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CONTENTS

Groundwater Contamination and the "Beneficial Reuse" of Coal Ash in Southeast Wisconsin

Clean Wisconsin

Background

What is Coal Ash and Where Does it Come From?

Each year, utility companies in the United States burn nearly one billion tons of coal. This coal burning produces exhaust, wastewater, and about 130 million tons of leftover solid waste known as "coal ash."[1]

"Coal ash" waste takes four general forms: fly ash, bottom ash, boiler slag, and flue gas desulfurization ("FGD") sludge, which each come from a slightly different place in a coal burning furnace. It is made up of the materials in the original coal that do not burn. As a result, it has concentrated levels of many contaminants, like heavy metals, that occur naturally in the coal.[2] This means that coal ash can contain high levels of hazardous materials like arsenic, chromium, lead, mercury, and molybdenum.

Those concentrated levels of hazardous materials can then leach out of the coal ash into the environment. This is especially true when coal ash used in unencapsulated applications (where the ash is not bound up in a product) comes into contact with water, where it can release the contaminants in dangerous quantities.

Water Pollution and the Failure to Regulate the Disposal of Coal Ash

Largely unregulated by the U.S. Environmental Protection Agency (EPA) for decades, coal ash contains toxic chemicals that can harm health and the environment. For most types of waste, that potential for harm would require careful treatment under the Resource Conservation and Recovery Act (RCRA)—the federal law that governs waste disposal. However, lobbying by the coal and electric utility industries resulted in a loophole excluding coal ash from any specific federal requirements.[3]

Consequently, each state has been free to regulate coal ash as it sees fit. Some states have absolutely no regulations, while others like Wisconsin have established coal ash regulatory programs. This has led to an inconsistent patchwork system of controls that have failed to protect Americans nationwide from pollution.

In fact, toxic coal ash has contaminated water at more than 200 sites[4] in 37 states, including at 13 sites in Wisconsin.[5] This underestimates the actual damage though, because most coal ash dumps are not monitored—meaning coal ash pollution goes largely undetected.

The lack of federal safety standards has also led to three huge spills in the last six years. This includes the largest toxic waste spill in the nation's history at the TVA Kingston Plant in Tennessee in 2008, where 5.4 million cubic yards (more than 1 billion gallons) of toxic waste covered 300 acres of river and shore,[6] the We Energies Oak Creek landslide in 2011 where 25,000 tons of ash collapsed from a bluff on the shore of Lake Michigan;[7] and the Duke Energy Dan River coal ash spill in February 2014, where 140,000 tons of coal ash and wastewater fouled 70 miles of the Dan River in North Carolina.[8]

Unfortunately, the lack of specific limitations or safeguards on coal ash disposal also means that much

of it is discarded in ways that are even less controlled than dumping it in landfills. Often termed "coal ash reuse," these types of disposal have been increasing in recent years—to the point where they account for tens of millions of tons of coal ash disposed of each year. In 2012 for example, over 26 million tons of coal ash was used in "unencapsulated" ways (where the ash is not bound up or contained in a product)[9] that have not been evaluated and endorsed by the EPA.[10]

Reuse dumping of coal ash can range from disposal under buildings, roadways, or highway berms, to spreading it on roadways, paths, fields, and even in parks. In addition to doing nothing to prevent toxic materials from leaching into groundwater, lack of regulation on those projects means that there is little information available to the homeowners whose faucets may be affected. It also means that very little research has been done on what cumulative impacts decades of that dumping may be having on our water resources.

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A lawsuit, brought by Earthjustice in 2012, required EPA to finalize national coal ash regulations in December 2014.[11]

Clean Wisconsin's Research

Drinking Water Contamination in Southeastern Wisconsin

In the five years leading up to this report's publication in 2014, it became clear that there was a significant drinking water contamination in southeastern Wisconsin. In order to protect families in the area, the Wisconsin Department of Health Services (DHS) offered free well testing to residents in the area starting in 2010, and later suggested that residents throughout the region have their water tested. While this testing provided data that allowed us to conduct this study, the full extent of the groundwater contamination problem in the region and the rest of the state is still not known.

To assess the range of the contamination, we gathered testing data from nearly 1,000 private drinking water wells in southeast Wisconsin. By mapping that data, we found that the contamination is not isolated to the small zone around Caledonia studied by the DNR.[12] Instead, while there were some areas with consistently safer

water, the contamination spans across southeastern Wisconsin, including parts of Racine, Waukesha, Kenosha and Milwaukee Counties (Figure 1).

The data available for this analyses also point to the severity of the drinking water contamination in the region; the average value from all wells sampled is nearly 50 ppb of molybdenum (much higher than typical natural levels below 10 ppb, and above the DNR Enforcement Standard of 40 ppb). One in every five wells exceeded the new "health advisory level" of 90 ppb.

While these data clearly show widespread and significant groundwater contamination in the region, we still don't know the full extent of the problem. The wells for which there was molybdenum data come solely from private home-owners who choose to have their water tested. As a result, there are geographically clustered well samples, as well as large unsampled areas. There were also areas outside of the study region (where molybdenum data were available) where spatial trends indicate the potential for significant contamination—particularly southward into Kenosha County. Systematic sampling and testing throughout the region and state, including analysis of well construction information that was not available for this study, would provide further information on where drinking water contaminant concentrations may exceed the state water and health standards.

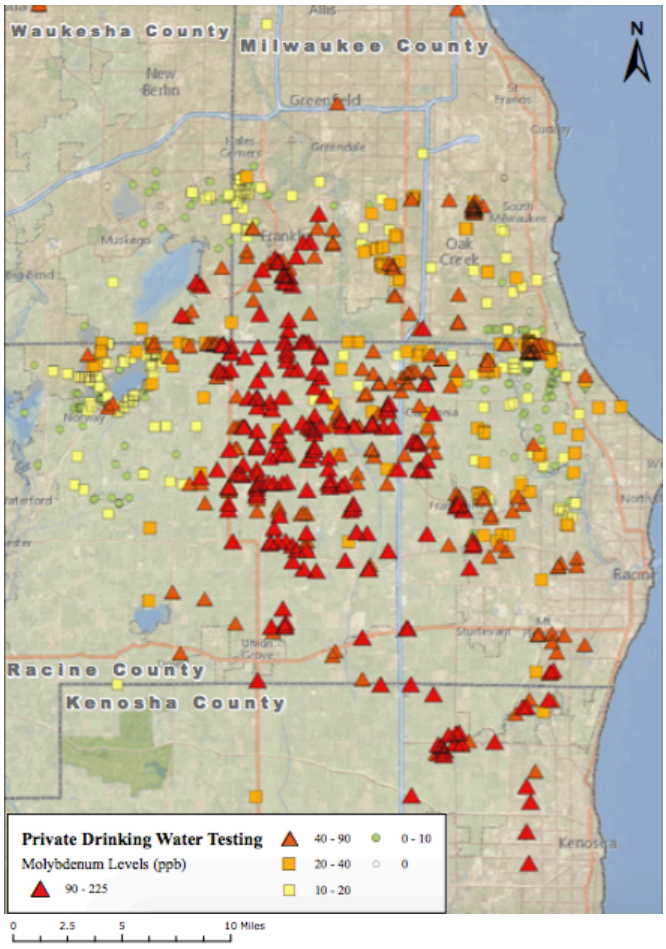

Figure 1. Map of molybdenum concentrations in drinking water in southeast Wisconsin. (Private well test results from 967 unique well locations.)

Coal Ash Placement in Southeast Wisconsin

When the DNR conducted its investigation into the cause of water contamination in Caledonia, they focused on three coal ash landfills in the area, because they were deemed to be the most significant potential sources. While the DNR was unable to find evidence definitively pointing to those landfills as the cause of contamination, the DNR did not examine the other coal ash disposed or "reused" in the region. Yet reports to the Energy Information Administration showed that over 833,000 tons of coal ash from Wisconsin coal plants operated by the local utility (We Energies) were "used offsite" in 2011 alone.[13]

The lack of reporting requirements means that complete information on where coal ash has been placed is not available. Of the roughly 833,000 tons of coal ash that We Energies reported as being used offsite in 2011, the records obtained from DNR contain documentation for only 26,000 tons for that year.

However, the information that we were able to access in public records reveals that coal ash placement is indeed widespread, and isn't limited to the Caledonia area. We found records from 1988 through 2012 of 1.6 million tons of We Energies' coal ash being "reused" in over 575 projects throughout the region. These records are likely only a small subset of the total amount; coal ash has been spread in the area for over 50 years.[14] Of those records we were able to find, we were able to locate 399 projects in southeast Wisconsin in Kenosha, Milwaukee, Racine, and Waukesha counties. Those amounted to over one million tons of coal ash we were able to map (Figure 2).

Connection Between Coal Ash Reuse and Drinking Water Contamination

Since there are limited natural sources of molybdenum,[15, 16] any high concentrations (i.e., greater than 20 ppb) are very likely to be the result of human activity.[17, 18] In southeastern Wisconsin in particular, research has shown that groundwater contamination with molybdenum is not likely to come from natural sources. In contrast, molybdenum is one of the signature elements of coal ash contamination, because burning coal concentrates and magnifies molybdenum levels in the ash.[2]

Based on this, we conducted an analysis to see if there was a relationship between the wide-spread "reuse" of coal ash in southeastern Wisconsin and the widespread molybdenum contamination in the area. We found a strong correlation between the widespread molybdenum contamination in southeastern Wisconsin and the "reuse" of coal ash in the region: the closer a well was to a large coal ash reuse site, the higher the molybdenum values were likely to be (Figure 3).

For example, for all the wells that were tested within 1 mile of where large amounts of coal ash (more than 500 tons) had been disposed of into the environment, the median level of molybdenum in drinking water wells was 47 ppb, and the average was 55 ppm—above the enforcement standard of 40 ppb. For wells more than 3 miles from large reuse sites, on the other hand, the median concentration was 10 ppb, with an average of 11.7 ppb.

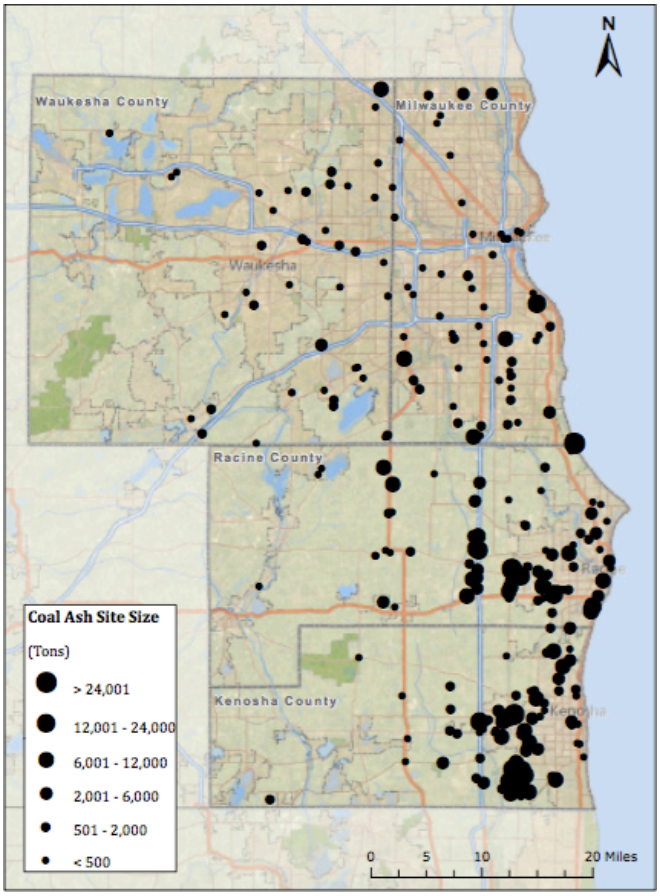

Figure 2. Coal Ash in Study Area: Map of 399 documented "reuse" project sites, totaling over 1 million tons, in Waukesha, Milwaukee, Racine, and Kenosha counties.

