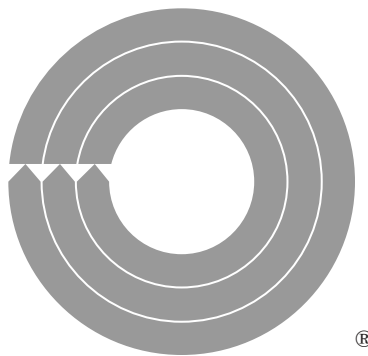


RENEWABLE RESOURCES JOURNAL



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About RNRF

Purposes

The Renewable Natural Resources Foundation (RNRF) is an I.R.C. §501(c) (3) nonprofit, public policy research organization, founded in 1972. It is a consortium of scientific, professional, educational, design and engineering organizations whose primary purpose is to advance science, the application of science, and public education in managing and conserving renewable natural resources. RNRF's member organizations recognize that sustaining the Earth's renewable resource base will require a collaborative approach to problem solving by their disciplines and other disciplines representing the biological, physical and social sciences. The foundation fosters interdisciplinary assessments of our renewable resources requirements and advances public policies informed by science.

Members

RNRF's members are membership-based nonprofit organizations with member-elected leaders. The foundation

MEMBER ORGANIZATIONS

American Geophysical Union

American Meteorological Society

American Society of Civil Engineers

American Society of Landscape Architects

American Water Resources Association

Geological Society of America

Society of Environmental Toxicology and Chemistry

Society of Wood Science and Technology

Universities Council on Water Resources

is governed by a board of directors comprised of a representative from each of its member organizations. Directors also may elect "public interest members" of the board. Individuals may become Associates.

Programs

RNRF conducts national conferences, congressional forums, public-policy briefings and round tables, international outreach activities, and a national awards program.

Renewable Resources Journal

The quarterly journal, first published in 1982, features articles on public policy related to renewable natural resources. It also includes news from member organizations, general announcements, meeting notices, and international conservation news. The journal is provided as a program service to the governing bodies of RNRF member organizations, members of the U.S. Congress and staff of its natural resources- and science-oriented committees.

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News and Announcements

Renewable Natural Resources Foundation

*John S. Dickey Jr. and Erik Hankin
Join RNRFF Board of Directors*

RNRFF welcomes John S. Dickey Jr. and Erik Hankin to the board of directors.

John S. Dickey Jr. was elected to serve as public interest member of the board during the 2013 annual meeting of the RNRFF board of directors. He represented the American Geophysical Union (AGU) as an alternate on the board of directors from 1998-2002, while he served as the AGU director of education and research. He received the RNRFF Chairman's Award for Professional Service to the Foundation in 2002. John previously served as dean of sciences, mathematics, and engineering at Trinity University in San Antonio, Texas. He also served as program director for geochemistry and petrology at the National Science Foundation and as head of the department of geology at Syracuse University. John received his A.B. from Dartmouth in 1963, his M.Sc. from Otago (New Zealand) in 1966, and his Ph.D. from Princeton in 1969. He is a specialist in igneous petrology. His scientific studies have included lunar samples (Apollo 11 and 12), chromium ore bodies, and mid-ocean ridge volcanic rocks. John is a native of Washington, D.C. and has homes in Washington, D.C. and Quebradillas, Puerto Rico.

Erik Hankin has joined the board as AGU's representative. Erik has been serving as AGU's public affairs specialist for two and a half years. Prior to that he served for two years and four months as a science assistant for the National Science Foundation in the marine geol-



John Dickey



Erik Hankin

ogy and geophysics program and also as the executive secretary for the National Ocean Council's ocean science and technology interagency policy committee. Erik received a M.S. in geology from the University of Maryland in 2009, where he researched the effects of urban development on stream bank erosion in the Anacostia River Watershed. He received a B.A. in geology and environmental studies from Macalester College in 2005.

Spring Meeting on Food Production and Climate Change

In preparation for RNRFF's 2014 Congress on Adapting Food Production to a Changing Climate, RNRFF board members and guests gathered on April 21, 2014, at the American Geophysical Union headquarters in Washington, D.C. The 17 participants explored the critical issues, strategies and priorities for increasing the adaptability and resilience of food production systems. Climate change will affect agricultural production worldwide in the years ahead. Historical patterns of temperature and precipitation will change, affecting crop production cycles and output and the proliferation of disease, insect pests and weeds. The consequences of a changing climate will vary from region to region and will be alleviated or exacerbated by each region's respective

social, economic and political environment.

Mark Rosegrant, Division Director for Environment and Production Technology at the International Food Policy Research Institute, began the discussion with a presentation on climate change and global food security. Rosegrant identified drivers of agricultural growth and food security and presented models identifying the global consequences of climate change on agricultural production. To reduce adverse impacts of climate change, investment in climate-ready technology and policies and the promotion of sustainable agriculture are needed.

Charlie Walthall, National Program Leader for Natural Resources & Sustainable Agriculture Systems at the USDA Agricultural Research Service, presented the biotic and abiotic effects of climate change and identified adaptation needs and mechanisms to enhance the adaptive capacity of agriculture. Interdisciplinary collaboration and attention to genomics, the environment, and management practices are required.

Carol Jones, Senior Economist at the USDA Economic Research Service, presented information to inform decision-making when assessing climate change impacts and adaptation strategies. Targeted public and private investment in data collection, research and development, and infrastructure are needed to increase our adaptive capacity.

RNRFF continued collaborating with meeting participants and other interested parties to develop the program for the upcoming congress. The congress will be held on December 9-10, 2014 in Washington, D.C. For more information, visit www.rnrff.org/2014congr.

*RNRF Hosts Congressional Forum:
Regionality—A Tool to Promote
Coastal Resilience*

RNRF hosted a congressional forum on regionality at the Longworth House Office Building on June 9, 2014. The forum followed the 2013 Congress on Coastal Resilience and Risk. Regional, systems approaches were identified as a strategy to efficiently bolster the resilience of coastal communities. Present at the forum were thirty-three congressional staffers and members of the NGO community.

RNRF Chairman Howard Rosen presented an overview of congress findings and recommendations. He identified a number of tools that can be utilized to increase the resilience of coastal communities, including effective land-use planning, shoreline and buffer management, updated building codes, and natural resource management. The insurance industry recommends risk-based pricing for hazard insurance to influence the placement and resilience of structures. Communities can utilize assessment tools to be more informed about their relative risks and disaster preparedness planning. Future investments can be made using innovative funding strategies. Improving resilience is a complex task that requires a holistic, systems approach.

Charles Chesnutt, a coastal engineer with U.S. Army Corps of Engineers Water Resources Institute, and Howard Marlowe, chairman of Alden Street Consulting, described the need for a regional approach to coastal resilience and the associated benefits. For the Corps, a fragmented approach to storm protection projects in conjunction with a shrinking budget jeopardizes the viability of the entire coastal protection system. Budgeting, planning, and implementing projects on a regional, rather than project-by-project, basis would significantly improve the Corp's budgeting, planning, and implementation process.



Pictured standing (L-R): Dick Engberg (AWRA), Renee Johnson (Congressional Research Service), Richard Waite (World Resources Institute), John S. Dickey Jr. (RNRF Public Interest Member), Jessica Ball (GSA), Tom Chase (ASCE), Erik Hankin (AGU), Melissa Goodwin (RNRF), Julie McClure (American Society of Agronomy, Crop Science Society of America, Soil Science Society of America); seated (L-R): Noel Gollehon (USDA Natural Resources Conservation Service), Janet Perry (USDA Natural Resources Conservation Service), Charlie Walthall (USDA Agricultural Research Service), Howard Rosen (SWST), Carol Jones (USDA Economic Research Service), Margaret Walsh (USDA Climate Change Program Office); present but not pictured: Mark Rosegrant (International Food Policy Research Institute), Barry Starke (ASLA), Robert Day (RNRF).

Chesnutt and Marlowe's Power-Point presentation can be downloaded at www.rnrf.org/regionality.pdf.

Hurricane Sandy has revitalized the national discussion on coastal resilience.

For more information on RNRF's Congress on Coastal Resilience and Risk, visit www.rnrf.org/2013cong.

RENEWABLE RESOURCES JOURNAL

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Editorial Policy: The editors seek general interest articles concerning public policy issues related to natural resources management. Recommended maximum length of manuscripts is 4,000 words. All manuscripts will be reviewed by the editors and, where appropriate, by experts in the subject matter. (A "Guide for Contributors" is posted at RNRF's website.) **Editorial Staff:** Robert D. Day, editor; Melissa M. Goodwin, assistant editor; Jennee Kuang, editorial intern.

Round Table Meeting on Hydraulic Fracturing

The RNRW Washington Round Table on Public Policy met with Dr. David Vanko, chairperson of the Maryland Marcellus Shale Safe Drilling Initiative Advisory Commission, at the American Society of Landscape Architects headquarters on June 11, 2014. Vanko provided an insider's perspective on the work of the Marcellus Shale Safe Drilling Initiative Advisory Commission and the debate in Maryland over whether to approve the use of hydraulic fracturing. Though local in focus, issues concerning this extraction method are being debated by states throughout the nation as they consider its regulation and use.

Potential development of the Marcellus Shale in Maryland would occur at a much smaller scale and density than it has in neighboring states like Pennsylvania and West Virginia. Regardless of scale, several major concerns exist, including damage to the environment, ecosystem and human health, and quality of life.

To address these concerns, the commission has recommended a number of best management practices. These include a mandatory comprehensive gas development plan and comprehensive landscape-scale planning to address cumulative impacts prior to the issuance of a permit, as well as engineering controls and water-use, storage, and discharge regulations. Setbacks from aquatic habitats, cultural and historical sites, private groundwater wells, and other locations for resource protection and public safety are also identified. Maryland has already passed legislation influenced by the commission, including legislation to hold fracking companies liable for damages to the water supply and requirements to obtain environmental pollution insurance.

More information on the initiative is available at www.mde.state.md.us/programs/land/mining/Marcellus.



Pictured standing (L-R): David Vanko (Chairman, Maryland Marcellus Shale Safe Drilling Initiative Advisory Commission), Dick Engberg (AWRA), Barry Starke (ASLA), Bradford McKee (Landscape Architecture Magazine, ASLA), Keith Swann (ASLA), Melissa Goodwin (RNRW), Jennee Kuang (RNRW), Curtis Millay (ASLA), John Durrant (ASCE); seated (L-R): Lindsey Bowman (GSA), Jessica Ball (GSA), Nancy Somerville (ASLA), Howard Rosen (SWST), Sarah Gerould (SETAC); present but not pictured: Karl Anderson (American Society of Agronomy, Crop Science Society of America, Soil Science Society of America), Robert Day (RNRW).

American Geophysical Union

*AGU to Make Journals Freely
Available Online*

Beginning in May 2014, all AGU journal content from 1997 to content that was published 24 months prior was made freely available online. This change applies to all articles and supplementary materials from journals that are not already open access, as well as AGU's weekly newspaper, *Eos*. It currently represents more than 80,000 journal articles and issues of *Eos*. Additional content will continue to become open every month, on a 24-month rolling cycle.

