleaning products

HYPOXIA
a condition in which a body of water contains inadequate amount of oxygen, compromising the health of aquatic organisms

IMMUNOCONTRACEPTION
a type of contraceptive technique that uses immunochemistry as opposed to hormones to prevent pregnancy

INACTIVE INGREDIENT
an ingredient that does not increase or affect the intended action or purpose of a formulated product, drug, or pesticide

INFRASTRUCTURE
the physical and organizational structures and facilities needed for a functioning society

INHOSPITABLE
an environment where organisms cannot grow or live easily

INSECTICIDE
chemicals used to kill insects

INVASIVE SPECIES
a nonnative species whose introduction is likely to cause environmental or economic harm; a nonnative species that disrupts the local ecosystem

IODINE-131
heavy radioactive isotope of iodine with a half-life of 8 days; a major product produced by uranium plutonium nuclear power plants

ISOTOPE
an atom of a given element that differs in the number of neutrons in its nucleus

IVORY
mammalian teeth or tusk composed of mostly dentin, the desirable white material in which elephant tusks are made

KEYSTONE SPECIES
a species whose presence in its ecosystem is necessary to prevent the system from collapse

LACTATION
when mammary glands (breast tissue) secretes milk, often occurring after a female has given birth and is supporting offspring

LANDSAT
a satellite imagery program first launched in 1972

LARVAE
the immature and often wormlike feeding form that hatches from the egg of many insects that have a metaphoric lifecycle

LETHAL CONTROL
a method of controlling wildlife populations that result in the death of individuals from the target population

LIMITING NUTRIENT
a nutrient in limited supply relative to others that when exhausted prevents further growth of an organism

MACRONUTRIENT
in the case of plants, phosphorus, nitrogen, and potassium; a nutrient needed in large amounts for normal growth to occur

MATRIARCH
the female who is the leader of a family unit

MICROORGANISM
an organism that cannot be seen with the human eye

MICROSCOPY
the practice of using a microscope to study objects

MIDDLE EAST
geographic region northeast of Africa and southwest of Asia that contains the country Syria

MIOCENE AGE
the first geological epoch of the Neogene period and extends from about 23.03 to 5.332 million years ago, this time period had a warmer global climate

MISSISSIPPI RIVER BASIN

the area covering much of the central United States that includes tributaries that drain into the Mississippi River

MOBBING

when more than one adult male attempts to mount a female in heat; often leads to serious injury and has been linked to a boost in testosterone and uneven distribution of gender in a population

MODIS IMAGES

Moderate Resolution Imaging Spectroradiometer; a satellite imaging instrument that views the entire Earth's surface every 1-2 days

MONOCROP

a single crop produced year after year on the same land that is economically efficient but ultimately damaging to soil ecology

MONSANTO

an American multinational chemical and agricultural biotechnology company; the leading producer of genetically engineered seeds

MUSTH

a period in which a bull (male) elephant is ready to mate, characterized by increased aggression and a surge of reproductive hormones – mainly testosterone

NATIONAL ACADEMY OF SCIENCES

a non-profit society established by the U.S. congress in 1863 in order to provide independent and objective consultation on matters related to science and technology

NATIONAL PARKS

an area of land set aside by the national government of a country specifically for the purpose of safeguarding nature and wildlife biodiversity

NATIONAL TIGER RECOVERY PROGRAM

a conservation program enacted in 2011 by the Ministry of Forestry in Indonesia with the goal of doubling the number of wild Sumatran tigers by 2022

NATURAL GAS

a combustible mixture of gaseous hydrocarbons consisting mostly of methane

NEBRASKA SANDHILLS

a region of mixed-grass prairie on grass-stabilized sand dunes, it is the largest sand dune formation in the western hemisphere

NO-TILL

growing crops without disturbing the soil through tilling or plowing in order to increase soil organic matter and decrease soil erosion

NOBLE GAS

any of the gaseous elements helium, neon, argon, krypton, xenon, and radon, occupying Group 0 (18) of the periodic table that are believed to be unreactive

NON-GMO PROJECT

a non-profit organization that verifies non-GMO products and educates consumers

NON-LETHAL CONTROL

a method of controlling wildlife populations through actions that do not harm the health of the target population

NUCLEOTIDE SEQUENCE

the order in which nucleotides are situated in a chain relative to one another, which provide the template of a particular amino acid

OCEAN ACIDIFICATION

the decrease of pH levels in the ocean due to the uptake of carbon dioxide from the atmosphere

OGALLALA AQUIFER

an aquifer located on the High Plains in the United States, it is composed of clay, sand, silt, and gravel

OZONE LAYER

a region of Earth's atmosphere that absorbs most of the Sun's ultraviolet (UV) radiation

PAPAYA RINGSPOT VIRUS (PRSV)

a virus that infects papayas and is transmitted by aphids. Infested papayas exhibits yellowing, leaf distortion, and severe mosaic. The papaya fruit will have bumps and a "ringspot".