Data from We Energies, as reported to Wisconsin DNR. A total of 399 projects, using 1,065,365 tons of coal ash were able to be geocoded to the region.

Years range 1988-2012; no records were found for the years 1990, 1991, 1993, 1995,or 1998.

Standard distance measurements aren't ideal for such analysis, however, because groundwater contamination does not flow uniformly in all directions. Instead, contaminants leach down through the ground and then generally follow the path of groundwater flow. To account for this, we conducted a similar analysis based on a model that accounts for general groundwater flow. Using this analysis, we found that the trend was even more striking: wells "downflow" of large coal reuse sites tended to have much higher levels of molybdenum (Figure 4).

It should be noted that due to a lack of detailed well information, we were forced to group together the test results from all wells, which could be drawing water from different sources of groundwater. However, in this area in particular, water moves freely between the primary sources of private drinking water (the sand and gravel aquifer and the Silurian dolomite aquifer).[19]

To rule out other manmade sources of molybdenum, we also looked at the other potential sources of facilities with permits for water discharge,[20] hazardous waste storage facilities, solid waste transfer facilities, closed and active landfills,[21] and EPA Superfund sites.[22] When taken together, these non-coal sources did not show trends consistent with being causes of contamination.

In addition to showing the overall correlations between coal ash reuse and groundwater contamination, our research clearly demonstrates the need for more information to be collected and made public. For example, there is a cluster of wells with high levels of molybdenum around Raymond, Wisconsin, with no identified potential source (it is this cluster that causes the secondary peaks in Figure 3 and Figure 4). It is very possible that the contamination in this area is the result of coal ash reuse sites for which we had no data due to the gaps in available information.

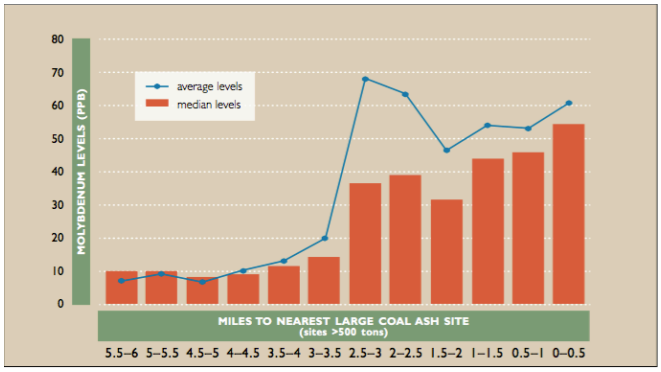

Figure 3. Trends in molybdenum concentrations measured at private drinking wells in southeast Wisconsin, near coal ash "reuse" sites larger than 500 tons (by linear distance).

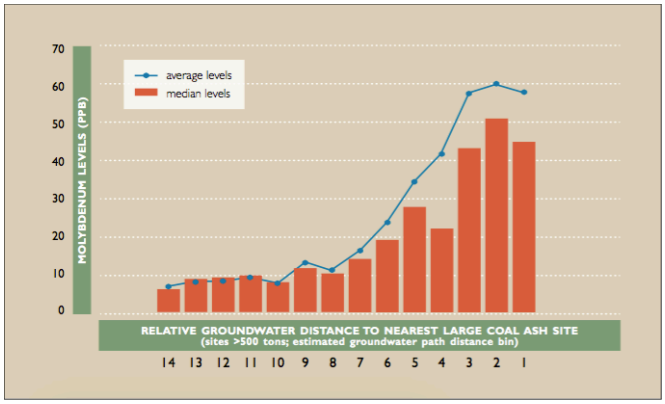

Figure 4. Trends in molybdenum concentrations measured at private drinking wells in southeast Wisconsin, near coal ash "reuse" sites larger than 500 tons (by estimated groundwater path distance).

Recommendations for Public Safety

Wisconsin DNR Must Take Actions to Protect Public Health

As the case of southeastern Wisconsin demonstrates, there is an urgent need to rethink how coal ash is handled to ensure the health and safety of our water, our land and our families. To do this, we offer ten practical solutions to improve the management and regulation of coal ash reuse in Wisconsin.

1. Wisconsin should conduct systematic testing of groundwater in areas where coal ash has been placed in the ground, including throughout Kenosha, Milwaukee, Racine, and Waukesha counties.

The available information on groundwater quality shows a widespread pattern of groundwater contamination in southeast Wisconsin. With limited information, however, it is impossible to determine the extent of the contamination, or to predict which wells will be most affected. A systematic sampling and testing plan throughout the region is needed to assess the full extent of the problem in Kenosha, Milwaukee, Racine, and Waukesha counties, as well as other areas in the state where coal ash has been placed in the ground, or where groundwater contaminant concentrations may exceed the state water and health standards, including those in Wis. Admin. Code ch. NR 140. Additionally, residents in areas that have been shown to be at risk for exceedances of those limits should be advised of the risks associated with the contamination.

2. Wisconsin should investigate historical coal ash use and dumping, make all records publicly available, and identify potentially dangerous placement.

Our work brought to light 1.6 million tons of coal ash spread through southeast Wisconsin. However, it is clear that considerably more coal ash has been spread in the region over a long period of time. The records we obtained only date back to 1988, and the records we have are incomplete for the period 1988-2014. Given the reports of coal ash placement dating back to at least the 1950's, our records likely represent only a very small fraction of the coal ash "beneficially" used. Of particular importance are sites where coal ash was placed below the water table such as wetland filling. It is also important to identify potentially unstable coal ash fills, like the ravine fill that collapsed in Oak Creek in 2011.

A first step would be to publicly release all historical records of coal ash "reuse," or any other sort of dumping into the environment. This includes any records at the DNR as well as utility records throughout the state. Wisconsin families have a right to know where coal ash has been placed in their neighborhoods. Thereafter, additional investigation by DNR is needed to provide a more complete picture of coal ash placement and its associated risks for the public.

3. Wisconsin should establish complete reporting requirements for uses of coal ash.

Wisconsin state law does not currently require coal ash generators or users to report many coal ash reuse sites through the state regulations of "beneficial use" (Wis. Admin. Code ch. NR 538). For example, We Energies power plants in SE Wisconsin used over 833,000 tons of coal ash offsite in 2011.[13] However, the records obtained from DNR contain documentation for only 26,000 tons, or 3% of the total offsite use. The lack of reporting makes it difficult to identify problem areas where coal ash may be contaminating groundwater and to identify locations of coal ash when groundwater contamination is found. It also leaves families in the dark about coal ash dumping in their neighborhoods. Generators and users of coal ash should be required to report at a minimum where, when, how much, and in what manner coal ash is being used, as well as the characteristics of the coal ash in that particular project, regardless of the project type or size.

4. Wisconsin should require coal ash to be tested for all chemicals with the potential to contaminate drinking water supplies, in accordance with Wis. Admin. Code ch. NR 538.04.

Wisconsin's rules on the use of industrial byproducts (NR 538) require that no coal ash storage, handling, or use be allowed that will have a "detrimental effect on any surface water," or that will cause a "detrimental effect on groundwater quality or will cause or exacerbate an attainment or exceedance of any preventive action limit or enforcement standard [...] as defined in ch.NR 140."[25] Wis. Admin. Code ch. NR 140 in turn, establishes public-health-related groundwater standards for 138 chemicals and public welfare related groundwater standards for an additional 8 chemicals.

However, testing of coal ash leaching is only required for at most 14 chemicals for any beneficial uses listed under NR 538. Notably absent from those required tests is any testing of coal ash for the leaching of molybdenum for any listed use. Yet molybdenum is known to be associated with coal ash contamination and there are widespread exceedances of both the preventive action limit and the enforcement standard for molybdenum in southeast Wisconsin. Similarly there is no testing required of arsenic, lead, or mercury, for the category of coal ash uses which include covered structural fill—and therefore no limit to the amount of leaching allowed under roads, or non-residential parking lots or buildings like schools and churches.

In order to prevent drinking water contamination and protect public health, as well as to comply with existing rules at NR 538.04, Wisconsin needs to revise NR 538 to require that all coal ash to be "beneficially used" is tested for any chemicals where that use could contribute to exceedance of groundwater standards listed in NR 140.

5. Wisconsin should establish groundwater monitoring requirements for beneficial uses of coal ash.

It is imperative to require environmental monitoring wherever coal ash is disposed or "reused." While Wisconsin requires coal ash generators to monitor transportation facility embankments, the state does not currently require any monitoring for other beneficial uses. Wisconsin should follow the lead of other states like North Carolina that better monitor coal ash use. Wisconsin should require coal ash disposal and uses to comply with water monitoring regulations and require the development and implementation of a water quality monitoring plan. Such monitoring must include all potential coal ash contaminants to ensure that toxic chemicals in coal ash are not leaching from the ash into drinking water.

6. Wisconsin should conduct research and testing to determine the role of coal ash in groundwater contamination.

This study shows that along with exceptionally high molybdenum levels in southeast Wisconsin groundwater, there is a potential source of contamination from the widespread "reuse" of coal ash in the area. Moreover, in spite of limitations such as gaps in available information, this study shows that molybdenum levels are generally higher closer to known coal ash reuse sites. Based on this information, there is a clear need to fully assess the contribution of coal ash reuse sites to groundwater contamination. Higher priority should be given to sites most likely to cause significant contamination, such as those where large quantities of coal ash have been placed below the water table. At those sites, detailed and targeted investigations are needed to determine the extent of contaminant leaching.

Such targeted research and testing are urgently needed given the toxicity of coal ash leachate, the extent of the potential contamination, and the fact that "reuse" projects are becoming an increasingly popular way to dispose of coal ash. If the widespread elevated levels of molybdenum in southeastern Wisconsin are due even in part to coal ash disposal, residents may also be exposed to more acutely dangerous toxins such as arsenic.

7. Stop spreading coal ash into the environment until better safeguards to prevent groundwater contamination are in place.

The additional research and testing that must be urgently conducted will provide more clarity on exactly how damaging current coal ash practices are and what new rules need to be put in place to protect our water supply. Until the results of such a study are known, Wisconsin should place a moratorium on spreading coal ash into the environment, as North Carolina has recently done.[23] In particular, the unencapsulated reuse that is currently allowed under NR 538 and examined in this report should be prohibited unless it can be proven that it is not causing or contributing to groundwater contamination in the state. Additionally, Wisconsin should start immediately by following the lead of other states that prohibit or conditionally prohibit the most harmful uses of coal ash. The rules in place now are clearly limited in effect and not sufficient to protect our drinking water.

8. Wisconsin should require liners, leachate collection systems, caps, and additional groundwater monitoring for large structural fills, as well as limitations on where structural fill can be used.