This new policy marks the latest innovation in AGU's publishing strategy, which already includes providing access to developing nations through its participation in the Research4Life program, enabling more than 5,000 institutions to freely access AGU's content. In addition to these new programs, AGU offers Green Open Access after six months that allows a copy to be placed in a repository, and it also offers three fully open access journals—*JAMES*, *Earth's Future*, and the recently announced *Earth*

and Space Science, which will publish its first articles later this year.

For more information contact AGU, 2000 Florida Ave. NW, Washington, DC 20009; (202) 462-6900, www.agu.org.

American Meteorological Society

*AMS releases Report:
State of the Climate in 2013*

On July 17, 2014, AMS released its annual State of the Climate Report online. In 2013, the report found, the vast majority of worldwide climate indicators continued to reflect trends of a warmer planet.

Scientists from NOAA's National Climatic Data Center in Asheville, N.C., served as the lead editors of the report, which was compiled by 425 scientists from 57 countries. The report uses dozens of climate indicators to track patterns, changes, and trends of the global climate system, including greenhouse gases; temperatures throughout the atmosphere, ocean, and land; cloud cover; sea level; ocean salinity; sea ice extent; and snow cover. The report also details cases of unusual and extreme regional

events, such as Super Typhoon Haiyan, which devastated portions of Southeast Asia in November 2013.

For more information, contact AMS, 45 Beacon Street, Boston, MA 02018; (617) 227-2425, www.ametsoc.org.

American Society of Landscape Architects

Chinatown Green Street Demonstration Project

ASLA has signed a contract with landscape architecture firm Design Workshop to serve as lead consultant for a project greening the streets surrounding ASLA's headquarters in Washington, D.C.'s Chinatown.

The Chinatown Green Street Demonstration Project involves the design and installation of an interconnected series of vegetated systems and innovative technologies to manage stormwater runoff and beautify the public right-of-way in the Chinatown neighborhood of Washington, D.C. ASLA intends this project to be a world-class model and education tool for developers, designers, city officials, and the public.

Additional information on the project is available at asla.org/greenstreet.

For more information, contact ASLA, 636 Eye Street NW, Washington, DC 20001; (202) 898-2444, www.asla.org.

American Water Resources Association

Annual Conference

AWRA's Annual Water Resources Conference will be on November 3-6, 2014, at the Sheraton Premiere Hotel in Tysons Corner, Virginia. The 2014 conference marks AWRA's 50th anniversary. The conference will provide a unique opportunity for myriad water resource professionals to gather and reflect on the history of water management over the past 50 years and to see the latest work

on the policy and science of water management that will help shape the future.

The conference program, registration information, and more is available at www.awra.org/meetings/Annual2014/.

For more information, contact AWRA, P.O. Box 1626, Middleburg, VA 20118; (540) 687-8390, www.awra.org.

Geological Society of America

GSA Bulletin Articles from 1922 to 1944 Now Available

GSA has completed digitizing another 23 years of *The Geological Society of America Bulletin* content. Published between 1922 and 1944, this content includes many well-known authors and subjects, including Joseph Pardee, early works from Beno Gutenberg and Charles Francis Richter, as well as Ian Campbell, Arthur L. Day, and Kirk Bryan.

The cover-to-cover scanning included hundreds of large foldouts, all of which have been made available to GSA Bulletin and GeoScienceWorld subscribers. Nonsubscribers can access the content via pay-per-view or GSA's Bloc of Docs service, where access costs as little as \$4 per paper. The maps from the content will also be indexed in Geofacts.

The Society plans to digitize the remaining archive, 1890 to 1922, this fall. The Society's complete e-book archives, dating back to 1934, were digitized and made available last year.

For more information, contact GSA, P.O. Box 9140, Boulder, CO 80301; (303) 357-1806, www.geosociety.org.

Society of Environmental Toxicology and Chemistry

SETAC Joins the World Health Organization Chemical Risk Assessment Network

The Human Health Risk Assessment Advisory Group (HHRA) and SETAC are pleased to announce that the society

has joined the World Health Organization Chemical Risk Assessment Network (WHOCRAN). The network was established in late 2013 with a goal to support global efforts to assess and manage the risks associated with exposures to hazardous chemicals. Although the HHRA will serve as the SETAC focal point for the network, any SETAC member with expertise in the field of risk assessment is welcome to contribute.

SETAC, in concert with the network, will focus on issues related to the assessment of risks to human health associated with exposure to chemicals, through all pathways and routes of exposure. All activities support the framework of the Strategic Approach to International Chemicals Management (SAICM).

For more information contact SETAC, 229 S. Baylen Street, Pensacola, FL 32502; (850) 469-1500, www.setac.org.

Society of Wood Science and Technology

2015 Annual Convention

The SWST 2015 Annual Convention on Renewable Materials and the Bio-Economy will be held on June 7-12, 2015 at Grand Teton National Park in Jackson, Wyoming. The meeting will include morning and afternoon technical sessions interspersed with outdoor activity breaks. Potential sessions highlight a variety of topics including designing for durability, replacement of petrochemical-based products with bio-based products, and extension and outreach. Details are available online at swst.org/meetings/AM15.

For more information contact SWST, P.O. Box 6155, Monona, WI 53716; (608) 577-1342, www.swst.org.

The Marine Mammal Protection Act at 40: Status, Recovery, and Future of U.S. Marine Mammals

Joe Roman, Irit Altman, Meagan M. Dunphy-Daly, Caitlin Campbell, Michael Jasny, and Andrew J. Read

Introduction

Legislation protecting whales dates back to 1934, when right whale hunting was banned by an international treaty. In the early 1970s, further attempts to protect the great whales in the United States were met with resistance by the U.S. Department of Defense, which was concerned about the supply of sperm whale oil for use as a lubricant in submarines and other military engines. After a synthetic oil was produced, the Marine Mammal Protection Act (MMPA) was passed in October 1972. The MMPA went beyond protection for commercial reasons and attempted to restore the ecological role of all marine mammals. It was a critical step toward the passage of the Endangered Species Act (ESA) the following year.¹

The fundamental objectives of the MMPA are (1) to maintain stocks of marine mammals at their optimum sustainable populations (OSP) and (2) to maintain marine mammal stocks as functioning elements of their ecosystems. The act does not define OSP, but the National Marine Fisheries Service

(NMFS) has interpreted OSP to be a population level that falls between Maximum Net Productivity Level (MNPL) and carrying capacity (K). In operational terms, therefore, OSP is defined as a population size that falls between 0.5K and K. In addition, there is a clear mandate to protect individual marine mammals from harm, referred to as take.

In this review, we assess the success of the MMPA in protecting marine mammals, discuss its failures, and provide suggestions on ways to improve the act and marine mammal conservation in the United States and internationally.

By the Numbers:

U.S. marine mammal stocks 1995–2011

In the United States, two federal agencies direct the management and protection of marine mammals: NMFS is responsible for managing most marine mammal stocks, including cetaceans, sea lions, and seals; the U.S. Fish and Wildlife Service (USFWS) has authority over a smaller number of stocks that include polar bears, sea otters, manatees, and walrus. Under the MMPA, a marine mammal stock is defined as a group of individuals “of the same species or smaller taxa in a common spatial arrangement that interbreed when mature.” Stock assessment reports (SARs)

for all marine mammals that occur in U.S. waters were first required when the act was amended in 1994. Since that time, all stocks have been reviewed at least every three years or as new information becomes available.

Population Trends

For all currently recognized marine mammal stocks, we reviewed the earliest and most recent stock assessments to investigate trends in abundance. For many stocks, information on abundance is limited and even less is known about trends. It should be noted, however, that identifying trends in marine mammals is known to be difficult. Taylor et al., for example, found that even precipitous declines would not be noticed for 72% of large whale stocks, 78% of dolphins and porpoises, and all pinnipeds counted on ice with current levels of survey effort.² Whereas the MMPA does not require information on trends, stock assessment reports can describe a variety of available information on abundance trends, including information from the literature, unpublished data, and expert insight. Obtaining a formal assessment of trends over time is often restricted by inconsistencies in the methods of multiple independent studies and limited understanding of patterns across the whole spatial range of the stock. Despite these limitations, it is important to analyze the evidence available on

This article is adapted with permission from the 2013 article published by the Annals of the New York Academy of Sciences in “The Year in Ecology and Conservation Biology,” doi:10.1111/nyas.12040.

marine mammal trends since this is an essential metric for assessing the health of these populations.

Information on population trends is currently unknown for the majority (71%) of U.S. marine mammal stocks.

Status and trends: endangered species

We examined the status under the ESA for all current stocks of marine mammals using information from the latest SAR and additional sources of information (www.nmfs.noaa.gov/pr/species/esa/other.htm). Of the 212 current stocks, 38 (18%) are listed as endangered or threatened.

The highest number and proportion of threatened or endangered stocks are found in the Pacific region, where 21 of the 81 stocks are listed (26%).

To determine how the ESA status of marine mammals changed over time, we compared information from the earliest and most recent year each stock was assessed. The majority of the 38 stocks currently listed under the ESA were also listed at the time of their first assessment.

We did not identify any case in which a stock was listed as threatened or endangered in the earliest stock assessment and then delisted in the most recent assessment.

Status of U.S. marine mammals species: a global perspective

To assess the relative success of marine mammal protection in the United States under the MMPA and ESA, we compared the status of marine mammal species found within the U.S. Exclusive Economic Zone (EEZ) to those outside of the U.S. EEZ, using the most recent designations (1996–2012) provided by the International Union for Conservation of Nature (IUCN). The total number of marine mammal species associated with the two groups was nearly equal (number of U.S. marine mammal species = 65, non-U.S. species = 67) and results indicate that U.S. species generally fare better than non-U.S. species in

all categories. Specifically, fewer U.S. species are found in high-risk categories (vulnerable, critically endangered, near threatened, extinct) and more U.S. species are considered of least concern.

In such an uncontrolled comparison, it is impossible to draw definitive conclusions regarding the factors responsible for this difference; nevertheless, the patterns suggest fundamental prohibitions against the taking of marine mammals in the MMPA, along with the ESA, likely contribute to this difference. We conclude that marine mammals found in the United States do appear to be doing as well and in many cases better than

We lack sufficient information to ensure that many stocks are not in significant decline: trends are unknown for 71% of marine mammal stocks.

species found outside of U.S. waters, suggesting that current management actions are having a positive influence on marine mammal populations.

Successes

The MMPA was passed in response to concern over the conservation status of several species of marine mammals due to unregulated harvest or incidental mortality. Section 2 of the act notes that “certain species and population stocks of marine mammals are, or may be, in danger of extinction or depletion as a result of man’s activities.” The MMPA, buttressed by additional protection from the ESA, has successfully prevented the extirpation of any marine mammal population in the United States in the 40 years since it was enacted. Count-

less tens of thousands of individual cetaceans, pinnipeds, and sirenians have been protected from harm since 1972, exactly as intended by those who crafted the legislation. As a consequence, many marine mammal populations, particularly seals and sea lions, have recovered to or near their carrying capacity. The recovery of these stocks has been so successful that fisheries representatives have occasionally advocated for culls. Yet several recent studies have shown that whales, seals, and dolphins are not a threat to human fisheries and even a complete eradication of marine mammals would show little to no benefit and come at an ecological cost.^{3,4} The remarkable recovery of harbor and gray seals in New England and California sea lions, harbor seals, and elephant seals on the Pacific Coast highlights the value of the act and serves as a striking reminder of the magnitude of the persecution of these species before 1972.