PARTICULATE MATTER

pieces of matter small enough to remain suspended in the the air for long periods of time

PARTURITION

giving birth; synonymous with pupping

PATHOGEN

a bacterial, viral, or fungal agent of disease

PESTICIDE

a substance that is used to prevent or kill animals or insects that damage plants of crops

PETROLEUM HYDROCARBONS

the primary molecular constituent in oil, gasoline, diesel, and other petroleum products; the simplest of organic compounds containing only carbon and hydrogen atoms

PHLOEM

a complex tissue in the vascular system of high plants like trees; responsible for the translocation and storage of nutrients and water

PHOTOSYNTHESIS

the conversion of sunlight, carbon dioxide, and water into glucose and oxygen by organisms for use as energy

PLANKTIVOROUS

referring to planktivore, an aquatic organism that feeds on zooplankton and phytoplankton

PLANKTON

microscopic organisms that float freely in marine and fresh bodies of water PM10 particulate matter less than 10 micrometers in diameter

PM10

particulate matter less than 10 micrometers in diameter

POACHING

the illegal hunting, killing, or capturing of wild animals

POLLINATE

the transfer of pollen from the anther to the stigma of a plant often from one plan to another

POLYCHLORINATED BIPHENYLS (PCBS)

a broad range of man-made chemicals used as a coolant and flame retardant; a chemical known to be carcinogenic, neurotoxic, and cause developmental and reproductive disorders

POLYMER SHEET

a chemical compound or mixture of compounds formed by polymerization and consisting essentially of repeating structural units

POLYMERASE CHAIN REACTION (PCR)

a method to amplify copies of DNA using many cycles of DNA denaturation, primer annealing, and DNA polymerization

POLYP

the individual base of a coral; sedentary form of a coelenterate

POPULATION

a group of organisms that are of the same species, which reside in the same general geographic location and are able to interact and breed

PRECIPITATION

weather activity in the form of rainfall, hail, or snowfall

PRESERVE

a protected area set aside for the refuge and safety of plants and animals

PRIMARY FOREST

mature forests of native trees that have not been affected by deforestation

PROPAGANDA

use of communications to try and influence a person or group of people with often biased information

QUANTIFIABLE

the ability to be expressed or measured in terms of quantity

QUARANTINE

a state of enforced isolation, often imposed when a human or animal has been exposed to an infectious disease

RADIOACTIVE

atoms that spontaneously emit subatomic particles and/or energy; emitting ionizing radiation when decaying

RADIONUCLIDE

atoms with an unstable nucleus, characterized by the availability of excessive energy; can be naturally occurring or artificially produced

RANCH HAND

an U.S. Military Operation during the Vietnam War that involved spraying millions of liters of herbicide in order to rid Vietnam of crops and vegetation to expose roads and trails used by the Viet Cong

REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION (REDD)

a mechanism to mitigate climate change through reducing net greenhouse gas emissions; under negotiation by the United Nations

RESERVOIR

a natural or artificial body of water that is used to store water

REVERSE OSMOSIS

a process by which a solvent passes through a porous membrane in the direction opposite to that for natural osmosis when subjected to a hydrostatic pressure greater than the osmotic pressure

RNA

ribonucleic acid; a molecular structure present in all living cells that carries and transmits commands to build proteins

ROTOR

the non-stationary part of a rotary motor or generator; contains electromagnets which are used by the generator to induce an electrical current

ROUNDTABLE ON SUSTAINABLE PALM OIL (RSPO)

a non-profit organization that aims to transform markets towards sustainable palm oil

RUNOFF

the portion of precipitation on land that is not absorbed by the ground but instead flows into nearby waterways; waste products that are carried by rain into surface waters

RUST BELT

referring to economic decline in a region of the United States surrounding the Great Lakes

SAFE DRINKING WATER ACT

Federal law setting standards for water quality across the United States to be enforced primarily by the U.S. Environmental Protection Agency

SALMONIDS

a fish belonging to the family Salmonidae which includes the salmon, trout, and whitefish

SANCTUARY

a protected area set aside for the refuge and safety of plants and animals

SECONDARY PRODUCTION

the rate at which primary consumer organisms convert food into their own biomass

SEDIMENT

a solid material that moves and settles in a different location, often from erosion

SESSILE

an organism that is immobile or fixed to one place

SHOAL

a piece of land where moving water promotes sediment deposition, such as a sandbar

SIERRA NEVADA MOUNTAIN RANGE

mountain range in the western United States between the Central Valley of California and the Basin and Range Province, the majority of the range lies in California

SNOWPACK

a layer of compacted snow on the ground that often accumulates in high altitudes for long periods of time

STAND

a contiguous area that contains a number of trees that are relatively homogeneous or have a common set of characteristics.

STATOR

the stationary part of a rotary motor or generator; contains conductors on which electric current is induced by the rotation of the rotor

SYMBIOTIC RELATIONSHIP

a close relationship between two organisms in which they mutually benefit

THERMAL PROCESS

a process by which phosphate rock is heated to create phosphorus pentoxide, which is then dissolved in dilute phosphoric acid to form very pure phosphoric acid

THYROID CANCER

cancer originating in the thyroid gland, which is located in the front of the neck

TOPOGRAPHY

surface features or an area or a region on a map

TRANSLOCATION

immobilizing and transporting one or more individuals of a population from an area of high population density to an area of lower population density where they will have less of an environmental impact

TROPICAL STORM

a localized, powerful storm that forms in tropical areas

TSUNAMI

a series of high sea waves caused by an earthquake, submarine landslide, or other disturbance

TURBIDITY

a measure of the amount of suspended solids in water

VASCULAR

of or relating to a channel for the conveyance of a body fluid (as blood of an animal or sap of a plant)

VIRUS

an acellular particle containing a genome that can replicate only inside a cell; a noncellular pathogen

WATER STRESS

a lack of sufficient water resources available to meet the demands of water usage

WATER TABLE

the planar level at which water saturated soil or rock meets unsaturated ground

WEANING

a period in which young mammals transition to sources of food other than their mother's milk

WESTERLIES

consisting of the winds that blow from the west towards the east; a belt of major air currents in the mid-latitudes of the northern and southern hemispheres

WET ACID PROCESS

a process by which phosphate rock is dissolved in sulfuric acid forming phosphoric acid and waste products

WICKET GATE

doors used to control the rate of water intake through a generator's turbine

WORLD HEALTH ORGANIZATION (WHO)

an agency of the United Nations that promotes health and control of diseases around the world