Wisconsin state law generally does not currently require protections be put in place for much of the coal ash dumping that is deemed a "beneficial reuse," even when those uses involve large quantities of coal ash in close proximity to private drinking water wells. Wisconsin should protect the health of its citizens by enacting regulations like those enacted in North Carolina that require large structural fill projects to protect groundwater and surface water by using liners, leachate collection systems, caps, and groundwater monitoring systems.[23] Wisconsin should also require safeguards to protect groundwater from small fill projects and follow the lead of other states that prohibit the placement of coal ash as structural fill near streams, floodplains, wetlands, private dwellings or wells, near property boundaries, or near the seasonal high groundwater table. Pennsylvania, for example, requires that coal ash not be used in a manner that causes water pollution and not be placed within 8 feet of the water table.[24]

9. Wisconsin should require a more accurate leach test to access the toxicity of coal ash.

There are many toxic chemicals present in coal ash that can be released into water supplies. Depending on the characteristics of the coal ash, how it is disposed, and the characteristics of the water it comes into contact with, these chemicals can leach out at different rates and quantities. When pollutants leach, they can seep into wetlands, creeks, underground aquifers, and drinking water supplies.

Unfortunately, the way the DNR evaluates the risk of heavy metal leaching out of coal ash is wholly inadequate. Currently, the DNR utilizes a "shake extraction test" where water is added to a sample of coal ash, the mixture is shaken, and the results are based on the amount of chemicals that leach out within 24 hours.[25] However, this testing does not simulate natural processes and environments. In reality, coal ash comes in contact with differing levels of acidity and different temperatures that affect how chemicals are released. The current test used by DNR also doesn't account for changes in leach rates over time, which can peak long after initial environmental exposure. As a result, the EPA's Science Advisory Board and the National Research Council of the National Academies of Science have rejected its use, stating that this test will not reliably characterize the leaching potential of coal ashes.[26]

In order to protect residents from toxic chemicals contaminating the groundwater from coal ash, Wisconsin should implement a test method for the leaching potential of coal ash that better reflects the complex conditions that are present in the real world. EPA recently approved a test method that more accurately assesses the leaching potential of coal ash, the Leaching Environmental Assessment Framework (LEAF).[27] Wisconsin should require coal ash to be tested using the LEAF prior to approval for unencapsulated reuse. Coal ash currently being used for beneficial use should also be required to be recharacterized using the more accurate leach test.

10. Wisconsin should regulate hazardous coal ash as a hazardous waste.

Coal ash is known to contain toxic chemicals that are hazardous to human health and the environment. Currently, however, Wisconsin exempts any and all coal ash from being considered a "hazardous waste" under state regulations, even when the current testing shows that it is highly toxic and corrosive.

Wisconsin needs to revise its rules so that when coal ash is truly hazardous, as shown by an up-to-date and accurate leach test, it is regulated as hazardous. Coal ash should only be exempted from a "hazardous waste" classification when tests determine that the ash will not leach toxic chemicals at levels sufficient to harm health and the environment.

Due to the history of widespread disposal of coal ash throughout the environment, dangerous pollution from coal ash will continue to be a problem well into the future in Wisconsin and across the nation. In light of the significant impact such pollution can have on drinking water, and the loopholes coal ash producers currently enjoy that keep the public uninformed about where and how coal ash is used, Wisconsin and the EPA need to take action to ensure that rules governing coal ash reuse and disposal genuinely protect Americans and their environment.

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This article is adapted from a report originally published by Clean Wisconsin: Don't Drink the Water– Groundwater Contamination and the "Beneficial Reuse" of Coal Ash in Southeast Wisconsin. *The original report and hyperlinks to references can be accessed here*: http://www.cleanwisconsin.org/wp-content/uploads/2015/02/dont-drink-the-water-report-clean-wisconsin.pdf

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2018 Update

Since this Clean Wisconsin report was initially published in 2014, the EPA created a new rule entitled the Disposal of Coal Combustion Residuals from Electric Utilities, which was published in the *Federal Register* in April 2015. This rule finalized a new set of requirements for the disposal of coal ash, called coal combustion residuals (CCR), from coal-fired power plants.

Along with new requirements establishing the first national standards for CCR disposal, the 2015 rule includes recording keeping and reporting requirements for each coal-fired power facility.

On March 1, 2018, EPA Administrator Scott Pruitt announced the first of two new rules proposing to amend the Obama-era 2015 regulations, a move which would provide state governments with "the ability to incorporate flexibilities into their coal ash permit programs based on the needs of their states." Pruitt additionally noted that the new rule would save utility companies up to $100 million per year in compliance costs. The EPA is accepting written commentary until April 30, 2018, 45 days after the proposal was published in the *Federal Register*. The EPA will also hold a public hearing on the proposed rule on April 24, 2018.

2018 Earthjustice Report: New Industry Data Confirms Toxics are Polluting Groundwater at Coal Ash Dumps

Unlined pits filled with coal ash waste are leaking toxic substances—including arsenic—into groundwater near old coal-burning power plants in eight states, an Earthjustice review of 14 industry reports has found.

Coal ash—what's left after a power plant burns coal—is dumped into pits at approximately 1,400 sites around the country and poses threats to drinking water, neighborhoods, and air quality. The pits are unlined, so toxics can seep into groundwater.

"Hundreds more power plants will be making their required groundwater tests available online soon—and this is critical information that communities need to protect their drinking water from toxic pollution," said Earthjustice Senior Counsel Lisa Evans. "From just this initial survey of these reports, we can see that groundwater contamination from coal ash pits is a grave concern."

Under a 2015 U.S. Environmental Protection Agency (EPA) coal ash rule, all U.S. electric generating utilities were required to analyze groundwater pollution at each of their operating coal ash dumps by January 31, 2018 and publish the results online by March 2.

As of early February, 2018, the largest electric utilities in the nation have not posted the results of their groundwater monitoring, including Duke Energy, First Energy, Ameren, NRG, AES and Dominion. By law, these reports are already completed, but all of the major utility companies were delaying public posting until the March 2 deadline.

Because most coal ash dumps are unlined and many have already been found to be leaking deadly chemicals, like arsenic, hexavalent chromium, lead and thallium (rat poison), these first-ever groundwater monitoring reports are critically important to the safety of the nation's drinking water. The EPA and environmental groups have already confirmed over 200 cases of water contamination from leaking coal ash sites.

A review of the reports that some of the country's smaller utilities have posted online reveals that a majority have groundwater contamination.

Out of the 14 power plants so far that posted test results and analyses, nine noted "statistically significant increases" of substances such as arsenic, antimony, molybdenum, lithium, boron, chlorides and more in groundwater. Three additional plants confirmed findings of preliminary contamination, but have not completed testing and analysis. The data also reveal levels of arsenic and radium above drinking water standards in some groundwater wells.

The plants are located in eight states spanning from Florida to Alaska. Under the EPA's coal ash rule, power plants that find contamination will have to do more testing and come up with cleanup plans to protect groundwater.

"Coal ash is a silent, tasteless killer," Evans said. "But once the pollution is discovered, the EPA's coal ash rule requires protection and cleanup. That's why it is critical that this law stay in effect."

As soon as President Donald Trump took office, polluters petitioned the EPA to weaken the critical protections of the coal ash rule. EPA Administrator Scott Pruitt quickly complied by writing a new rule, which was was announced on March 1.

"The groundwater testing reports we examined reveal that the EPA's coal ash rule is working as planned and will help protect aquifers near coal ash dumps from further pollution," Evans said. "Communities that rely on this water for drinking should sleep better knowing that the existing federal law requires full disclosure of the hazardous chemicals leaking from these toxic dumps."

See a list of links to all utility coal ash websites here.

The original Earthjustice report appeared here.

Best Practices for Coal Ash Management?

Coal ash is the second most abundant waste material in the United States, right after household waste. In 2014 about 130 million tons of coal ash were produced by U.S. power plants, adding to the 1.5 billion tons of coal ash already stockpiled.

Is there such a thing as best practices for coal ash management? Following are observations and findings that surfaced from a review of scientific literature.

Many of the most dangerous disposal practices involve placement of coal ash in landfills or wet ponds. The EPA noted two factors in coal ash disposal that most dramatically increase risks to human and environmental health:

1) The use of wet surface impoundments rather than dry landfills
2) The absence of composite liners to prevent leaching and leaking

As noted in a study by Earthjustice and the Physicians for Social Responsibility, many wet impoundments use only native soils as their bottom and side material. However, those lined with clay are also at high risk of leaking and contaminating groundwater. Even the best liners made of manufactured materials such as high-density polyethylene have limited lifespans and must be regularly monitored for leaks.

Oak Ridge National Laboratory studies have found that burning coal concentrates radiation that may naturally occur in coal. Thus, this coal ash can release up to 100 times the amount of radiation as nuclear power plants with similar energy production levels.

While dry disposal is preferable to wet ponds, coal ash particles can escape from dry landfills, which very often are not capped or covered daily, and cause severe health complications when inhaled. Additionally, windblown ash particles can contaminate air as coal ash is loaded, transported, and unloaded.

Various studies, including Clean Wisconsin's report, have reported that "beneficial reuse" is a misleading description, with some beneficial reuse practices being directly harmful to human and ecosystem health. Nevertheless, even the more dubious beneficial reuse practices are subjected to fewer regulatory burdens than would normally be imposed on the disposal of toxic waste. Some of the most dangerous reuse practices include:

- Mine filling
- Construction fill
- Agricultural field "soil amendments"
- Snow and ice melting
- Traction support for cars
- Embankment material for highway construction projects

While all of these uses put human and environmental health and risk, mine filling was consistently pointed out as particularly problematic and controversial. As one Earthjustice report observed, mine filling frequently amounts to little more than disposing of coal ash directly into active or abandoned coal mines. While the practice is meant in part to neutralize the acidity of coal refuse found in mines, mine filling can also put industrial waste in direct contact with the water table and aquifers.

In essence, there is no long-term permanent solution to coal ash disposal that does not have significant risk of leakage or soil, groundwater, and airborne contamination, unless encapsulation is pursued.

Beneficial reuse programs that encapsulate coal ash particles in other materials, such as concrete, bricks, bowling balls, or wallboard have proven to be least likely to leak toxins, and are widely agreed to be the best possible reuse of this industrial waste. A 2014 EPA study concluded that concrete and wallboard derived from coal combustion residuals were comparable to products derived from virgin materials. While encapsulated beneficial reuse programs can reduce the use of landfills, limit exposure to toxins, and reduce the amount of virgin materials used in manufacturing, these methods face both technological and logistical hurdles. While some concrete/cement and manufacturers have the capability and capacity to incorporate coal ash into their products, others have yet to adopt coal ash into their manufacturing processes. Furthermore, power plants must see beneficial reuse as an economically viable option, requiring incentives such as low transportation costs and high demand for an encapsulated beneficial reuse market.

In 2014, about 50% of coal "fly" ash, the ash most commonly used in cement and brick manufacturing, so called because it is composed to the particles that fly into the cooling stacks, was recycled for beneficial reuse. Of that 50% recycled, only about 50% were used in the manufacture of cement and concrete products.

—Eds.

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Managing Acoustic Habitat in U.S. Waters

National Oceanic and Atmospheric Administration

Introduction

The U.S. National Oceanic and Atmospheric Administration (NOAA) is a steward of the nation's oceans, with a variety of statutory mandates for conservation and management of coastal and marine ecosystems and resources of ecological, economic, and cultural significance. To this end, NOAA is charged with protecting the long-term health of a wide variety of aquatic animal populations and the habitats that support them, including whales, dolphins, turtles, fishes, and invertebrates. While these animals fill very different roles in marine ecosystems, many of them share a common and fundamental biological need: the ability to hear, produce, and respond to sound.