The provisions in Section 117 of the MMPA, which require NMFS and the USFWS to prepare assessments for each stock of marine mammals living in waters under the jurisdiction of the United States, have spurred an enormous amount of research by federal agencies, greatly increasing our understanding of marine mammal biology. As a result, we have an unparalleled grasp of the distribution, population structure, and status of marine mammals within the U.S. EEZ. The SARs, mandated under Section 117, are a treasure trove of information on the status of marine mammals in the United States, tracing the history and reviewing new information at least once every three years for every stock.

Each SAR contains an estimate of potential biological removal (PBR), the number of marine mammals that can be removed from a stock while allowing it to reach or maintain its optimum sustainable population. This allows for a rapid quantitative assessment of the status of each stock. No other country has attempted such an audacious scientific undertaking.

The status of many marine mammal populations is considerably better today than it was in 1972. The abundance of some pinnipeds, including California sea lions and harbor and gray seals, and some mysticetes, like humpback, blue, and gray whales, have greatly increased in the past 40 years. The act has also been effective in providing protection to marine mammal populations from direct threats, including those posed by unregulated harvest, persecution, and bycatch.

In contrast to Canada, where there have been recent government proposals to cull transboundary stocks of harbor and gray seals in the northwest Atlantic, there have been relatively few serious calls for culls of marine mammals in the United States since passage of the act. Perhaps most tellingly, marine mammals in U.S. waters appear to be doing better than those outside the U.S. EEZ. The large percentage of species of least concern in the United States is especially encouraging, considering that its coastlines are highly affected by shipping, pollution, and fishing activities.⁵ Along with federal regulation, the work of academic researchers and nonprofit groups has been an essential asset to protecting species.

Challenges

The MMPA is a well-intentioned and well-crafted piece of legislation that was improved by amendments in the 1990s. Despite the successes mentioned above, it has not yet succeeded in restoring many marine mammal stocks to OSP levels. Even under ideal circumstances, 40 years may not be enough time to restore populations of long-lived species with slow rates of potential population growth. In other cases, failures appear to be associated with a lack of enforcement or funding, political pressure, or a disregard for precautionary principles.

Although no species or stock of marine mammals has been extirpated in U.S. waters since passage of the

MMPA, 19% are listed as threatened or endangered and 7% are reported to be declining. Perhaps the biggest concern is that we lack sufficient information to ensure that many other stocks are not in significant decline: trends are unknown for 71% of marine mammal stocks. The PBR scheme was designed to address this issue, but its focus is on direct human-caused mortalities, providing little information on natural mortality or indirect effects. As a result some declines that do not result from direct kills may go unnoticed.²

The MMPA on its own does not afford enough protection for many populations or from many stressors, and the protection of the Endangered Species Act is still a critical last resort when populations are in decline.

Section 118 stipulates a goal of reducing the incidental mortality and serious injury of marine mammals to insignificant levels approaching zero (known as the Zero Mortality Rate Goal, or ZMRG), which has been interpreted by the agencies as equivalent to 10% of PBR. Unfortunately, many stocks continue to experience mortality rates considerably greater than ZMRG, and there is little serious effort to meet this mandate.

The MMPA on its own does not afford enough protection for many populations or from many stressors, and the protection of the ESA is still a critical last resort when populations are in decline. In several cases, the MMPA has not proven

capable of protecting individual stocks. The Alaskan AT-1 killer whale, affected by the *Exxon Valdez* spill and other factors, has fewer than 10 individuals, has never been protected by the ESA, and is likely unsavable.⁶ In general, the ESA can act as valuable safety net for the stocks most in need of protection, provided sufficient evidence is available on trends and the cause of decline to support the establishment of a distinct population segment. The absence of such data is an impediment to assessing the need for protection for many species and is a serious shortcoming to effective management under the act.

Collisions with ships and fisheries entanglements are significant causes of mortality among marine mammals, and several recent review articles provide ample evidence that great whales in particular remain at risk.⁷ Van der Hoop et al., for example, estimated that 67% of known mortalities of large whales in the North Atlantic resulted from human interactions, mostly from entanglement with fishing gear.⁸ Humpback whales exceeded PBR by 579% and right whales by 650%. Efforts to reduce large whale mortality have become more extensive since 2003, and policies continue to evolve.⁸ The shipping channel into Boston Harbor was rerouted to reduce collisions with humpback and right whales.⁹ The movement of this channel required long-term data on whale distribution that is unavailable for many areas. Speed-reduction measures and passive acoustic monitoring can help protect large whales and other marine mammals in areas that are less well studied.¹⁰

Failure of implementation and enforcement

One of the most significant sources of failure in implementing the MMPA has been political interference. The U.S. Coast Guard and NMFS have not consistently pursued enforcement of violations related to domestic and foreign bycatch from fisheries, illegal shootings, oil and gas operations, and whale watching.^{11,12}

The failure of the harbor porpoise TRP, for example, is the result of a lack of compliance with conservation measures; few, if any, violations of the plan have been enforced.¹³ In a critical conservation failure, NMFS has failed to deal effectively with the bycatch of North Atlantic right whales. On the east coast of the United States and Canada, right and humpback whales become entangled in fixed fishing gear, which is designed to maximize strength and durability. Such entanglements result in long, painful deaths: lines can become embedded in baleen plates and wrap around flippers, flukes, and blowholes; gear can flense large sections of blubber; and impaired feeding and infections are common.¹⁴ Knowlton et al. found that 519 of 626 photo-identified right whales (82.9%) had been entangled at least once and 306 of the 519 (59.0%) had been entangled multiple times.⁷ These authors conclude that the efforts made since 1997 to reduce entanglements and fatalities from fishing gear have not succeeded.

The continued mortality of Florida manatees from boat strikes represents another failure of the MMPA and the ESA to protect individual marine mammals from harm. Speed-limited zones and restrictions have been aggressively challenged in court and in Congress, although the total area of regulated boat speeds is only a small fraction of available waterways in Florida.¹⁵ In both of these cases, powerful political interests (the commercial fishing and recreational boating industries) have managed to delay or prevent implementation of conservation measures that could improve the status of endangered marine mammals.

As a result of these limitations, increased protection often depends on evidence collected outside of the federal government. The authors of the ESA were prescient in including an innovative citizen initiative that allows individuals to petition the government to list unprotected species and challenge USFWS and NMFS decisions. Recent analyses have shown that species that

are petitioned by such initiatives, on land and in freshwater, are overall more biologically threatened than those selected by the government.¹² Although, to our knowledge, no such analysis has been conducted for marine mammals, it is clear that these initiatives are essential in providing enhanced legal protection under the ESA.

Failure to monitor trends

Another failure in implementing the MMPA is inadequate resources to survey each marine mammal stock on a regular basis. For most species (71%), population trends remain unknown. This makes efforts to protect species by

Since the early 1990s, undersea noise has emerged as a major topic of research, regulation, and public advocacy.

NMFS and engaged citizens especially challenging. It should be noted that the monitoring of more than 200 stocks in the U.S. EEZ is a huge undertaking, especially because many species, like ice seals and pelagic small cetaceans, are difficult to survey. Given the challenge in reliably assessing population numbers or biological removals, Robards et al. have recommended that managers base decisions on ecological needs and observed ecological changes.¹⁶

Failure to manage particular anthropogenic stressors and impacts

Contaminants.

Marine mammals have ecological and physiological characteristics that make them highly susceptible to the negative effects of anthropogenically derived contaminants. Typically occupying high trophic levels, they are subject to

contaminants that bioaccumulate within food webs. Moreover, the blubber tissue found in many marine mammal species is concentrated with lipids, which readily store some types of toxins. Contaminants like persistent organic pollutants (POPs) are known to compromise immune activity in laboratory animals and appear to cause similar effects in marine mammals based on both field-based and experimental studies.^{17,18,19,20,21,22} Finally, maternal transfer of contaminants in marine mammals can be very high. Compared to adults, juveniles may be at even greater risk from the damaging effects of these pollutants given their high rates of development.²³

A number of recent studies demonstrate high concentrations of contaminants in tissues of U.S. marine mammal populations. Contaminants in tissues of bottlenose dolphins from Charleston, South Carolina, and Indian River Lagoon, Florida were compared to threshold concentrations established through experimental dose-response studies focused on immunological and reproductive effects. Of the 139 individuals sampled in the wild, 88% of males exhibited levels of polychlorinated biphenyls (PCB) five times the established PCB threshold (the level at which an adverse effect is expected to become evident), with many individuals exhibiting PCB levels 15 times the threshold.²⁴ A suite of other organic contaminants found in blubber tissue from the two populations was also found to be at or above levels known to adversely affect humans, wildlife, and laboratory animals. Endangered killer whales that are summer residents of the Northeastern Pacific also exhibit contaminant levels that exceed thresholds for health effects in marine mammals.²³

In the United States, successful efforts to restrict and in some cases ban the use of some toxic substances (e.g., DDT) have benefited wildlife populations. Although little is known about the long-term trends regarding contaminant levels in many marine mammal populations,

some studies do exist. For example, DDT levels recently measured in California sea lion populations were found to be 10 times lower than values reported from 1970.²⁵ However, organic contaminants still persist in this population and may make individuals more susceptible to some types of disease. Specifically, California sea lions that likely died from metastatic carcinoma exhibited higher tissue burdens of PCBs than animals that died from other causes.²⁶

Some examples above indicate a high risk for marine mammal populations to be affected by contaminants. However, understanding the population level consequences of contaminants requires broad sampling across all the demographic groups present. Knowledge of the relationship between body condition and contamination is also critical, since metabolic pathways that can change with food availability or other factors can influence the release of fat- or lipid-associated contaminants. Finally, a better understanding of contaminant patterns over long time scales is necessary to assess whether the potential threat is currently changing. Two U.S. programs provide useful resources in this context. First, the U.S. National Biomonitoring Specimen Bank includes well-preserved and documented tissue specimens associated with nine marine mammal species that are regularly analyzed for chlorinated hydrocarbons and trace elements.²⁷ These tissues can serve as a baseline to compare to recent samples. Second, the U.S. Navy directs a unique marine mammal program in which a large number of bottlenose dolphins are maintained in netted open water enclosures. These animals could serve as sentinels to assess contaminants and disease in a relatively controlled environment.²⁸

Trophic impacts and declines in prey species.

Fisheries can affect marine mammals through incidental capture in fishing gear or indirectly by reducing their

prey base or competitors.^{29,30,31,32} When resources are limited, competition can occur between marine mammals and commercial fisheries, with negative effects for both fisheries and marine mammal populations. The recovery of sea otters (*Enhydra lutris*) along the coast of California, for example, caused direct competition with, and the demise of, some shellfisheries, as invertebrate prey populations were reduced by the otters.³³ Likewise, commercial fisheries have caused the depletion of marine mammal prey, resulting in a negative indirect effect on populations: according to one recent study, a reduction in prey populations results in a 60–70% decline

To restore the ecological role of marine mammals, there is a need for an ecoregional approach to conservation

in predators.³⁴ Thus, a 50% prey reduction would result in a predator reduction of roughly 30–35%. Although the MMPA accounts for the direct effects of fisheries on marine mammals using PBR as a reference point, it typically fails to account for such indirect effects.

The depletion of world fish stocks has been well documented,^{35,36,31} but the relationship between exploited fish species and marine mammals is complex. In some cases, when fisheries reduce competitors to marine mammals, they can have an indirect positive effect on populations by reducing competition for prey resources.³² On the eastern Scotian Shelf ecosystem off Nova Scotia, overfishing caused a cod collapse in the mid-1980s and early 1990s. Gray seals (*Halichoerus grypus*) may have benefited from this collapse, which released

benthic fish prey species, resulting in a subsequent increase in seal abundance.³⁷

When negative indirect effects of fisheries on marine mammal populations do occur, overexploited fisheries can prevent the MMPA from meeting its objectives by reducing the carrying capacity.

Cumulative sublethal effects from noise and disturbance.

Since the early 1990s, undersea noise has emerged as a major topic of research, regulation, and public advocacy. Marine mammal research has seen an explosion of investment in the issue, often driven by litigation, public pressure, and regulatory requirements^{38,39} and fed by user groups such as the U.S. Navy and the oil and gas industry, which annually fund more than \$25 million in related research. For NMFS, most take authorizations issued each year under the MMPA are for the impacts of noise and disturbance, caused by military training, geophysical surveys, offshore construction, and aircraft overflights.⁴⁰ Several of these matters have had high public profiles, centered on what has been described as focalizing events such as mass strandings.⁴¹

It has long been recognized that the ocean is an acoustic world, and that marine mammals (and many other species) depend on sound for foraging, breeding, predator avoidance, navigation, maintaining social bonds, and environmental awareness.⁴² Impacts associated with anthropogenic noise include dramatic, acute effects such as atypical mass strandings and mortalities of whales,^{43,44} but also sublethal effects such as habitat displacement, silencing, and masking of biologically important sounds.^{45,46,47,48} Anthropogenic noise can disrupt mother–calf bonds, resulting in increased call duration, with possible fitness consequences.⁴⁹ The cumulative effects of disturbance are extremely difficult to study in the wild, but in some discrete cases they have been causally linked to population decline.⁵⁰ But for

many species, these effects occur at large temporal and spatial scales that challenge our capacity to monitor.^{51,52}

Through the 1990s and 2000s, the MMPA's regulatory scheme was increasingly applied to major producers of ocean noise. For example, most naval activities within the U.S. territorial sea and EEZ are now the subject of programmatic rulemakings; in the oil and gas sector, operators regularly apply for MMPA incidental harassment authorizations as a condition of their geophysical exploration permits in the Arctic. Regulation remains spotty, however. Large sectors of some industries, like geophysical exploration in the Gulf of Mexico, the most heavily prospected body of water in the world, remain unregulated under the MMPA, and some industries, such as commercial shipping and whale watching, stand as yet outside the act's authorization process. Even for regulated activities, NMFS has not addressed the emergent problem of cumulative impacts from noise and disturbance, and, in general, relevant management tools in the MMPA have not been applied.

Various entities are attempting to develop means to evaluate cumulative impacts from noise and disturbance. Perhaps the most ambitious is the Population Consequences of Disturbance effort, led by the Office of Naval Research, which is attempting to quantify cumulative impacts in a small number of data-rich species by applying a series of transfer functions, running from short-term disturbance to impacts on biologically important activities and ultimately to effects on vital rates in individuals and populations.⁵³ An alternative approach is to develop proxies for significance and negligible impact based on multifactorial analyses, with at least one such effort applied successfully on the state level for a seismic survey off California.⁵⁴ Still others have proposed modifying the MMPA to incorporate concepts from marine spatial planning and ecosystem management.⁵⁵ In one

of the most important developments, NMFS has produced cumulative noise and cetacean distribution maps covering, in varying degrees of resolution, the entire U.S. EEZ.⁵⁶ These maps could well become a transformative tool for cetacean management, and NMFS should invest in their further development and implementation.

Finally, many stakeholders inside and outside the government are focused pragmatically on developing effective mitigation: new technologies that can reduce the environmental footprint of large commercial ships and airgun surveys; new models that can define important habitat for protection; and a variety of measures that can reduce the amount of disruptive activity taking place seasonally or annually in a given area.^{57,58,59,60} For these measures to succeed, NMFS must take concerted and proactive steps to use available methodologies to reduce impacts.

Disease.

Disease reports in marine mammals, as with a variety of other ocean taxa, have increased over the past three decades.^{22,61,62} The worrisome trend appears to reflect a real phenomenon rather than an artifact of increases in scientific publishing of marine mammal studies,⁶³ although new detection techniques using molecular genetics have also played a role in identifying and characterizing disease agents in marine environments.⁶² A variety of large-scale factors (and their interactions) are likely influencing the distribution and prevalence of these diseases, including shifts in host/pathogen distribution, increased global temperatures, habitat loss and alteration, and changes in immunological response of individuals.²²

Disease resulting from biotoxins has emerged as another serious threat: marine mammal mortalities associated with these toxins have exhibited an increase in frequency along the east and west coast of the United States since the mid 1990s.⁶² Over the same period,

the frequency of harmful algal blooms (HABs) has also increased, suggesting a direct link between the two.⁶⁴ Biotoxins are known to be inhaled by marine mammals,⁶⁵ and recent findings demonstrate that these toxins can also accumulate in fish tissues and spread through marine food webs.⁶⁶

A better understanding of the interactions between disease and a long list of anthropogenic factors is critically needed.⁶⁷ Some expected changes are likely to favor disease, including range shifts, compromised immunity as a result of stressors, and increased host density; others, such as population decreases or pathogens being more sensitive to environmental factors than their hosts, may result in their reduction.⁶⁸ Arctic stocks of marine mammals may be particularly at risk from interacting factors because environmental and ecological dynamics occurring from climate change are magnified there.⁶⁹ Relevant factors include loss of sea-ice habitat, which could lead to higher density of hosts and favor density-dependent disease; decreases in food availability leading to impacts on body condition and immune system function; and increases in human activity throughout the region leading to increased likelihood of pathogen introduction. Anthropogenically exacerbated diseases in pinnipeds, cetaceans, and sea otters, from harmful algal blooms to pathogen pollution from pets and livestock, demonstrate that the protection of marine mammals also requires protection of the adjacent terrestrial environment.

The Way Forward

The MMPA has been very successful in protecting many marine mammals from harm and largely successful in restoring and protecting individual marine mammals stocks. One of the reasons for this success has been the development of the PBR approach by NMFS, designed expressly for management under the act. This current focus on species and

individual animals is appropriate not only from a welfare perspective but also, given the lack of data and the need for precaution, from a demographic standpoint.

There have been few, if any, attempts to address the second fundamental objective: maintaining marine mammals as functional elements of their ecosystem. Many species lack historic baselines, and the understanding of the ecological role of marine mammals was limited when the act was passed. It is increasingly clear, however, that upper trophic level predators, such as marine mammals, play critical roles in structuring their ecosystems.^{70,71,72} Humpback and fin whales in the Gulf of Maine increase productivity by pumping nutrients to the surface.⁴ The benthic plowing of gray whales alters the microtopography of the seafloor and enhances benthic-pelagic coupling.⁷³ Estes et al. have even suggested that productive and dense kelp forests can be used as a sensitive and cost-effective measure of sea otter recovery, an approach that has broad potential in establishing recovery criteria for other reduced populations with clearly measurable ecosystem impacts.⁷⁴

To restore the ecological role of marine mammals, there is a need for an ecoregional approach to conservation, with an increased understanding of predator-prey interactions and the cumulative effects of human impacts. A precautionary generalization of PBR that combines the direct and indirect effects of fisheries, including predator-prey relationships and ecological interactions, as well as cumulative impacts from other stressors, could form a central part of such policy. Such an effort would balance the apparently competing management goals of optimum fishery yield and sustainable marine mammal populations. This would, of course, require a fundamental rethinking of how we manage fisheries and other extractive and nonextractive ocean uses.

Our increased understanding of the stock structure of marine mammal popu-

lations has clearly aided in our ability to manage them. Assessing the status of marine ecoregions together with the dynamics of individual stocks would represent a significant step forward in ocean conservation. Such a comprehensive management framework would move the species-based approach to one that can effectively restore the ecological function of marine mammals.

The MMPA, along with the Endangered Species Act, has helped put several great whale species, including the Pacific gray whale, Pacific blue whale, and humpbacks in the Atlantic and Pacific, on the road to recovery, a process that was aided by the moratorium on commercial whaling by the great majority of nations. The restoration of whales and other marine mammals has been a great benefit to coastal communities in the United States, bringing more than \$956 million a year in the form of whale watching,⁷⁵ increasing the diversity of jobs in areas suffering from fisheries decline, such as Gloucester and Provincetown, Massachusetts, and enhancing environmental tourism. The increase in whale watching has come at a cost, including collisions between whale-watching boats and whales and reduced reproductive fitness.^{76,77} Other threats have also emerged or been acknowledged in the 40 years since the act was passed, including the rise of disease, ship collisions, declines in prey species, and noise and disturbance. Research and new technologies are clearly needed to protect marine mammals from noise-related impacts, including the study of behavioral responses to impulsive and continuous noise.⁴⁹

The MMPA has focused on addressing direct effects, but it should be kept in mind that there are indirect consequences of restoration: you cannot have healthy marine mammal populations without a healthy marine ecosystem. In this way, a fully enforced MMPA could serve as a de facto marine conservation act, much as the ESA has become a habitat protection act, at least in ter-

restrial ecosystems. The restoration of marine mammals may go well beyond such legislative boundaries: as active members in the marine food web, they can help restore coastal and pelagic ecosystems simply by becoming functional members of marine communities.

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Nanomanufacturing: Emergence and Implications for U.S. Competitiveness, the Environment, and Human Health

U.S. Government Accountability Office

Nanotechnology has been defined as the control or restructuring of matter at the atomic and molecular levels in the size range of about 1–100 nanometers (nm); 100 nm is about 1/1000th the width of a hair.

The U.S. National Nanotechnology Initiative (NNI), begun in 2001 and focusing primarily on R&D, represents a cumulative investment of almost \$20 billion, including the request for fiscal year 2014. As research continues and other nations increasingly invest in R&D, nanotechnology is moving from the laboratory to commercial markets, mass manufacturing, and the global

marketplace—a trend with potential future import that some compare to history’s introduction of technologies with major economic and societal impact, such as plastics and even electricity. Today, burgeoning markets, innovation systems, and nanomanufacturing activities are increasingly competitive in a global context—and the potential environmental, health, and safety (EHS) effects of nanomanufacturing remain largely unknown.