The purposeful use of sound for communication by marine mammals, many fish, and a few marine invertebrates is well documented (reviewed by Tyack & Clark 2000, Normandeau Associates 2012, Ladich 2015). For example, fin and blue whales produce low frequency calls that are thought to play roles in finding mates, sharing food resource information, and navigating at ocean-basin scales (Payne & Webb 1971, Morano et al. 2012). In contrast, bottlenose dolphins use higher-frequency signals to maintain social structure, identify individuals, and echolocate during foraging (Janik & Slater 1998).

Fish are well known to produce loud low-frequency choruses for communicating with conspecifics and attracting mates (Myrberg 1981). Cavitating bubbles produced by snapping shrimp emit sound upon their collapse that stun prey and provide a means for individuals to communicate with one another and defend territories (Versluis et al. 2000). In addition, there is evidence from both terrestrial and marine organisms illustrating the ecological importance of adventitious sounds: those gathered opportunistically from the surrounding habitat through eavesdropping rather than from a purposeful sender (Barber et al. 2010, Slabbekoorn et al. 2010, Radford et al. 2014).

Many animals hear and respond to frequencies outside of those they produce, underscoring the importance of eavesdropping on other species or of detecting meaningful sounds made by the physical environment. Aquatic examples are wide ranging, including baleen whales responding to sounds within frequencies used by killer whales (e.g. Goldbogen et al. 2013); herring detecting sounds used by echo locating whales; fish and crab larvae using reef sounds dominated by snapping shrimp as directional cues; sharks approaching the sounds made by struggling prey; and surface-feeding fish responding to sounds of prey falling into the water (reviewed by Slabbekoorn et al. 2010). Barber et al. (2010, p. 183) summarize a pattern that appears broadly consistent for both terrestrial and marine realms:

"It is clear that the acoustical environment is not a collection of private conversations between signaler and receiver but an interconnected landscape of information network and adventitious sounds."

These complex and dynamic assemblages of natural sounds are inherent aspects of marine habitats (Figure 1). All of the sound present in a particular location and time, considered as a whole, comprises a 'soundscape' (Pijanowski et al. 2011). When examined from the perspective of the animals experiencing it, a soundscape may also be referred to as 'acoustic habitat' (Clark et al. 2009, Moore et al. 2012a, Merchant et al. 2015).

Acoustic habitats identified today are often significantly modified by noise produced by human activities, and thus efforts must be made to characterize both their natural and altered conditions. Such activities, and the resulting noise levels that they

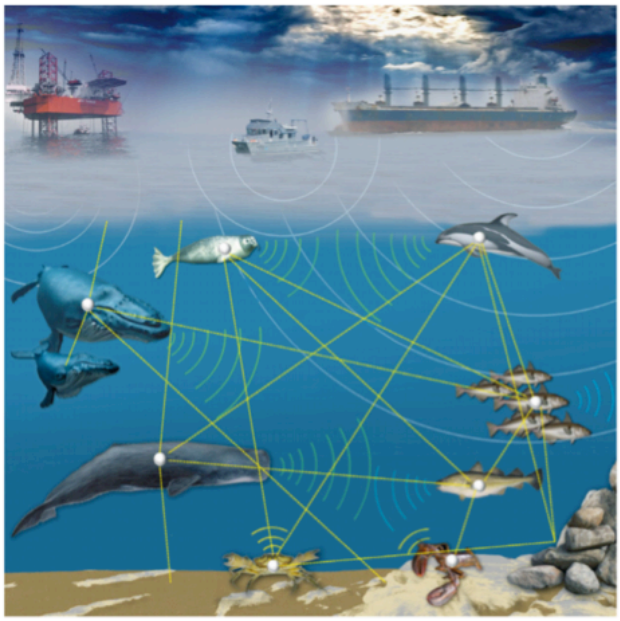

Figure 1. Potential acoustically mediated information pathways (yellow dotted lines) in a marine community, including, but not limited to, purposeful communication between individuals, use of echolocation over distances (large and small), eavesdropping on sounds made by other animals, detection of human activities, and identification of seafloor characteristics, all supporting biologically important behaviors such as settlement, recruitment, feeding, migration, and reproduction. White circles and blue, green and yellow semicircles generically represent information-gathering opportunities and sound production, respectively.

produce, are increasing throughout coastal and ocean waters in both time and distribution. There are few aquatic areas where anthropogenic noise is absent. Changes in noise conditions over time are predicted to vary considerably among ocean and coastal areas. In some heavily used areas, several-fold increases in the contribution of human noise to acoustic habitats have been measured over just a few decades (Andrew et al. 2002, McDonald et al. 2006).

While some marine animals are capable of adjusting communication signals in the presence of noise (e.g. Holt et al. 2009, Parks et al. 2010), it is unknown whether these changes can transfer between generations or whether they result in long-term fitness consequences. Relative to the life spans of marine organisms, noise levels have seen significant growth over just a handful (e.g. some fish, turtles and marine mammals) to tens (e.g. some fish and invertebrates) of generations. Given this rapid increase, the potential for true evolutionary adaptation to a noisier environment is limited.

NOAA recognizes the need to develop an approach to underwater noise management that considers not only its effects on individual animals, but also the importance of natural sounds in the places where those animals live. As the world's coasts and oceans become busier and noisier, NOAA will be challenged to craft and implement new management approaches that balance the competing needs of coastal and ocean resource users and natural acoustic habitats. In this paper, the authors describe key elements of an agency-wide strategy to more comprehensively manage noise impacts on acoustic habitats, including implications for the science needed to assess habitat status and noise influences. The authors then examine NOAA's management tools and consider their application to acoustic habitat protection goals, highlighting activities that are underway or could be undertaken to achieve these goals.

NOAA's Tools for Managing Acoustic Habitat

Historically, NOAA has managed the impacts of noise on its trust resources by using legal frameworks designed to protect target populations and species. These populations and species are those that society has determined need special care, including those that are endangered or threatened, and those that are of particular ecological, cultural, or economic interest, including all marine mammals. The Endangered Species Act (ESA 1973) and the Marine Mammal Protection Act (MMPA 1972) are the primary statutes by which NOAA requires mitigation strategies and monitoring action designed to reduce or eliminate and better understand the impacts that specific types of noise have on this limited suite of species. Under these statutes, management action has focused on reducing the potential for relatively loud noise sources (e.g. air guns, sonars, pile drivers) to unambiguously injure animals or cause them to respond behaviorally over (usually) relatively small spatial and temporal scales. This traditional approach has played an important role in fulfilling NOAA's stewardship mandates by preventing or minimizing acute harm to individual animals.

	All US MPAs Number	%	NOAA MPAs Number	%
MPA area coverage in US EEZ				
No. of MPAs in US EEZ	1774	—	227	13
US EEZ area covered by MPAs (km^2)	6.85M	55	6.78M	99
Primary conservation focus of US MPAs (no. of sites)				
Natural heritage	1179	67	80	35
Sustainable production	442	25	145	64
Cultural heritage	153	9	2	1
Level of protection of US MPAs (no. of sites)				
Uniform multiple use	1402	79	187	82
Zoned multiple use	111	6	21	9
Zoned with no take	35	2	6	3
No take	127	7	13	6
No impact	16	1	0	0
No access	83	5	0	0
Ecological scale of protection (no. of sites)				
Focal resource	674	38	164	72
Ecosystem scale	1100	62	63	28
MPAs managed by NOAA line office (no. of sites)				
NOAA Fisheries	182	10	182	80
National Ocean Service	45	3	45	20

Table 1. Prevalence and diversity of management approaches for all existing Marine Protected Areas (MPAs) in US Exclusive Economic Zone (EEZ) waters, as well as NOAA-managed or co-managed areas.

The U.S. National Ocean Policy (US NOP; Executive Order 13547 2010), however, firmly directs federal agencies to implement ecosystem-based approaches to management. Fundamentally place-based, these management efforts seek to conserve functioning ecosystems and the services they provide. Ecosystem based management approaches highlight the importance of natural habitats and parallel additional efforts within NOAA to focus the agency's many mandates to protect and restore habitats. Inherent in these policy directives is the need for NOAA to begin to address the widespread degradation of natural acoustic habitat for a broad range of acoustically sensitive species due to increasing noise from accumulated anthropogenic sources.

The degree to which NOAA's management tools can be used to focus on specific habitats ranges widely. Many, but not all, areas managed or co-managed by NOAA meet the national definition of a marine protected area (MPA). In the U.S., an MPA is broadly defined as "*an area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (Executive Order 13158 2000, Section 2 (a)).*

Covering over half the total area of the U.S.'s Exclusive Economic Zone (EEZ) and occupying most habitat types (Table 1), U.S. MPAs have been established by a variety of federal, state, and tribal agencies to protect a diversity of species (e.g. mammals, fish, invertebrates, and plants), cultural resources, and natural ecosystem features and processes. MPAs in the U.S. also vary widely in their conservation purposes, and in the associated level, scale, and permanence of protection afforded the resources they protect (Table 1, categories discussed in National Marine Protected Areas Center 2011). NOAA manages or co-manages only 13% of MPAs within U.S. waters. However, these 13% represent 99% of the total area contained within U.S. MPAs. This is due mainly to the existence of many large sustainable production fishery MPAs, a few large marine mammal MPAs on the east coast, and four large National Marine Monuments in the Pacific.

While two-thirds of U.S. MPAs have a broad ecosystems conservation focus, two-thirds of NOAA MPAs focus on the conservation of specific focal resources. The remaining one-third of NOAA MPAs, including 15 sites managed by the Office of National Marine Sanctuaries, focus on comprehensively protecting marine ecosystems. Regardless, as the main federal managers of large, offshore MPAs, NOAA plays a key role in shaping and executing U.S. marine spatial protection.

A fuller understanding of how and where NOAA's existing spatial management tools can be used to sustain viable acoustic habitats will help the agency meet and adapt to the growing threat ocean noise poses to our trust resources. NOAA's place-based tools can generally be categorized as those that are applied by the agency to fulfill mandates to protect specific, high-value populations or species, versus those that are applied towards protecting a high-value area, including all its attributes.

The Path Forward

NOAA has embarked on a path to better understand the importance of sound in marine ecosystems, and to more effectively manage anthropogenic threats to acoustic habitats using both current and augmented tools. Growing threats from noise to acoustically sensitive species coupled with limited agency resources needed to address these challenges, suggest a need to simultaneously move forward aggressively while making clear strategic decisions about where and how to prioritize those efforts in the coming years. While specific decisions in the future will be influenced by many factors, the following actions seek to match the broad spatial and long temporal ecological scales over which noise is impacting acoustic habitats.

Create and Support International Initiatives to Reduce Influence from Distant Noise Sources

NOAA acknowledges that addressing chronic noise conditions within some acoustic habitats of concern will necessitate management action that can reduce noise exposure over very large spatial scales (McCarthy 2004, Hatch & Fristrup 2009). Drivers for wide-ranging mitigation solutions stem from both presumed species-specific communication ranges (e.g. fin and blue whales) and documented propagation distances for low-frequency noise sources (e.g. seismic airguns and ships). Distant sources of noise will have differential impacts within acoustic habitats of interest.

In general, deep-water habitats at northern hemisphere mid-latitudes or in highly trafficked seas are likely to be significantly influenced by wide-ranging noise sources (National Research Council of the U.S. National Academies 2003). Additionally, many highly migratory populations of endangered baleen whales are known to produce low-frequency calls and songs throughout most of their ranges (e.g. Charif et al. 2001, Oleson et al. 2014). Acoustic conditions could be considered relevant to these species wherever they occur. NOAA's authorities for addressing range-wide threats to target populations and listed species often explicitly recognize and direct multilateral approaches (e.g. endangered species recovery planning). Such drivers provide important mechanisms for the agency to engage in long-term, international efforts to reduce chronic noise influence, in addition to more nationally focused activities.