Participants Encouraged an Integrated Framework to Assess and Address EHS Implications of Nanotechnology

Forum participants offered a wide range of perspectives on the EHS implications of nanotechnology, nanomanufacturing, and nanomaterials. They presented information on what is currently known about these implications and expressed frustration about the lack of progress in understanding the risks from potential exposure to nanomaterials. Participants specifically noted a current dilemma related to identifying or determining EHS risks. Because so few nanomaterials have been studied and no long-term or chronic data are available, it is very difficult to predict and manage risks for new nanomaterials. Forum participants also identified significant research needs to discern EHS implications, and they discussed the need to

fully communicate the benefits and risks of nanotechnology to the public, helping to distinguish between perceived and real risks. While participants noted an underlying tension between advancing innovation in nanotechnology and adopting regulation to address any negative EHS implications, they suggested that an integrated EHS framework and a collaborative approach could help offset these tensions. Forum participants discussed developing an EHS framework that would help build safety into product design and include industry, academia, nonprofits, and government.

Participants Expressed Frustration about Lack of Progress in Understanding EHS Implications of Nanotechnology, Nanomanufacturing, and Nanomaterials

Some forum participants expressed frustration that EHS implications have been discussed for roughly 10 years and yet little is known about the risks from potential exposure to nanomaterials. Some participants noted that only a few types of nanomaterials have been studied and that the universe of nanomaterials available in the market is unknown given the range of nanomanufacturing activities. However, a participant presented research that concluded that a number of characteristics or properties of nanomaterials may contribute to EHS

This article is an excerpt of a GAO report to congressional requesters featuring highlights of a forum convened by the Comptroller General of the United States. At the July 2013 forum, twenty-eight participants from industry, government, and academia discussed the future of nanomanufacturing; investments in nanotechnology R&D and challenges to U.S. competitiveness; ways to enhance U.S. competitiveness; and environmental, health, and safety concerns. This excerpt features the recommendations of forum participants concerning EHS implications of nanotechnology. The complete report is available online at www.gao.gov/assets/670/660591.pdf. Appendices II and III list forum participants and experts consulted.

hazards and that workers, in particular, may be exposed to nanomaterials.

One presenter noted that while hazardous effects have been seen in certain nanomaterials, only certain types of nanomaterials have been studied and that we lack the ability to predict hazards for nanomaterials generally. This presenter provided exposure data that showed risks are higher for workers than the general population, since material used in production is in a freer form, but presenters also discussed how clean rooms and other practices could reduce workplace exposures.¹ One presenter also stressed that most EHS research to date has been animal-based and that very little data for human exposure have been collected. Another presenter stated that there is a fundamental lack of data and information for identifying and quantifying the EHS impacts through the life cycle of the nanomaterial, and that the U.S. government alone cannot generate this data.

Participants debated the risks that nanomaterials pose, with some suggesting that risks could be categorized as perceived rather than real. A few industry participants explained that the nanomaterials used in their products are inert and pose no potential risk of exposure. One of these participants emphasized that nanomanufacturers have been using known approaches for protecting workers' health, such as technologies used in clean rooms and those developed for handling dangerous chemicals. A few participants emphasized the concept of responsible development of nanotechnology, with one saying it is an essential

component for nanomanufacturing. Such an approach requires acknowledging possible hazards and taking precautions to prevent exposure to them until more detailed information is developed.

Significant Research Needed to Discern EHS Implications

Participants discussed some similarities and differences between nanotechnology and prior technologies. One participant noted that nanomaterials have been used for a long time, although our understanding and control of them is now much more sophisticated. However, participants also discussed the wide range of new materials and products that nanotechnology could create. Participants described nanotechnology as generating new questions about EHS impacts.

Participants said significant research was needed to discern or anticipate EHS implications of manufacturing with nanomaterials and using nanotechnologies. Participants noted the presence of significant funding—both governmental and private—for nanotechnology research, but one participant suggested relatively little funding supports research on EHS implications, an observation that is consistent with our previous reporting on the National Nanotechnology Initiative.² Some forum presenters pointed out significant challenges for EHS research stemming from the very complex science involved, including the innumerable chemistries of various nanomaterials. For example, one participant explained that the universe of materials is diverse and heterogeneous. In addition, exposures in the workplace have not been uniformly

measured or widely characterized, and measurements to date have been related to specific tasks and locations. Another participant noted that the effects at the quantum level are less predictable and therefore less defined. Some participants noted the significant information gaps that EHS research could help fill, for example, to determine where the highest risks of exposure existed. While acknowledging research challenges, one presenter made the comparison with weather simulations for hurricanes, where improving the models used in weather prediction has had a dramatic impact, and suggested that computational tools are necessary for modeling complex nanomaterial risks. In addition to increased computational capacity, multiple participants discussed sustainable design and “green chemistry” as potential areas upon which nanoscience research could draw or from which it could benefit in considering EHS implications. One participant suggested that an increased focus on responsible development of nanomaterials could alleviate international trade disputes over precautionary regulation.³

The identification of research needs and assessment of progress toward meeting those needs is also the subject of a 2013 National Research Council study. This study identified needs in areas such as modeling nanomaterial releases along the value chain and developing instrumentation to measure key nanomaterial properties and changes in them in complex biologic and environmental media.

Participants also discussed differences between considering the EHS implications of therapeutic uses of nanomaterials and the occupational safety and health implications of nanomaterials.

1 In November 2013, NIOSH published guidance on engineering controls for nanomaterial production (see NIOSH. 2013. Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes. DHHS (NIOSH) Publication No. 2014-102. Cincinnati, Ohio: DHHS, November.).

2 See GAO (U.S. Government Accountability Office). 2012. Nanotechnology: Improved Performance Information Needed for Environmental, Health, and Safety Research. GAO-12-427. Washington, D.C.: GAO, May 21.

3 The precautionary principle recognizes that government intervention beyond that normally justified by scientific evidence may be warranted if there are signals that a possible threat may, if unchecked, seriously harm the population.

als. When designing therapeutic uses, one participant noted the significant resources expended on investigating nanomaterials and performing clinical trials. However, worker health and safety issues may be more challenging since workers are the first people in society exposed to the products of any technology. A few participants stated that a company whose priority was to bring a new product to market as quickly as possible and profitably, may rush to market and risk EHS implications. Thus, the underlying research for worker safety may not be an individual company priority. However, one participant said that many protective measures already used to reduce workplace exposures to larger, aerosolized particles—such as controls often used in the pharmaceutical industry—will also apply to nanoparticles.

Multiple participants spoke about the need for long-term commitment for EHS research. One participant stated that EHS research would need to be carefully orchestrated and thought through; that it would not be a 2-year project. For example, multiple participants stated research would need to consider new approaches to the assessment of product life cycles—that is, to go beyond just disposal, but also include recycling of materials.

Participants Recognized Tension between the Rapid Introduction of New Products and the Need to Discern EHS Implications

While multiple participants conveyed that companies could mitigate potential hazards to gain benefits from product innovations, some feared regulation to address EHS concerns could damage U.S. competitiveness and others noted the need for precaution when dealing with nanomaterials. For example, one participant noted that a company had designed an easier-to-clean scope for colonoscopies using nanotechnology. While the company assumed it would be an easy

approval, the regulatory agency asked it to run a clinical trial to prove the new scope was safe and effective. Estimates for clinical trials of similar medical devices have been projected to be \$30 million, which the participant suggested raised questions about whether investors could be found. One participant also raised the concern that constituencies (in other countries) that have been developed with the precautionary principle would significantly delay the continued expansion of nanotechnology, that is, until the risks are known and mitigated. Another participant, noting global competitiveness issues, worried that early but lengthy standard-setting efforts might put U.S. industry on hold at a very competitive and time-sensitive stage of the innovation process—while other nations progressed. In contrast, one participant stated that there is enough evidence of health effects for workers that prudent precautionary practices are warranted and effective, and could be a positive factor in business growth. For example, one participant noted that his company's product was manufactured in a clean room environment and included a nanomaterial bonded into a larger aggregate. Some participants also discussed how companies perform research on the safety of their nanomaterials and their efforts to inform regulators on the science behind their products. Others noted that innovation and regulation in relation to nanomaterials and technology would have to be considered as part of an evolving environment that extends beyond traditional research and industry settings. Some forum participants pointed out that technology involving nanomaterials has been evolving and that new implications for EHS could arise. One participant pointed out the new desktop technologies and the democratization of manufacturing raised concerns that certain nanomaterials (for example, those in powder form) could be inhaled and lead to widespread exposure without users' knowing about and managing the potential hazards.

For example, consumer use of desktop 3-D printers could rapidly and widely advance innovations, but controlling the associated EHS risks for individual homes or garages would present major regulatory challenges.⁴

Participants Saw a Need to Raise Public Awareness and Understanding of Benefits and Risks

A few forum participants presented information that suggested that the public does not understand nanotechnology and likely perceives risks from nanomaterials. For example, one participant noted that based on some public surveys and statistically valid samples, his or her research found that perhaps 40 percent of people had heard the term “nano.” Because of this lack of awareness, the public's perception is going to be dependent on the application and how the benefits are presented. This participant noted that the public does not have a sense of differentiation about nanomaterials—some may be considered high value, for example, materials for a better colonoscopy, but others address everyday concerns, such as stain-resistant ties and pants.

The forum's participants discussed the need to educate the general public on nanotechnology and that companies should fully consider how they develop communication strategies about the potential hazards associated with using such products. For example, one presenter's research pointed out the public's basic distrust of where to seek information, including from both industry and government. Some participants

4 The manufacturing process known as 3-D printing has been defined as “build[ing] layers to create a three dimensional solid object from a digital model,” accessed January 13, 2014, <http://whatis.techtarget.com/definition/3-D-printing-rapid-prototyping- stereolithography-or-architectural-modeling>.

noted that this concern will need to be considered when determining how to educate the public on the benefits and potential risks from new products developed from nanotechnologies and nanomaterials. One participant also noted that the legal community would have to develop scientific literacy to implement and communicate scientifically sound legal standards. One participant from the business community wondered whether to continue referring to nanotechnology in product names, advertising, or labels—given that “nano” may convey risks that actually might not apply. Participants also discussed public reaction to genetically modified organisms as highlighting the need to understand and communicate about nanotechnology risks.

Participants Encouraged a Collaborative Approach for Developing an EHS Framework

Multiple forum participants emphasized during their discussions that a collaborative approach—to include industry, academia, nonprofits, and government—could help realize the benefits of nanotechnologies and associated products and mitigate EHS risks. Participants suggested ideas for and roles within such an approach. For example, industry could identify which products use nanotechnologies or incorporate nanomaterials and disclose what it had learned concerning those materials. Academics could help catalogue such information in a way that would be useful for designing new products or create frameworks that companies could consider during product design and when conducting life-cycle assessments. In addition to supporting education and research programs, government could work with industry and academia to set appropriate standards and support public-private partnerships and international collaborations. One participant stated that government involvement in collaborations between academics and

industry is instrumental to their long-term success.

A few of the participants wanted a stronger role for industry to assist in the identification of nanomaterials and their uses, as well as disclosure of any EHS implications learned. Specifically, participants pointed out that it is challenging to identify the range of uses of nanomaterials in consumer and commercial applications without the input of the companies involved in the development and production of these materials. Since there are few tools and methods to predict the behavior of nanomaterials in the environment, industry is in the best position to help identify which materials are in use. A few participants noted that industry could explain the research behind the product and its real-world impact so that others could understand and distinguish real from perceived risks.

A few participants emphasized a stronger role for government in setting standards for nanotechnology and nanomanufacturing. While some industry participants feared potential regulation would stifle competitiveness, forum participants discussed the need for some standardization, especially in defining basic terminology, in order to characterize specific materials and products across global markets. Some participants discussed how a standard descriptive system would enable efforts to characterize the physical attributes of materials at the nanoscale and allow greater collaboration among industry, academic, and government researchers. One participant noted that in the field of nanomedicine, a central characterization laboratory has spurred innovation and commercialization by providing standardized information on nanomedicines in an open database. A few participants suggested that this approach could be applied to the broader topic of nanotechnology products.

Multiple participants suggested developing an integrated EHS framework for thinking about nanotechnology, nanomanufacturing, and nanomateri-

als. One participant explained that the framework would be based on incorporating assessments of EHS implications into the design phase of the product—not at the end of life, not at disposal, and not after problems or health impacts to consumers or workers have already occurred. Participants characterized this concept as “safer by design.” One participant explained the idea as capturing the functionality of the product while addressing safety concerns. Participants also discussed the importance of considering the life cycle and conducting life-cycle material assessments. Such an assessment would consider not only the use of the material, but all stages of the product’s life cycle from production and development through disposal and recycling.

One participant expressed the opinion that the United States lacks a coherent governance and oversight system for nanomaterials and nanotechnology, a lack that could be problematic for U.S. industry and innovation as individual municipalities or other countries put governance structures in place. One participant suggested that the nations that complete standards and risk management systems first will have an advantage in supporting development of new nanotechnology products and companies. Others specifically cited the European Union’s precautionary approach and required labeling as at least reducing uncertainty in how such products are regulated in that market. One participant noted ongoing participation in international cooperative efforts over the last 8 years in about 10 different global standardization efforts with respect to nanotechnology. Another participant discussed one global effort at the OECD to develop approaches for responsible development of nanosci-

ence and nanotechnology.⁵ We previously reported that early and ongoing coordination with foreign governments in emerging areas before regulations are in place may facilitate international regulatory cooperation.⁶ While some participants considered the National Nanotechnology Initiative a productive government effort, participants also noted that the initiative does not have a centralized source of funding or decision-making authority.

Considerations Going Forward

Forum participants described nanomanufacturing as an emerging global megatrend: a technological revolution that will likely bring future world-changing developments, including:

- new applications across many industries and related social impacts that may match or exceed levels of change associated with the digital revolution or the advent and spread of electrical power (a view that is in line with forward-looking literature indicating that nanotechnology has the potential to qualify as a general purpose technology in the future), and
- new global-scale economic opportunities and an increasingly intense international competition.

5 The OECD Working Party on Nanotechnology (WPN) advises governments on emerging policy issues related to the responsible development of nanotechnology and promotes international cooperation to facilitate research, development, and responsible commercialization of nanotechnology.

6 GAO (U.S. Government Accountability Office). 2013. *Global Manufacturing: Foreign Government Programs Differ in Some Key Respects from Those in the United States*. GAO-13-365. Washington, D.C.: GAO, July 25.

According to forum participants, the anticipated importance of future nanomanufacturing developments suggests that going forward, the United States should consider both retaining effective existing policies (with updates as needed) and taking steps toward new actions or strategic responses that could address key gaps and challenges.

Participants Said Maintaining a High Level of Investment in Fundamental Research is Essential

Forum participants said that it is essential for the United States to maintain a high level of investment in fundamental nanotechnology research. Two reasons are: (1) while the United States is currently viewed as the likely overall leader in nanotechnology R&D, certain other countries are now making significant investments in R&D as well as, in at least one case, publishing large numbers of papers, and (2) ongoing research breakthroughs will continue to drive the future of nanomanufacturing. Further, forum participants explained that nano-innovators may need to both:

- develop the new technology or product itself—a process that typically begins with fundamental research (“early technology readiness levels”),⁷ and
- devise a new and potentially innovative manufacturing method to mass-produce that product—a process that may begin with basic engineering

7 Early *technology* readiness levels concern the transition from scientific research to applied research and proof-of-concept validation.

research (“early manufacturing readiness levels”).⁸

Although these two research processes—one involving technology development and the other, manufacturing development—may often be intertwined, one participant emphasized that it may be important to consider, as nanotechnology increasingly moves into manufacturing, not only (1) continuing support for fundamental nanotechnology research but also (2) targeting at least some of the funding for nanotechnology research to early-stage research on nanomanufacturing (that is, research aimed at conceptualizing innovative processes for eventually testing and mass-producing new nanomaterials and nano-enabled products and developing these processes in a laboratory environment.)

Participants Identified Four Key Areas Needing Action

Forum participants identified gaps and challenges in four key areas where they believe future action is needed:

1. *International data on R&D investment*: Public-sector investments by nations have been considerable. The U.S. National Nanotechnology Initiative (NNI), begun in 2001 and focusing primarily on R&D, represents a cumulative investment of almost \$20 billion including the federal request for fiscal year 2014. With respect to recent and current annual levels of R&D investment,

8 Early *manufacturing* readiness levels range from the identification of basic manufacturing implications through developing a manufacturing proof of concept. For specific definitions of manufacturing readiness levels, see GAO. 2010. *Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks are Managed*. Appendix II. GAO-10-439. Washington, DC: GAO, April 22.

NNI's fiscal year 2013 budget was over \$1.5 billion, and some other nations are now making public-sector investments that may surpass that figure. Private-sector R&D investments are also significant in some countries, including the United States. Overall, the United States currently appears to be the lead-investor nation. However, two key participants cited data reliability issues. According to one of these, a pathway forward might include actions such as convening international conferences on tracking public-investment data and other related data (such as program evaluation data), with representatives from key governments from around the globe.

2. *International Standards:* Forum participants said there is a lack of basic, agreed-upon standards to facilitate industry progress in nanotechnology, international trade, and potentially, appropriate labeling of nano-enabled consumer products. Progress on basic standards may also help address other challenges and gaps discussed in this report. Importantly, forum participants said there is currently insufficient effort, especially by the United States, to participate in and “jump start” standards development. Notably, participants said that in the currently restricted U.S. budget environment, federal agencies have appeared not to prioritize staff travel to participate in international conferences—and that it is important to remedy this situation with respect to nanotechnology standards.

3. *U.S. competitiveness:* Participants recognized that current challenges to U.S. competitiveness in nanomanufacturing across world markets, taken together, represent a serious threat to realizing a level of future economic benefits commensurate with U.S. investments. These challenges range from U.S. gaps in funding or investment for nano-commercialization (the Valley of Death and the Missing Middle) and issues such as prior offshoring and possible workforce education and training issues—to the lack of a U.S. vision for a nanomanufacturing capability. Also relevant are issues concerning knowledge about and recognition of practices of other countries that may be key to global competition and may, in some cases, constitute threats. Participants outlined three possible approaches to enhancing U.S. competitiveness:

- updating federal policies aimed at supporting innovation across the economy (for example, investments in infrastructure and education), for which is a long-standing approach;
- encouraging or facilitating public-private partnerships that specifically address the Valley of Death and the Missing Middle in advanced manufacturing and innovation, a step that could help support a strong manufacturing base in the United States (although the examples provided by participants include centers that focus specifically on nanotechnology or nanomanufacturing); and

- defining a national vision and designing an overall grand strategy for U.S. nanomanufacturing—an approach that might be justified if nanomanufacturing is deemed a potential or likely future general purpose technology.

These three approaches to enhancing U.S. competitiveness might be considered alternative, or two—or possibly all three—approaches that might be used together.

4. *EHS issues:* Participants indicated that currently limited research, including a lack of data on the long-term or chronic EHS impacts of new nanomaterials, makes it difficult to predict and manage relevant risks—and difficult to help the public distinguish between real and perceived risks. The underlying tension between advancing innovation in nanotechnology and adopting regulation to address any negative EHS implications represents another possible difficulty. Participants also indicated that to advance in this area would require a revitalized approach that is integrative and collaborative.

While participants noted that action in each of the four areas above deserves consideration, these areas—and future efforts to address them, if made—may overlap. For example, basic international standards that set definitions to facilitate industry progress and trade could also help advance efforts to achieve more comparable international-investment data. Such overlap could serve as the basis for the development of a coordinated framework for nanomanufacturing-related issues.

Risky Business: The Economic Risks of Climate Change in the United States

Risky Business Project

The U.S. faces significant and diverse economic risks from climate change. The signature effects of human-induced climate change—rising seas, increased damage from storm surge, more frequent bouts of extreme heat—all have specific, measurable impacts on our nation’s current assets and ongoing economic activity.

If we continue on our current path, many regions of the U.S. face the prospect of serious economic effects from climate change. However, if we choose a different path—if we act aggressively to both adapt to the changing climate and to mitigate future impacts by reducing carbon emissions—we can significantly reduce our exposure to the worst economic risks from climate change, and also demonstrate global leadership on climate.

Climate Change: Nature’s Interest-Only Loan

Our research focuses on climate impacts from today out to the year 2100, which may seem far off to many

This article is adapted with permission from the June 2014 report produced by the Risky Business Project, a joint partnership of Bloomberg Philanthropies, the Paulson Institute, and TomKat Charitable Trust. The report can be read in its entirety at www.riskybusiness.org.

investors and policymakers. But climate impacts are unusual in that future risks are directly tied to present decisions. Carbon dioxide and other greenhouse gases can stay in the atmosphere for hundreds or even thousands of years. Higher concentrations of these gases create a “greenhouse effect” and lead to higher temperatures, higher sea levels, and shifts in global weather patterns. The effects are cumulative: By not acting to

lower greenhouse gas emissions today, decision-makers put in place processes that increase overall risks tomorrow, and each year those decision-makers fail to act serves to broaden and deepen those risks. In some ways, climate change is like an interest-only loan we are putting on the backs of future generations: They will be stuck paying off the cumulative interest on the greenhouse gas emissions we’re putting into the atmosphere now,

Short-Term Climate Threats

The American economy is already beginning to feel the effects of climate change. These impacts will likely grow materially over the next 5 to 25 years and affect the future performance of today’s business and investment decisions in the following areas:

Coastal property and infrastructure. Within the next 15 years, higher sea levels combined with storm surge will likely increase the average annual cost of coastal storms along the Eastern Seaboard and the Gulf of Mexico by \$2 billion to \$3.5 billion. Adding in potential changes in hurricane activity, the likely increase in average annual losses grows to up to \$7.3 billion, bringing the total annual price tag for hurricanes and other coastal storms to \$35 billion.

Agriculture. A defining characteristic of agriculture in the U.S. is its ability to adapt. But the adaptation challenge going forward for certain farmers in specific counties in the Midwest and South will be significant. Without adaptation, some Midwestern and Southern counties could see a decline in yields of more than 10% over the next 5 to 25 years should they continue to sow corn, wheat, soy and cotton, with a 1-in-20 chance of yield losses of these crops of more than 20%.

Energy. Greenhouse gas-driven changes in temperature will likely necessitate the construction of up to 95 gigawatts of new power generation capacity over the next 5 to 25 years—the equivalent of roughly 200 average coal or natural gas-fired power plants—costing residential and commercial ratepayers up to \$12 billion per year.

with no possibility of actually paying down that “emissions principal.”