Efforts to recover, restore, and ensure sustainable harvest of species over large ranges identify key partnerships with other agencies and countries, and industries, with direct mechanisms to influence implementation of quieting programs. NOAA has provided such leadership in efforts to develop technical guidelines to reduce noise from commercial ships through the United Nations' International Maritime Organization. In partnership with the U.S. Coast Guard, NOAA supported the U.S.'s chairing of these efforts beginning in 2008, with successful passage of guidelines in 2014 (International Maritime Organization 2014). NOAA continues to work with interagency and non-governmental partners to support international implementation of these guidelines.

Key next steps include pilot programs for select shipping companies and, ideally, select ports, with interests in supporting 'green ship' development, in which new ships are built or existing ships are modified to include quieting in design and operational goals. Pilot programs would evaluate time horizons for cost recovery (e.g. via increased fuel efficiency, reduced maintenance), consider integration of quieting goals with other environmental protection goals included in green ship design projects, and develop monitoring and docking incentives associated with participating ports.

NOAA has been less directly engaged in international efforts to encourage the development of quieter technologies to modify or replace other dominant low-frequency noise sources, like airguns, other seismic sources, pile-driving activities, and vessel dynamic positioning systems that are used in a wide variety of offshore energy development phases (e.g. exploration, platform construction, extraction/ generation). For such sources, NOAA's current regulation and consultation activity to address physical and behavioral effects due to acute noise exposure focuses on noise-reduction techniques to reduce peak pressures or short-term (e.g. 1 d) accumulated energy experienced by animals swimming nearby (e.g. some pile-driving sound-attenuation techniques).

Broadening such designs to address lost listening opportunities over larger spatial and longer temporal scales will necessitate setting of engineering targets that reference biological effects at those scales. Longer-term effect targets are emerging from modeling the population-level consequences of displacing harbor porpoises from their habitat in the North Sea as a result of regional wind farm development (SMRU Consulting 2015).

However, effect targets assessed via modeling of consequences mediated through full ecosystems are also important, to ensure that species-specific noise optimizations benefit habitat conditions more holistically. Many of the companies conducting noise-producing activities in support of offshore energy exploration and production have increased their investment in quieting technologies, recognizing that quieter alternatives would be environmentally preferable and would reduce the complexity of operating within highly variable international regulatory constraints. For example, a wide range of international oil companies and the International Association of Geophysical Contractors continue to invest in the development of marine vibroseis technology as an alternative to airgun technology for use in seismic data acquisition (E&P Sound & Marine Life Joint Industry Program: www.soundandmarinelife.org).

Improve and Apply National Tools to Reduce Cumulative Impacts

Given the increasing number of noise producers seeking permits from NOAA to authorize impacts, there is a need to address the implications of accumulated exposure to acoustic habitats. This need is not isolated to noise among environmental stressors, nor to the USA alone. Tools to address cumulative, multi-source effects over wider spatial scales are emerging in the European Union associated with the implementation of the Marine Strategy Framework Directive (EU MSFD). The EU MSFD defines its objective, Good Environmental Status, to include the requirement that 'Introduction of energy (including underwater noise) does not adversely affect the ecosystem' (EU MSFD 2008).

Regional registries of noise-producing events, developed by individual countries (e.g. U.K. and The Netherlands) but with high levels of multi-lateral collaboration, are being used to characterize contributions to national and regional noise budgets. Importantly, these registries collect information regarding nationally permitted noisy activities both at the times they are proposed and then again after they are completed. Such registries thus allow European countries with collective, regional interest in regulating noise to describe relative, actualized noise contributions to localized acoustic habitats of concern. Noise predictions based on registered events can be compared to monitoring data to estimate remaining contributions from nonregistered source types.

A geospatially explicit registry of all federally authorized (i.e. NOAA permitted and/or requiring non NOAA federal action) noise-producing events in U.S. waters would inform many facets of NOAA's activities to address cumulative noise impacts on high-risk acoustic habitats. In parallel with EU MSFD efforts, such a registry would inform NOAA's role in implementing the U.S. National Ocean Policy. The U.S. National Ocean Policy encourages Regional Marine Planning as:

"a science-based tool that regions can use to address specific ocean management challenges and advance their economic development and conservation objectives." (National Ocean Council 2013a, p. 21)

Regional Marine Planning Bodies have been established in several U.S. regions, with the northeast and mid-Atlantic Regional Marine Plans finalized. Several Regional Planning Bodies (as well as similar regional collaboratives) have invested in mapping coastal and offshore human use patterns as critical information to inform discussions of compatibility among uses and to achieve ecosystem protection goals. Some noise producing activities are likely well captured by current mapping initiatives, including the likely influence of ocean-going (e.g. cargo, tanker) and some more localized commercial (e.g. fishing, ferries, tugtow) and recreational (e.g. fishing, pleasure) vessels on regional acoustic habitats (e.g. SoundMap, http://cetsound.noaa.gov/sound_data). Others are captured in more generalized and often low-resolution projected terms, including levels of expected activity within boundaries of lease blocks for energy development or ranges for military activities. Higher-resolution information describing actualized activity levels evaluated after they occurred would significantly improve place-based characterization of noise contributions in areas with high federal authorization activity.

In other areas, improving noise estimates will demand approaches that account for activity types that are not federally authorized. In particular, noise in nearshore waters can be influenced by a diversity of human activities that may or may not require local, state, tribal, or federal authorizations, including offshore communication and energy installations, port and harbor operations, maintenance of bridges and waterways, pleasure craft, and even onshore road traffic. Inshore areas are often of high concern for environmental management, as they

support biologically important (and often acoustically sensitive) reproductive and early life stage behaviors for a wide range of aquatic taxa, including invertebrates, fish, and mammals.

Measurements of coastal noise levels are increasingly collected by nearshore monitoring efforts, although they disproportionately sample locations and time periods that contain noisy events and are often not regionally centralized. A new land-based modeling technique would, however, leverage the increasing quantity and spatial coverage of coastal noise measurement data and shows great promise for improving the accuracy and accessibility of noise predictions over large scales. This technique has been applied to relate well-distributed noise measurement data to geospatial datasets that de scribe key anthropogenic, biological, and geophysical predictors of noise, generating maps of noise levels that span the US continental states (Mennitt et al. 2014, www.nature.nps.gov/sound/soundmap.cfm).

Although necessitating continual improvements in noise measurement databases, this technique reduces reliance on high-resolution descriptions of noisy activities. Such regional to coast-wide noise predictions would improve representations of cumulative conditions within both Coastal Zone Management and Regional Marine Plans. States with approved Coastal Zone Management Plans can then determine whether federal actions or permits associated with proposed activities are consistent with the enforceable policies of their plans (Coastal Zone Management Act 1972). While Regional Marine Plans may not explicitly seek to reduce accumulated noise impacts within high-risk acoustic habitats, such an outcome is inherent to planning objectives that seek to reduce regulatory burdens for both NOAA and those promoting noise-producing activities by improving information regarding place-based cross-sectoral and environmental compatibility (National Ocean Council 2013b).

Marine planning seeks to augment statutorily directed consultation and environmental impact assessment processes that are standardly used to address noise impacts. Registries of federally permitted noise-producing events would allow NOAA, in concert with long-term monitoring capabilities, to guide project-specific consultation activity under the ESA (NMSA 1992 and MSFCMA 1996) towards longer-term mitigation designs to address noise sources that are identified as being dominant contributors to both accumulated acute and chronic noise in high-risk acoustic habitats. In addition, 'programmatic' NEPA evaluations and consultations are increasingly being performed by agencies with direct regulatory responsibility for noise-producing activities (Council on Environmental Quality 2014), often in partnership with NOAA. These actions seek to assess implications for populations, species, and places over regions and multi-regions and over multi-year time periods.

Cooperative evaluation of environmental consequences, including noise consequences, of longer-term and wider-ranging activity is improving inter agency information sharing and supporting the development of new tools to support risk assessment at these scales. Such tools would benefit from interagency cooperation to generate and contribute to registries of noisy events, particularly to improve information regarding actualized versus proposed activity profiles. Programmatic impact assessments and consultations also have the potential to improve characterization of noise budgets within acoustic habitats of management concern through longer-term monitoring requirements.

Finally, improved characterizations of accumulated noisy activity would support NOAA's decisions regarding use of the agency's statutory authorities to strengthen localized protection for acoustic habitats. NOAA has applied its generalized authorities under the MMPA and ESA to regulate ship speeds in areas and during time periods when risks of collision with North Atlantic right whales are heightened. These regulations thus applied range-wide authorities to direct long-term, though more spatially restricted, mitigation in targeted areas. Monitoring required to support this action has in turn supported better understanding of collision risk, as well as measuring compliance and informing enforcement actions as necessary. Such generalized authorities are available to the agency within several statutes, and provide opportunity for establishing long-term mitigation (e.g. seasonal or year-round exclusion or reduction in noisy activity levels, use of quieter technology) in a high-risk acoustic habitat. Such actions must be supported by a needs analysis documenting the detrimental (although mostly sub-lethal) consequences of the noise source(s) that will be mitigated, on targeted NOAA-managed resource(s), included in the 'basis and purpose' of the rulemaking.

In addition, NOAA's support for the development of Cetacean Biologically Important Areas has identified places, additional to those defined as critical for ESA listed species, to inform management action across the many permitting and consultation actions currently being taken to address noise impacts on these species. Just as these areas will be modified in the future to reflect additional scientific information, their application to management actions should be evaluated over time to determine whether they are effective in enhancing the condition of the acoustic habitats they contain. Long-term monitoring within biologically important areas and critical habitats associated with highly vulnerable and acoustically sensitive cetacean populations (e.g. southern resident killer whales, North Atlantic right whales, Cook Inlet beluga whales) will be critical to establishing baselines for assessing success of multi-action mitigation, and determining whether existing or additional place-based management authorities are or would be effective.

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A 2018 Horizon Scan of Emerging Issues for Global Conservation and Biological Diversity

Cambridge Conservation Initiative

Twenty-four experts in conservation research and practice, ecology, economics, policy, and science communication identified 15 topics following a wide consultation. They followed a Delphi like process to score and identify the most important.

The issues highlighted span a wide range of fields and include thiamine deficiency in wild animals, the geographic expansion of chronic wasting disease, genetic control of invasive mammal populations and the effect of culturomics on conservation science, policy and action.

Trends

This is our ninth annual horizon scan to identify emerging issues that we believe could affect global biological diversity, natural capital and ecosystem services, and conservation efforts. Our diverse and international team, with expertise in horizon scanning, science communication, as well as conservation science, practice, and policy, reviewed 117 potential issues. We identified the 15 that may have the greatest positive or negative effects but are not yet well recognized by the global conservation community. Themes among these topics include new mechanisms driving the emergence and geographic expansion of diseases, innovative biotechnologies, reassessments of global change, and the development of strategic infrastructure to facilitate global economic priorities.