Our key findings underscore the reality that if we stay on our current emissions path, our climate risks will multiply and accumulate as the decades tick by. These risks include:

Large-scale losses of coastal property and infrastructure

- If we continue on our current path, by 2050 between \$66 billion and \$106 billion worth of existing coastal property will likely be below sea level nationwide, with \$238 billion to \$507 billion worth of property below sea level by 2100.
- There is a 1-in-20 chance that by the end of this century, more than \$701 billion worth of existing coastal property will be below mean sea levels, with more than \$730 billion of additional property at risk during high tide. By the same measure of probability, average annual losses from hurricanes and other coastal storms along the Eastern Seaboard and the Gulf of Mexico will grow by more than \$42 billion due to sea level rise alone. Potential changes in hurricane activity could raise this figure to \$108 billion.
- Property losses from sea level rise are concentrated in specific regions of the U.S., especially on the Southeast and Atlantic coasts, where the rise is higher and the losses far greater than the national average.

Extreme heat across the nation—especially in the Southwest, Southeast, and Upper Midwest—threatening labor productivity, human health, and energy systems

- By the middle of this century, the average American will likely see 27 to 50 days over 95°F each year—two to more than three times the average annual number of 95°F days we’ve seen over the past 30 years. By the end of this century, this number will

likely reach 45 to 96 days over 95°F each year on average.

- As with sea level rise, these national averages mask regional extremes, especially in the Southwest, Southeast, and upper Midwest, which will likely see several months of 95°F days each year.
- Labor productivity of outdoor workers, such as those working in construction, utility maintenance, landscaping, and agriculture, could be reduced by as much as 3%, particularly in the Southeast. For context, labor productivity across the entire U.S. labor force declined about 1.5% during the famous “productivity slowdown” in the 1970s.¹
- Over the longer term, during portions of the year, extreme heat could surpass the threshold at which the human body can no longer maintain a normal core temperature without air conditioning, which we measure using a “Humid Heat Stroke Index” (HHSI). During these periods, anyone whose job requires them to work outdoors, as well as anyone lacking access to air conditioning, will face severe health risks and potential death.
- Demand for electricity for air conditioning will surge in those parts of the country facing the most extreme temperature increases, straining regional generation and transmission capacity and driving up costs for consumers.

Shifting agricultural patterns and crop yields, with likely gains for Northern farmers offset by losses in the Midwest and South

- As extreme heat spreads across the middle of the country by the end of the century, some states in the Southeast, lower Great Plains, and Midwest risk up to a 50% to 70% loss in average annual crop yields (corn, soy, cotton, and wheat), absent agricultural adaptation.

- At the same time, warmer temperatures and carbon fertilization may improve agricultural productivity and crop yields in the upper Great Plains and other northern states.
- Food systems are resilient at a national and global level, and agricultural producers have proven themselves extremely able to adapt to changing climate conditions. These shifts, however, still carry risks for the individual farming communities most vulnerable to projected climatic changes.

The Risky Business Project is designed to highlight climate risks to specific business sectors and regions of the economy, and to provide actionable data at a geographically granular level for decision-makers. It is our hope that it becomes standard practice for the American business and investment community to factor climate change into its decision-making process. We are already seeing this response from the agricultural and national security sectors; we are starting to see it from the bond markets and utilities as well. But business still tends to respond only to the extent that these risks intersect with core short term financial and planning decisions.

We also know that the private sector does not operate in a vacuum, and that the economy runs most smoothly when government sets a consistent policy and a regulatory framework within which business has the freedom to operate. Right now, cities and businesses are scrambling to adapt to a changing climate without sufficient federal government support, resulting in a virtual “unfunded mandate by omission” to deal with climate at the local level.² We believe that American businesses should play an active role in helping the public sector determine how best to react to the risks and costs posed by climate change, and how to set the rules that move the country forward in a new, more sustainable direction.

Introduction

Americans understand risk. Our ability to evaluate risk—to take calculated plunges into new ventures and economic directions and to innovate constantly to bring down those risks—has contributed immensely to the nation’s preeminence in the global economy. From the private sector’s pioneering venture-capital financing model to the government’s willingness to invest in early-stage inventions like the computer chip or the solar panel, our nation’s ability to identify and manage potential risks has moved the economy forward in exciting and profitable directions.

The American economy faces multiple and significant risks from climate change. Climate conditions vary dramatically across the U.S., as does the mix of economic activity. Those variations will benefit our economic resilience to future climatic changes. But each region of the country has a different risk profile and a different ability to manage that risk. There is no single top-line number that represents the cost of climate change to the American economy as a whole: We must take a regional approach to fully understand our climate risk.

Given the range and extent of the climate risks the American economy faces, it is clear that staying on our current path will only increase our exposure. The U.S. climate is paying the price today for business decisions made many years ago, especially through increased coastal storm damage and more extreme heat in parts of the country. Every year that goes by without a comprehensive public and private sector response to climate change is a year that locks in future climate events that will have a far more devastating effect on our local, regional, and national economies. Moreover, both government and the private sector are making investment decisions today—whether in property, long-term infrastructure or regional and national supply chains—that will

be directly affected by climate change in decades to come.

Our assessment finds that, if we act now, the U.S. can still avoid most of the worst impacts and significantly reduce the odds of costly climate outcomes—but only if we start changing our business and public policy practices today.

Understanding Risk

In order to know how to best respond to climate change, we first need to fully understand the risks it presents. This is our core principle. Assessing and managing risk is how businesses, militaries and governments are able to remain productive and successful in an increasingly complex, volatile, and unpredictable global economy.

The risk approach is well suited to the issue of climate change. Even the single term “climate change” is shorthand for a diverse array of impacts, mostly stemming from increased heat in the atmosphere and oceans, but also radiating outward in myriad and geographically diverse ways. For example, in some regions sea levels will likely rise, while in others they may actually fall. In some areas we will likely see increased droughts, whereas in others the combination of heat and humidity could lead to physically unbearable outdoor conditions, with increased risk of heat stroke for the many Americans who work outdoors in sectors such as construction, utility maintenance, transportation, and agriculture.

Moreover, all these conditions can and will change based on the actions we take today and into the future, as well as on unknowable factors such as the precise rate of Arctic and Antarctic ice melt. Thus the “change” part of climate change is the crux of the matter: To plan for climate change, we must plan for volatility and disruption.³

The Risky Business Project examines the risks of the U.S. continuing on its current path, or “business as usual.” This assumes no new national policy or

global action to mitigate climate change and an absence of investments aimed at improving our resilience to future climate impacts. Taking these policy and adaptive actions could significantly reduce the risks we face.

Our research analyzes the risks of “business as usual” to specific critical sectors of the economy and regions of the country. We focus in particular on sectors that are already making large, expensive investments in infrastructure that will likely last well into the future: agriculture, energy, and coastal infrastructure. We also look at the impact of climate change on America’s labor productivity and public health, which influence multiple economic sectors. These latter impacts also are deeply connected to our shared future quality of life.

As with any risk assessment, our investigation looks at not only the most likely outcomes, but also climate futures that have a lower probability of occurring but particularly severe consequences should they come to pass. The focus on such “tail risks” is not unique to climate change. After all, households and businesses pay a premium for insurance to protect themselves against those tail risks, such as the possibility of flood or fire, that they deem unacceptable. The military plans for a wide range of possible (and sometimes highly unlikely) conflict scenarios, and public health officials prepare for pandemics of low or unknown probability.

When looking at climate change, it’s particularly important to consider the outlier events and not just the most likely scenarios. Indeed, the “outlier” 1-in-100 year event today will become the 1-in-10 year event as the Earth continues to warm. Put another way, over time the extremes will become the “new normal.”

Results: Risks Vary by Region & Sector

Our risk assessment begins with the straightforward fact that human-

induced climate change leads to rising temperatures.

If we continue along our current path, with no significant efforts to curb climate change, the U.S. will likely see significantly more days above 95°F each year. By the middle of this century, the average American will likely see 26 to 50 days over 95°F each year—from double to more than triple the average number of 95°F days we've seen over the past 30 to 40 years. Climate change impacts only accelerate with time, so that by the end of this century we will likely see 45 to 96 days per year over 95°F. That's between one and a half and three months of the year at what are now considered record hot temperatures. To put this in context, by the end of the century, Oregon, Washington, and Idaho could well have more days above 95°F each year than there are currently in Texas.

These are only the most likely scenarios; there are possible lower and higher estimates outside the most likely range. Within that range, there are also disparities, of course. Some regions of the country will be far harder hit by extreme heat than others, and some will experience rising temperatures in terms of warmer winters rather than unbearable summers.

What matters isn't just the heat, it's the humidity—or, in this case, a dangerous combination of the two. One of the most striking findings in our analysis is that increasing heat and humidity in some parts of the country could lead to outside conditions that are literally unbearable to humans, who must maintain a skin temperature below 95°F in order to effectively cool down and avoid fatal heat stroke. The U.S. has never yet seen a day exceeding this threshold, the Humid Heat Stroke Index, but if we continue on our current climate path, this will change, with residents in the eastern half of the U.S. experiencing 1 such day a year on average by century's end and nearly 13 such days per year into the next century.

Heat is a critical issue for the health of businesses as well as that of human beings. On their own, rising temperatures can have significant negative impacts on health and also labor productivity. But high temperatures are also at the root of several other important climate impacts that have long been recognized by scientists:

- Hotter air on the Earth's surface leads to higher ocean temperatures, which causes ocean expansion and sea level rise;
- Higher temperatures accelerate the rates at which land ice melts, further elevating average sea levels;
- A warmer atmosphere makes extreme precipitation more likely, which is expected to make wet regions even wetter, but could also make dry regions even drier.

Because the U.S. is such a large and geographically diverse country, it will experience every one of these climate impacts in the next century. Even the individual sectors we studied have regional variations: For agriculture, for instance, the national story is one of an industry able to adapt by changing where and what farmers plant; at the same time, the story within particular regions is quite different, as individual farmers potentially abandon traditional crops or move away from the farming business altogether. For the energy industry, the story in the warming North is starkly different than in the increasingly unbearably hot South. Sea levels, too, vary significantly across the U.S., and even across cities along the same coastline: For example, sea level rise at New York will likely be higher than at Boston, and sea level rise at San Diego will likely be higher than at San Francisco.

As in a standard business risk assessment, we looked at the data to see exactly where the greatest risks lie, and confirmed that some regions and economic sectors face extreme and unacceptable risks. These are some of our gravest concerns:

- Rising seas and greater coastal storm damage already threaten the financial value and viability of many properties and infrastructure along the Eastern Seaboard and Gulf Coast. If we stay on our current climate path, some homes and commercial properties with 30-year mortgages in places in Virginia, North Carolina, New Jersey, Alabama, Florida, and Louisiana and elsewhere could quite literally be underwater before the note is paid off.
- Rising temperatures will also reduce labor productivity, as some regions—especially the Southeast and Southwest—become too hot by mid-century for people to work outside during parts of the day.
- Heat will also put strains on our energy system, simultaneously decreasing system efficiency and performance as system operators struggle to cool down facilities, and increasing electricity consumption and costs due to a surge in demand for air conditioning.
- As parts of the nation heat up, the worst health impacts will be felt among the poor—many of whom work or even live outdoors or can't afford air conditioning at home—and among those too elderly or frail to physically withstand the heat or get themselves to air-conditioned facilities.