Introduction and Aims of Horizon Scanning

We present the outcomes of our ninth annual horizon scan. Our aim is to highlight systematically both risks and opportunities to the conservation of biological diversity that are not widely known by conservation scientists and decision makers. Collectively, our horizon scanning team has considerable expertise, experience, and perspectives on conservation science and allied disciplines. These disciplines encompass economics, policy, journalism, ecology, microbiology, conservation practice, and professional horizon scanning. Horizon scanning allows users, including but not limited to policy makers, researchers, innovators, educators, investors, and practitioners, to identify future political, environmental, technological, and societal changes and consider their possible effects. Horizon scanning can help reduce the degree for conservation biology to be a crisis discipline[1], and to be a proactive rather than a reactive science.

It is now well established that horizon scanning can support and shape local, national, and international decision making. For example, a foresight study on the detection and identification of infectious diseases by the U.K. Government Office for Science drove investment into new approaches.[2] We cannot easily track whether the issues we identified previously affected decisions by policy makers or conservationists because the issues are embedded within extensive political, social, and environmental changes such as urbanization, human migration, and population growth.

The potential opportunities and threats associated with each issue, and the response of the global conservation community will be affected considerably by the trajectory of these global drivers. In some

scenarios, the issues are likely to mature into trends, whereas in others they are not. However, several issues that we highlighted in previous scans gained broader attention that resulted in action, suggesting at the least that some of our issues were at the cusp of emergence.

In 2015, we discussed the underground gasification of coal and its potential to contaminate groundwater and produce greenhouse gases.[3] After publication of the scan, the U.K. Government commissioned an independent review of underground gasification of coal.[2] In November 2015, that review suggested that the technology could be responsible for a substantial increase in greenhouse gas emissions. Scotland banned underground gasification of coal in October 2015[4] and the U.K. Department for Business, Energy and Industrial Strategy stated that it was 'minded not to support' the technology in 2016. In 2017, we noted that the growing demand for sand and gravel was outstripping sustainable supply.[5] This same issue since has been the subject of media investigation and reporting in major outlets in the U.S., Europe, and Asia,[6] and an editorial on this issue[7] referenced our scan when identifying this topic as an emerging issue.

As the basis for the scan reported here, we compiled 117 issues. Participants and their colleagues suggested the issues on the basis of at least 444 sources that were referenced in descriptions of the issues: 178 articles from a total of 109 scientific journals, 138 online news articles, and an assortment of web pages, press releases, reports, surveys, blogs, videos, and radio programs. Most references were in English, but some were written in Chinese, Spanish, Icelandic, or Portuguese. Content producers were affiliated with, among others, universities, government, research institutions, national newspapers, and agricultural or industrial sectors.

Identification of Issues

The methods we used during this horizon scan were consistent with those used during our previous annual scans.[3, 5, 8, 9, 10, 11, 12, 13, 14] The 24 core participants in the horizon scan the authors used a modified version of the Delphi technique that is repeatable, inclusive, and transparent.[15, 16, 17]

We consulted our professional networks by person-to-person communication and through targeted Facebook groups, Twitter (e.g., six participants tweeted the same message to their 22,377 followers), the BiodivERsA network, and a project on ResearchGate. We communicated directly with 357 people in person, electronically, or via social media. Each coauthor then submitted at least two issues. Criteria for consideration of these issues by the group were that they must be related to conservation of nature or natural resources, relevant at regional or global scales, and emergent among the global community of researchers, practitioners, and policy makers. The resulting list of 117 issues was circulated to the participants.

Participants gave each issue a unique score in the range from 0 to 1000, with higher scores for issues that were not well known and likely to have considerable environmental effects. The scores were converted to ranks. Separately, participants also indicated whether they had heard of the issue, and the proportion of participants' awareness was used to indicate wider awareness or novelty of the issue, and hence to influence the final scoring. To counteract the possibility of scoring fatigue, or unconscious differences in scoring of issues near the start and end of a long list,[18] we developed two versions of the list in which the order of issues was changed, and distributed each version to half of the participants. We retained the 35 issues with the highest median ranks across all participants for further consideration.

Next, two or occasionally three participants were assigned to each of 35 issues to investigate further their novelty, apparent likelihood of occurrence or implementation, and likely magnitude of positive or negative effects. The participants then convened in Cambridge, U.K., during September 2017 and discussed each of the 35 issues. The proponent of each issue was not one of the first three people to contribute to discussion on that

topic. During our discussion, the emphasis of some issues was adjusted. Following discussion, participants again independently and confidentially ranked the issues, and the 15 with the highest median ranks across all participants were selected for inclusion in the scan. During our subsequent research on these issues, it became clear that two were substantially better known than we originally thought. We removed these two issues and replaced them with the next two highest-ranked issues. The duration of the formal process, from original submission to final selection of the 15 issues with the highest ranks, was four months, although participants gather issues throughout the year. The issues below are grouped thematically rather than presented in rank order.

Emerging Issues

Thiamine Deficiency as a Possible Driver of Wildlife Population Declines

Evidence is increasing that a range of taxonomic groups, including bivalve molluscs, ray-finned fish, and birds across the Northern Hemisphere, are deficient in thiamine (vitamin B1).[19, 20] Thiamine is required for basic cellular metabolism and functioning of neuronal membranes. Thiamine deficiency rarely is a direct cause of mortality, but impairs health and can cause immunosuppression or leads to behavioural and reproductive problems that ultimately could cause population decline or extirpation. Days of thiamine deficiency may present long-lasting sublethal effects, which makes recognition of the extent of thiamine deficiencies more complex. The deficiencies likely are caused by insufficient dietary intake, which may be related to shifts in thiamine-producing algal populations. A recent and extensive survey along the northwest coast of the U.S. found evidence of thiamine depletion in the water column.[21] Additionally, exposure to environmental pollutants may interfere with thiamine uptake. The extent to which thiamine deficiency may pose a substantial long-term risk to a range of species remains unclear.

Geographic Expansion of Chronic Wasting Disease

Chronic wasting disease is a progressive and fatal neurodegenerative disease in cervids. It is a prionic disease similar to scrapie and bovine spongiform encephalitis. Transmission appears likely to occur from animal to animal, with the infectious agent being passed in faeces, urine, or saliva and from mothers to offspring. The prions associated with chronic wasting disease are highly resilient, and contaminated pasture soils may become sources of infection. First discovered in mule deer (*Odocoileus hemionus*) in the U.S. in 1967, the disease subsequently was found in other deer species – white-tailed deer (*Odocoileus virginianus*), elk (*Cervus canadensis*), and moose (*Alces alces*) – in 23 U.S. states and two Canadian provinces. Chronic wasting disease may cause annual, population-level mortality of 10% in white-tailed deer, and may be constraining population growth.[22] There is a risk that chronic wasting disease will become epidemic in other continents, potentially inducing ecological cascades if key herbivore populations suddenly decline. Chronic wasting disease recently was discovered in captive elk in South Korea and in two individual reindeer (*Rangifer tarandus*) in Southern Norway; its first confirmed presence in Europe.[23] Infection later was detected in three additional reindeer in Central Norway, prompting the decision to cull a herd of 2000 animals.[24] Further emergence of chronic wasting disease in Norwegian reindeer may have substantial effects on vegetation structure, ecological succession, and prey availability for top predators in tundra ecosystems,[25] and on the culture and livelihoods of Arctic herding communities.

Breaks in the Dormancy of Pathogenic Bacteria and Viruses in Thawing Permafrost

Some viruses and bacteria can survive freezing for thousands of years.[26] Permafrosts (frozen soils usually held together by ice) that have persisted for millennia are now thawing because of recent and continuing climate changes. As permafrosts thaw, embedded viruses and bacteria, some of them pathogens of humans or other living organisms, may be released and break dormancy, with cascading ecological effects. During the 2016 heat wave in Siberia, for example, a release of anthrax bacteria (*Bacillus anthracis*) led to infections that resulted in one human fatality, the hospitalisation of 20 people, and the death of 2,000 reindeer.[27] The anthrax bacterium is thought to have emerged from the thawing carcass of a reindeer that died some 75 years previously. Pathogen viability may be far longer than 75 years, however. Following thawing in a laboratory, a virus (*Pithovirus sibericum*) that had been frozen in Siberian permafrost for 30,000 years was able to infect and kill amoebae.[28] If the pathogens are released in a given area from which they have been absent for a long period, then the pathogens could result in population-threatening epidemics. The extent and speed of fast-thawing permafrost may be further increased by mining for minerals and drilling for oil and gas that is facilitated by melting of Arctic Sea ice.

RNA-Based, Gene-Silencing Pesticides

Topical application of double-stranded RNA (dsRNA) is emerging as a novel method to control insects and viruses considered to be plant pests. The ingested dsRNA triggers enzymes within insect cells, stopping production of proteins that correspond to the dsRNA sequence. This process mimics the natural defence mechanism of RNAi; consumption of dsRNA sequences alters genetic expression in some species[29] and halts expression of genes that strongly affect survival or reproduction of the pests. dsRNA delivered via the vascular system of several crop plants killed sap-feeding insects[30] and a single application of dsRNA protected tobacco plants against a virus for 20 days;[31] albeit both studies were laboratory based. Diverse applications of dsNRA are being developed. For example, one company is developing an RNAi spray that kills Varroa destructor, a mite that threatens some honey bee populations (*Apis cerana* and *Apis mellifera*). Because gene silencing does not result in a heritable change, this approach may be more publicly acceptable than others that modify organismal genomes. Similarly, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services pollinator report identified RNAi gene silencing specifically as a promising technology for controlling viruses in honey bees.[32] In addition, dsRNA could be regulated as a chemical pesticide rather than a genetically modified product. Little is known about the potential effects of gene silencing on nontarget organisms with the same gene sequences. Although some studies[33, 34] found no measurable effects on survival, condition, or gene expression of nontargeted organisms, these studies were conducted on relatively few species. Ensuring the species specificity of gene-silencing methods is challenging, as is creation of effective, integrated pest management with fewer undesirable environmental effects.[35]

Genetic Control of Mammal Populations

Gene editing and self-replicating gene drive technologies, which can spread a deleterious allele to provoke a population crash, are developing rapidly.[36] A global partnership of scientists from diverse organizations, including the governments of the US and New Zealand, is fostering development of the technologies, and their accompanying regulations and ethics, to control non-native invasive rodents on islands. The program aims for applications within 10 years (Genetic Biocontrol of Invasive Rodents; http://www.geneticbiocontrol.org/). Controlling or eradicating invasive mammals on islands could reduce the likelihood of projected future extirpations of threatened vertebrates by 41–75%.[37] New Zealand aims to eradicate rats, possums, and stoats on all its land by 2050, and is investing NZ$6 million (U.S. $4.3 million) per year in this effort (Predator Free 2050;

http://www.doc.govt.nz/predator-free-2050). Laboratories worldwide are developing gene drive systems in mice (*Mus musculus*), although rats are responsible for a greater proportion of extinctions on islands than mice. The projections of individual-based models[38] suggest that some methods based on CRISPR-Cas9 (clustered regularly interspaced short palindromic repeats) gene editing could reduce the mouse population of an island from 50 000 to zero in 4–5 years.[38] Larger populations of mice, and populations of black rats (*Rattus rattus*) or rabbits (*Oryctolagus cuniculus*), also could be eradicated with these methods, although more slowly. Widespread use of these methods to manipulate the demography of mammal populations, however, raises ethical and ecological questions, such as the cascading effects of the eradication of the targeted populations and the potential consequences if an eradication trait spreads into nontarget regions or species within their native range.

Use of Lasers in Commercial Deep Water Fishing

An alternative to bottom trawling has been developed by the Innovation Center Iceland and Icelandic Marine Research Institute.[39] Currently one-third of the value of wild seafood landed in Europe is caught by bottom trawling, a fishing method that generates considerable bycatch,[40] causes extensive and enduring damage to benthic ecosystems,[41] and results in substantial carbon emissions.[42] Emissions of greenhouse gases and bycatch generated by trawling for shrimp, for example, are especially high; fuel use may approach 4 l of oil per kilogram of edible catch. The new method replaces the conventional trawl with a rigid frame and a small tapered net that corresponds to the cod end of a traditional trawl. Automated height control allows the frame to glide above the sea floor, and target species are herded with directed laser beams, leaving nontarget species and other elements of the benthic ecosystem undisturbed. Lasers also can be used to extend the effective size of the trawl without introducing additional drag.[39] Tests on caridean shrimp (*Pandalus borealis*) indicated that the volume of catch from the laser-based gliding trawl is greater than from bottom trawling. If the new technology proves viable, it may be a realistic alternative to traditional bottom trawls, causing much less sea-bed damage and substantially reducing the volume of fossil fuel used per catch. However, the potential for unsustainable catch levels and other undesirable effects have not yet been widely discussed.

Use of Metal–Organic Frameworks (MOFs) for Harvesting Atmospheric Water

A new technique is being developed to capture atmospheric water in a wide range of ambient conditions, including in low humidity. It involves MOFs (a form of porous crystals)[43, 44] or use of solar power. MOFs capture 2–5 l of water daily per kilogram of MOF. MOFs currently use expensive metals such as zirconium, but frameworks that are based on other materials are under development.[45] MOFs could reduce the time necessary to collect water and reduce displacement of humans or wildlife from arid ecosystems or during drought, increasing well-being of humans and reducing ecological effects of environmental migration or land abandonment. Conversely, capture of atmospheric water might make farming in marginal lands feasible, with adverse environmental and social effects. Future refinements might allow collection of sufficient water for plant growth in semi-arid areas, perhaps focusing on drought-tolerant species. Whilst this technique creates new opportunities for human and wildlife communities, its implementation across large areas could lead to major land-use or land-cover changes, with potentially widespread effects on local ecological communities. Effects of capture of atmospheric water in areas with low humidity are unclear, but across extensive areas, further reduction in local atmospheric humidity might exacerbate existing water stress in nonirrigated plant communities in arid areas.

Aquaporins Engineered to Increase Plant Salt Tolerance

While certain plant species, including some crops, have high salt tolerance,[46] increasing salinity of agricultural soils threatens crop production in many locations worldwide.[47] Recent advances in understanding of plant responses to salt stress suggest possible methods to increase salt tolerance in crops and thus expand their possible cultivation ranges. Aquaporins, for example, are proteins in the plasma membrane that transport water, and can transport solutes and ions in plants and animals. Rarely has transport of ions by aquaporins been reported in plants.[48] Nevertheless, it is becoming apparent that certain aquaporins in plants, such as AtPIP2;1, may transport sodium ions. Accordingly, genetic engineering of aquaporins may increase salt tolerance in plants.[49] Treatment of plants with silicon may increase tolerance of salt further through regulation of aquaporin gene expression.[50] If plants with these aquaporins can be selectively bred or engineered, it may be possible to increase the agricultural capacity of soils that currently are relatively saline or that may become more saline due to subsidence related to ground water extraction or sea level rise. The extent to which salt tolerance in native plants or crops might be increased via such aquaporins remains unclear. Should this, or other methods of increasing plant salt tolerance, become commercially viable, the positive or negative effects on biological diversity may be considerable. Increases in the extent of arable land may lead to loss or fragmentation of habitat for native species. Additionally, salt-tolerant agricultural plants may colonise natural ecosystems and out-compete native plants. An increase in salt-tolerant crops, however, may allow use of abandoned croplands, and reduce food shortages and human displacement, reducing pressure to convert presently nonfarmed land to agriculture or settlements.

Effect of Culturomics on Conservation Science, Policy, and Action

Culturomics analyses word frequencies and associations in large, digital sets of data to better understand human culture and behaviour. The methods are not new, but their applications to conservation are emerging.[51] Culturomics may affect the success of conservation strategies that depend on public support and the demonstration of societal and cultural impacts of conservation. Proposed applications of culturomics in conservation science, practice, and policy include identification of conservation-oriented constituencies, demonstration of public interest in nature, understanding the drivers of such interest, and assessing the effects of conservation interventions. Internet searches, Twitter and WeChat traffic can, for instance, be used to quantify public perception and interest in wetlands or bird species,[52, 53] or changes in public interest in biological diversity over time.[54] Culturomics could inform efforts to enhance conservation and guide decision-making. While originally applied exclusively to text-based sources, culturomics is becoming feasible for analysing video and audio files[55] and sentiments.[56] Advances in machine learning may enable the classification and use of new information sources, thus allowing further characterization of human–nature interactions that may increase support for conservation. It is probable, however, that culturomics also will be applied by organisations seeking to counteract or prevent conservation policy and actions.

Changes in the Global Iron Cycle

The global iron cycle is changing in response to accelerating ocean acidification, stratification, warming, and deoxygenation and is predicted to change further.[57] Changes in the iron cycle affect the aqueous chemistry, sources and sinks, recycling, particle dynamics, and bioavailability of iron.[58] Iron limitation constrains productivity of phytoplankton in many open ocean areas, which may affect entire ocean ecosystems. Iron is supplied to the oceans by wind-deposited particulates, anthropogenic sources, biological recycling, hydrothermal and riverine inputs, and upwelling. In polar regions, major sources include glacial runoff from scoured rock, resuspension of sediments from iceberg scour, and sea-ice cycles; all of which are predicted to

change substantially as climate changes.[57] Available iron may increase in the short-term as a result of increases in iceberg scour. However, in the longer term, as glaciers retreat to their grounding lines, a considerable decrease is likely to occur. The trade-off between iron bioavailability and use also is likely to change as the oceans warm and phytoplankton growth rates increase.[58] Increasing levels of iron limitation might further be used to justify ocean-fertilization efforts, either simply to enhance or to maintain previous CO2 draw-down from the atmosphere, or possibly to support offshore fisheries.[59]

Underestimation of Soil Carbon Emissions

Soil organic carbon contains most of the terrestrial carbon. The decomposition of this carbon stock as global temperatures increase represents a potentially large climate feedback mechanism, and is a major source of uncertainty in climate models. The loss of carbon from the upper soil layer in response to warming is well recognized,[60] but emissions of soil carbon from deeper layers have not yet been systematically considered. A deep-warming (to 100 cm) experiment detected a previously unobserved response at all depths, with CO2 production increasing by 34–37% given a 4°C increase.[61] Kauffman and colleagues reported losses in mangrove soil carbon stocks at depths >1 m following conversion to pasture.[62] Other research has indicated that soil volume change has been underestimated as a soil forming process, leading to errors of up to −87% to +54% in calculations of soil carbon change over longer time frames[63] and reinterpretation of soil organic matter transport between layers.[64] If a substantial proportion of the soil carbon, emitted through a feedback mechanism in response to increased temperatures, is missing from current climate projections, global warming could be more rapid than expected, with substantial effects on ecosystems, humans, and other species.

Rapid Climatic Changes on the Qinghai–Tibet Plateau

The Qinghai–Tibet plateau in Asia covers 2.5 million km^2, with an average elevation of more than 4000 m, and contains the third largest reservoir of ice in the world. From 1980 to 1997, temperatures on the plateau increased by an average of 0.21°C per decade, accelerating to 0.25°C per decade since 1997; precipitation has increased by 3.8 mm per decade since 1961.[65, 66] Glacial melt and increasing plateau temperatures will cause lakes on the plateau to overflow; the loss of permafrost will increase emissions of soil carbon and also have substantial effects on vegetation, hydrology, and species throughout and beyond the plateau.[67] Changes in the climate of the plateau also may affect Eurasian weather systems. Summer snow cover on the Qinghai–Tibet plateau affects atmospheric winds that modulate the El Niño–Southern Oscillation and in turn influence the East Asian Monsoon, which generates summer rain between the Yangtze and Yellow River basins.[68, 69] Snow cover on the Qinghai–Tibet plateau also has been linked to the onset of the summer monsoon on the Indian subcontinent and Indochina, and to heat waves in Southern Europe and Northern China.[70, 71] As the plateau continues to warm and snow cover decreases or becomes more variable, its effects on climate and hydrology in Asia and Europe may become more pronounced, with potentially major effects on species and ecosystems.

International Collaborations to Encourage Marine Protected Area Expansion in the High Seas

Areas beyond any national jurisdiction (the high seas) cover 44% of surface of the Earth, and <1% are protected. New designations and advances in international policy frameworks suggest that the expansion of marine protected areas (MPAs) in the open ocean is increasingly possible. The challenges of legally protecting biological diversity in the high seas are considerable.[72] The first high seas MPAs included the South Orkney Islands Southern Shelf MPA (2009) and several sites in the North Sea (from 2010). These MPAs sometimes are criticized because they are in areas with few other human demands[73] or because regulatory controls are insufficient to achieve conservation objectives.[74] The Ross Sea MPA in the Southern Ocean, was scheduled to come into force in

December 2017 as the largest MPA (1.55 million km^2) in the world. Members of the Commission for the Conservation of Antarctic Marine Living Resources (which include most of the G20 Group of nations) unanimously agreed to establishment of the MPA. In parallel, a preparatory commission established by the United Nations General Assembly in 2015 has drafted key elements of potential legislation to protect the biological diversity of the high seas, including novel mechanisms for establishing MPAs. This legislation would be managed under the International Convention for the Law of the Sea.[75] The lack of permanence of the Ross Sea MPA, which will expire after 35 years, has been regarded as a core weakness. However, the foundational agreement for the MPA, and the potential for a clearer international framework for management intervention, could lead to rapid increases in high seas conservation.

Belt and Road Initiative in China

In 2013, Chinese President Xi Jinping unveiled a strategic infrastructure program that would support development of six major land transport corridors across central Asia. The corridors would link China to Europe (the belt) and link Chinese ports to Indonesia, ports around the Indian Ocean, and, through the Red Sea, Southern Europe (the road). The cost of completing the corridors, estimated to be $1.25 trillion by 2025,[76, 77] will deliver economic development, supported by considerable scientific and technological development, across Eurasia to Africa. Nearly 70 countries have agreed to cooperate in the plan.[78] Given the growth of ecologically informed policies in China,[14] it may be possible to develop the corridors in an environmentally sustainable manner.[79] President Xi stated his ambition to create a big-data service platform for environmental protection, and to support climate change adaptation projects internationally.[78] However, official documents currently do not appear to emphasize environmental assessment, and there are concerns that the investors may push such big infrastructure projects through quickly at the expense of safeguards, with a cascade of negative environmental impacts.[80] For example, the proposed routes overlap protected areas supporting snow leopards (*Panthera unica*), Amur tigers (*Panthera tigris altaica*), and Far Eastern leopards (*Panthera pardus orientalis*).[81] The anticipated and extensive industrial and infrastructure development across central Asia, exacerbated by resulting human immigration to the region, would compound the undesirable ecological changes that are anticipated as climate changes.[79] Furthermore, any growth in trade throughout the region is likely to increase the risk of trade in endangered species and transport of non-native invasive species.

Potential Effects on Wildlife of Increases in Electromagnetic Radiation

Understanding the potential effects of nonionising radiation on wildlife could become more relevant with the expected adoption of new mobile network technology (5G), which could connect 100 billion devices by 2025. During use, mobile telephones and other smart devices generate radiofrequency electromagnetic fields (RF-EMFs), a form of nonionizing radiation, which may change biological processes such as neurotransmitter functions, cellular metabolism, and gene and protein expression in certain types of cells, even at low intensities.[82] The notion of risk to human health remains controversial, but there is limited evidence of increased tumor risk in animals.[83] 5G uses the largely untapped bandwidth of the millimeter wavelength, between 30 and 300 GHz on the radio spectrum, which uses smaller base stations than current wireless technology. As a result, wireless antennae may be placed densely throughout neighborhoods on infrastructure such as lamp posts, utility poles, and buildings. This could expose wildlife to more near-field radiation.

Although some studies reported negative associations between electromagnetic field strength (radiofrequencies and microwaves: 1 MHz–3 GHz range) and species, for example the density and abundance of house sparrows (*Passer domesticus*),[84, 85] these studies have not yielded clear empirical evidence that the observed effects are due to RF-EMFs. The potential effects of RF-EMFs on most taxonomic groups, including migratory birds, bats,

and bees, are largely unknown. The evidence to inform the development of exposure guidelines for 5G technology is limited, raising the possibility of unintended biological consequences.[86]

Discussion

Identifying issues that are truly on the horizon of current scientific thinking entails trade-offs. If there is little evidence that a phenomenon is emerging, it is difficult to gauge whether it is likely to become a major threat or opportunity. If there is considerable evidence, an issue no longer is novel. RF-EMFs are an example of the former. Discussions about the potential effects of RF-EMFs are unresolved and controversial.[83] However, the likely considerable global expansion in the use of RF-EMFs, and recognition that new technologies may allow radiation to use higher frequencies of the electromagnetic spectrum than previously were feasible, led us to include this issue among our 15. In contrast, we also discussed the impending global hydropower boom, but later decided it was no longer an emerging issue.[87, 88, 89]

Another challenge in horizon scanning is evaluating the degree to which the possible influence of an issue is exaggerated by news media, commercial interests, or individual scientists. Emerging environmental issues that are controversial are typically characterized by active campaigning voices, which can report or reference biased or misleading sets of research results and inferences.[90] When there is little evidence, the quality and provenance of that evidence is crucial to deciding whether an issue plausibly is emerging or whether it more likely represents a campaign mounted by one or more interest groups. We had discussions of this nature about EMFs, thiamine deficiency, and laser light trawling. We also debated the timeline along which we should judge emerging issues, and in many cases, we agreed that some required short-term action.

This year, two of our issues relate to emerging or returning disease. Previous horizon scans highlighted the re-emergence of rinderpest,[9] snake fungal disease,[13] and coral diseases.[3] These issues reflect growing evidence that emerging, or returning diseases are affecting native species and populations around the world, and, in some cases, leading to population declines or extirpations in once-common species.[91, 92] Animal and plant diseases pose a serious and continuing threat to food security, food safety, national economies, biological diversity, and the environment (U.K. Animal and Plant Health Agency and Department for Environment, Food & Rural Affairs; Protecting plant health: topical issues; https://www.gov.uk/guidance/protecting-plant-health-topical-issues). For example, plant health is a growing focus for governments and country risk registers.[93] Horizon scans can contribute substantially to focused research and its effects on government actions. Given the continued global transport of biological material and cumulative effects of stressors that increase the susceptibility of wild animals and plants to disease,[94] we suspect that future horizon scans will continue to highlight novel, emerging, or returning pathogens and diseases.

As we discussed in our 2017 horizon scan, biotechnology continues to yield transformational developments, many enabled by new and relatively cheap gene editing methods such as CRISPR-Cas9.[5] Two of the issues we identified this year, gene-silencing pesticides based on RNAi and genetic biocontrol of mammals, are being considered as solutions to the challenges of invasive non-native species and the need for increased food production. Both technologies may have major, positive effects on species and ecosystems through highly targeted control of unwanted species. However, both also represent technological interventions in natural populations and ecosystems that previously have not been attempted across extensive areas and could have long-term and unintended ecological or environmental consequences.

As new biotechnologies develop, ethical considerations and careful assessment of possible negative effects are usually given a high profile in the scientific literature and by regulators and governments (e.g.,[95, 96] on CRISPR-

Cas9). Nevertheless, these processes do not always stop the development of promising technologies that indeed have unintended consequences that are considered unacceptable by some sectors of society.

The horizon scanning process is not intended to draw attention to phenomena that are widely understood to affect societal needs or values, including those related to all aspects of biological diversity. Instead, it is intended as an early awareness and alert system drawing attention to novel issues that, if realized , may create pivotal opportunities or threats and thus warrant further analysis in the near future. It supports the capabilities of organizations to deal better with an uncertain and complex future.[97] We hope that our annual scans highlight issues of relevance not only to biological conservation but also to the wider environment and, by extension, to human well-being.

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Announcements

American Water Resources Association

2018 Spring Specialty Conference: GIS and Water Resources
April 22 - 25, 2018. Orlando, FL
http://www.awra.org/meetings/Orlando2018/index.html

This is the 10th in a series of conferences designed around geospatial solutions to water resources-related problems. Innovative water resources scientists, engineers, modelers, software designers from public/ government agencies, academic and private sectors convene to exchange ideas, compare challenges and identify solutions using process models, geo-referenced field data, remote sensing, or geostatistical models.

Summer Specialty Conference: Managing Transboundary Groundwater
July 9 - 11, 2018. Fort Worth, TX
http://www.awra.org/meetings/FortWorth2018/index.html

Growing populations and economies will increase competition for water resources around the world. Since water resources respect no political boundaries - sometimes not even intra-national or intra-state boundaries - equitable agreements to govern, manage, and protect these resources are essential to the social and economic well-being of all water users. The conference will provide attendees the opportunity to learn about and engage in discussions on innovative approaches for identifying transboundary groundwater resources and the methods to develop sustainable governance and management agreements.

2018 Annual Conference
November 4 - 8, 2018. Baltimore, MD
http://www.awra.org/meetings/Baltimore2018/index.html

This conference will convene water resource professionals and students from throughout the nation and will provide attendees the opportunity to learn about and engage in multi-disciplinary water resource discussions. The program will stimulate conversations on water resource management, research and education. The 2018 conference will also include locally relevant topics such as the Chesapeake Bay, the Delaware River watershed, and eastern water law as well as globally significant issues such as coastal resilience, fire effects on watersheds, communication and outreach strategies and integrated water resources.

American Meteorological Society

2018 Washington Forum
April 24 - 26, 2018. Washington, DC
https://www.ametsoc.org/ams/index.cfm/meetings-events/ams-meetings/2018-ams-washington-forum/

This annual event provides an important platform to examine public policy issues across the weather, water and climate sciences. The Washington Forum broadens and fosters the AMS mission of advancing of atmospheric and related sciences, technologies, applications, and services for the benefit of society.

10th International Conference on Urban Climate/14th Symposium on the Urban Environment
August 6 - 10, 2018. New York, NY
https://www.ametsoc.org/ams/index.cfm/meetings-events/ams-meetings/10th-international-conference-on-urban-climate-14th-symposium-on-the-urban-environment/

This conference comes at a time when accelerated urban development is challenged by the risks and consequences of extreme weather and climate events and global socio-economic disparity. Resiliency and reduced vulnerability to all socio economic sectors have become critical elements to achieve sustainable development. The conference theme is Sustainable and Resilient Urban Environments.

Geological Society of America

2018 GSA Southeastern Section
April 12 - 13, 2018. Knoxville, TN
https://www.geosociety.org/GSA/Events/Section_Meetings/GSA/Sections/se/2018mtg/home.aspx

This meeting will feature presentations on themes that range from the structure and tectonic evolution of the Southern Appalachians and environmental problems and solutions associated with coal mining, to seismic hazards and linkages among subterranean ecosystems and geological events in the eastern U.S.

2018 GSA North-Central Section
April 16 - 17, 2018. Ames, IA
https://www.geosociety.org/GSA/Events/Section_Meetings/GSA/Sections/nc/2018mtg/home.aspx

This meeting will feature presentations and posters that highlight advancements in the geosciences, including current or emerging research issues at the boundary of geoscience and related disciplines.

GSA Joint Section Meeting: Rocky Mountain and Cordilleran
May 15 -17, 2018. Flagstaff, AZ
https://www.geosociety.org/GSA/Events/Section_Meetings/GSA/Sections/rm/2018mtg/home.aspx

GSA has devised a diverse technical program and field trips that explore the geology of the Southwest and span from modern to ancient processes, and from environmental problems to tectonics, geophysics, paleontology, climate, education, and more. The meeting include sessions on planetary geology and Southwest rivers that build on the strong legacy and current expertise of the local U.S. Geological Survey.

Annual Meeting & Exposition
November 4 - 7, 2018. Indianapolis, IN
http://community.geosociety.org/gsa2018/home

This annual meeting will highlight Indiana area geology as well as the wider world of geoscience research.

American Society of Civil Engineers

World Environmental & Water Congress.
June 3 - 7, 2018. Minneapolis, MN
https://www.ewricongress.org/

The Environmental & Water Resources Institute (EWRI) is the recognized leader within ASCE for the integration of technical expertise and public policy in the planning, design, construction, and operation of environmentally sound and sustainable infrastructure impacting air, land and water resources. Join leading environmental and water resource professionals to discuss the latest topics in water resources.

Society of Environmnetal Toxicology and Chemistry

2018 Asia-Pacific Conference
September 16 - 19, 2018. Daegu, South Korea
http://setac-ap2018.org/

This conference is dedicated to provide highly scientific programs as well as stimulating discussion under the main theme “Data, Science, and Management Promoting Environmental Welfare”. In Daegu, experts from different fields of academia, business, and regulatory communities and large student community will take a part of the conference to provide a multidisciplinary and comprehensive overview of the latest researches with advanced solutions to environmental challenges.

North America Annual Conference.
November 4 -8, 2018. Sacramento, CA
https://sacramento.setac.org/

This meeting will explore the link between sustainable economic development and environmental stewardship, with particular focus on ecological and societal considerations. In this context, stewardship represents the practice of transforming sustainable thinking into action. However, we are challenged to decouple the historical connection between economic growth and ecological integrity, and the resultant societal effects. This meeting offers opportunities to feature the connections between desired ecosystem goods and services, stable flourishing societies and sustainable economies.

American Society for Landscape Architects

2018 Annual Meeting
October 19 -22, 2018. Philadelphia, PA
https://www.asla.org/annualmeetingandexpo.aspx

The ASLA annual meeting will feature a diverse spectrum of industry experts providing perspectives on a wide range of subjects, from sustainable design to active living to best practices and new technologies. More than 130 education sessions, field sessions and workshops will be presented during the meeting.

American Geophysical Union

Geoscience and Society Summit
September 23 – 28, 2018. Hamilton, Bermuda
https://connect.agu.org/gss/home

The Summit aims to create a highly interactive forum for effective cooperation between scientists and users of scientific information to tackle global and local challenges around sustainability of natural resources and systems, global health, and resilience.

Fall Meeting
December 10 - 14, 2018 Washington, DC
https://fallmeeting.agu.org/2018/

The AGU 2018 Fall Meeting provides an opportunity to share science with world leaders in Washington, D.C. As the largest Earth and space science gathering in the world, the Fall Meeting places participants in the center of a global community of scientists drawn from myriad fields of study whose work protects the health and welfare of people worldwide, spurs innovation, and informs decisions that are critical to the sustainability of the Earth.

Renewable Natural Resources Foundation
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