More than any other factor, our direct economic exposure to climate change will be determined by where we do business. Still, as any business person knows, these impacts won't be contained within regional boundaries; the ripple effects are likely to resonate throughout the economy. Put another way, just because it's not hot where you are doesn't mean you won't feel the heat of climate change.

The Northeast

While the Northeast region of the U.S. is expected to experience a sizeable increase in temperatures and average

number of extremely hot days over the course of the century, the region's major climate impact will be sea level rise and its effect on coastal infrastructure.

Sea level rise that had already occurred over the past century exacerbated storm surge during Hurricane Sandy, expanding the reach of the storm-related flooding and making the storm more costly. Our research shows that, if we continue on our current path, additional projected sea level rise will likely increase average annual property losses from hurricanes and other coastal storms by \$6 billion to \$9 billion over the course of the century. Potential changes in hurricane activity, also caused by atmospheric warming, would raise these estimates to \$11 billion to \$17 billion — a 2-to-3-fold increase from current levels.

The Northeast will also suffer from increased heat, especially because so many of the region's residents live in cities that have higher temperatures due to the so-called "heat island effect." By mid-century, the average resident in the Northeast will likely see between 4.7 and 16 additional extremely hot days; by late century this range will likely jump to between 15 and 57 additional extremely hot days, or up to two additional months of extreme heat. As we discuss further in the Southeast section, these increasingly hot summers will have serious negative effects on health, mortality, and labor productivity.

Southeast

Sea level rise could seriously threaten the Southeast's coastal infrastructure, given that some of the region's major cities (e.g., New Orleans) are at or below sea level while others (e.g., Miami) are built on porous limestone that allows water inundation even in the presence of a sea wall. Much of the region's critical infrastructure—including roads, rails, ports, airports, and oil and gas facilities—also sits at low elevations.

The Southeast will also likely be hit hardest by heat impacts. Over the past 30 years, the average resident of this

Why Regions Matter

In a country as large and diverse as the U.S., it does not make sense to aggregate the highly localized economic impacts of climate change into one headline number. Take the case of Hurricane Katrina: In the last quarter of 2005, every state in the nation prospered except the state of Louisiana, which lost 1.6% of Gross State Product (GSP) as businesses were shuttered and workers stayed home;⁴ meanwhile the following year, storm recovery activities in Louisiana (e.g., construction) actually increased the national Gross Domestic Product (GDP) by half a percent.⁵ Indeed, most economic successes and disasters in the U.S. happen at the individual metropolitan, state, and occasionally multi-state level.

Regions also have a cultural dimension: Americans often think of themselves as "belonging" to specific regions, according to Joel Garreau's famous 1981 book *The Nine Nations of North America*. Garreau posits that Americans live in nine completely different cultural and economic zones. He writes: "Each has a peculiar economy; each commands a certain emotional allegiance from its citizens. These nations look different, feel different, and sound different from each other, and few of their boundaries match the political lines drawn on current maps."⁶ Garreau's observations underscore the fact that as mobile as many Americans are, we're still often unwilling or unable to move out of our home regions simply because of weather or economic changes.

The regional nature of climate impacts and the regional nature of the overall American economy and cultural identity mean that there may not be one single national response to the risks highlighted by the Risky Business Project. But the reality of these impacts, especially in the Southwest and Southeast—which will likely experience the most extreme heat and sea level rise over this century—may also mean that Americans have no choice but to migrate to cooler and more livable areas, disrupting lives, livelihoods, and regional identities formed over generations.

region has experienced about 9 days per year at 95°F or above. Looking forward, if we continue on our current emissions path, the average Southeast resident will likely experience an additional 17 to 53 extremely hot days per year by mid-century and an additional 47 to 115 days per year by the end of the century. That's one and a half to four additional months of extreme heat each year.

This kind of weather could have serious economic impacts: Our research shows a decrease in labor productivity in high-risk sectors like construction, mining, utilities, transportation, agriculture and manufacturing of up to 3.2% by the end of the century in this region, and a smaller but still noticeable impact on la-

bor productivity in low-risk sectors like retail trade and professional services.

We are also likely to see an additional 15 to 21 deaths per 100,000 people every year in this region over the course of the century due to increases in heat-related mortality, with urban residents at greater risk due to the heat island effect. At the current population of the Southeast, that translates into 11,000 to 36,000 additional deaths per year. This will have a major impact on the capacity of local hospitals.

Midwest

For the Midwest, commodity agriculture is a crucial business, and the health and productivity of the agricultural sector is inextricably intertwined

with climate conditions. Our research shows that under the “business as usual” scenario and assuming no significant adaptation by farmers, some states in the region, like Missouri and Illinois, face up to a 15% likely average yield loss in the next 5 to 25 years, and up to a 73% likely average yield loss by the end of the century. Assuming no adaptation, the region as a whole faces likely yield declines of up to 19% by mid-century and 63% by the end of the century.

Yet while the agricultural industry will clearly be affected by climate change, it is also probably the best equipped to manage these risks. Farmers have always adapted to changing weather and climate conditions, with adaptation and flexibility built into their business models. Armed with the right information, Midwest farmers can, and will, mitigate some of these impacts through double- and triple-cropping, seed modification, crop switching and other adaptive practices. In many cases, crop production will likely shift from the Midwest to the Upper Great Plains, Northwest, and Canada, helping to keep the U.S. and global food system well supplied. However, this shift could put individual Midwest farmers and farm communities at risk if production moves to cooler climates.

Great Plains

The Great Plains region stretches from the far north (Montana) to the far South (Texas). Climate impacts will be felt very differently in the northern and southern parts of this region.

Altogether, 80% of the region is devoted to cropland, pastures, and range land, which produce \$92 billion in agricultural products each year. The story for the region’s agricultural sector is mixed: The more southern states may see declining crop yields as temperatures continue to rise, while the northern states may actually see yield gains, though this will depend on a number of factors, including water availability.

The region is also a major energy producer for the nation, making climate impacts on the energy sector particularly important for this area. Texas and Wyoming alone produce half of U.S. energy (primarily from crude oil and natural gas in Texas and coal in Wyoming), and North Dakota has recently become a major oil and gas producer. Power generation facilities in the region currently meet about 17% of the nation’s overall electricity needs.⁷

If we stay on our current path, our research shows a significant increase in demand for air conditioning over the course of the century which, when combined with other heat-related impacts such as reductions in power generation and in transmission efficiency and reliability, could place a considerable burden on the electricity power sector.

Most of this increase will occur during times of the day when electricity consumption is already high. Meeting higher peak demand will likely require the construction of up to 95 GW of additional power generation capacity over the next 5 to 25 years, the rough equivalent of 200 average-size coal or natural gas power plants. Constructing these new power-generation facilities will, in turn, raise residential and commercial energy prices. Our research concludes that climate-driven changes in heating and cooling will likely increase annual residential and commercial energy costs nationally by \$474 million to \$12 billion over the next 5 to 25 years and \$8.5 billion to \$30 billion by the middle of the century.

Northwest

The economy of the Northwest is dependent on its coastlines, but it is also heavily dependent on its forests. Oregon and Washington are the number one and two softwood-producing states in the nation, respectively;⁸ these two states plus Idaho produce more than \$11 billion in primary wood product sales.⁹ Our review of existing research suggests the Northwest’s forests will experience sig-

nificant potential impacts from climate change, in particular from wildfire—due to both increased drought and to wood damage from pests surviving warmer winters. One study we reviewed found that if temperatures rise 3.2°F by mid-century, this could lead to 54% increase in the annual area burned in the western U.S.¹⁰ The same study found that the forests of the Pacific Northwest and Rocky Mountains will likely experience the greatest increases in annual burn area (78% and 175%, respectively).

Southwest

This region is already warm and dry—about 40% of this area is covered by desert¹¹—and is likely to become more so in the coming decades. As the Southwest climate heats up, the region is likely to see significantly less snow in the mountains, leading to decreases in spring runoff especially in California and the Southern Rockies. Extreme heat may also lead to higher evaporation of existing reservoirs. This translates into less available groundwater for critical industries such as agriculture, as well as for simple drinking and bathing. Even as temperatures rise, increased energy demand from air conditioning will likely lead to increased water demand, since electricity generation is heavily water-dependent. Decreased water availability is also likely to be the most significant impact on this region’s agricultural industries.

Alaska

More than 80% of the state’s GDP comes from oil and gas production, and so increases in energy demand (as discussed above) will dramatically affect this region. Meanwhile, fisheries and tourism, the third and fourth largest contributors to the Alaska economy, depend on healthy oceans and coastal ecosystems.

Hawaii

Hawaii is expected to get significantly warmer: On our current path, by mid-

century average temperatures will likely be between 1.6°F to 3.6°F warmer than temperatures over the past 40 years. By the end of the century, temperatures will likely increase between 3.7 and 7.7°F. There is also a small but not insignificant chance that Hawaii's average temperatures could rise as much as 9.4°F by the end of the century.

Sea level rise in Hawaii is greater than the global average, and the extreme dependence of this state on the coasts will only intensify this impact. If we continue on our current path, sea level rise at Honolulu is likely 0.8 inches to 1.2 feet greater by mid-century, and 2.1 to 3.8 feet by the end of the century. Looking out at the 1-in-100 tail risk, sea level at Honolulu could rise by more than 6.9 feet by 2100.

From Risk Assessment to Risk Management: Next Steps

Taking a classic risk assessment approach to climate change in the U.S. leads to the inescapable conclusion that if we continue on our current climate path, the nation faces multiple risks across every region.

But risk assessment is not just about identifying risks and leaving it at that. Our research also shows that if we act today to move onto a different path, we can still avoid many of the worst impacts of climate change, particularly those related to extreme heat. We are fully capable of managing climate risk, just as we manage risk in many other areas of our economy and national security—but only if we start to change our business and public policy decisions today.

The Risky Business Project was not designed to dictate a single response to climate risk. We know that there will be a diversity of responses to our analysis depending on the particular risk tolerance of individual business and policy actors, as well as their particular region or sector of the economy. But the Risk Committee does believe, based on this project's independent research and the

significance of the climate risks it demonstrates, that it is time for all American business leaders and investors to get in the game and rise to the challenge of addressing climate change. The fact is that just as the investments and economic choices we made over the past several decades have increased our current vulnerability to climate change, so will the choices we make today determine what our nation looks like in 15 years, at mid-century, and by 2100.

In short, we have a choice whether we accept the climate risks laid out above or whether we get on another path. This is not a problem for another day. The investments we make today—this week, this month, this year—will determine our economic future.

There are three general areas of action that can help to minimize the risks U.S. businesses currently face from climate change:

Business Adaptation: Changing everyday business practices to become more resilient.

Some of the climate impacts we analyzed are already being felt across the nation; indeed, some are already an unalterable part of our economic future. Rational business actors must adapt. The agricultural sector is on the front lines of climate adaptation. In coastal communities, too, private and public sector decision-makers are beginning to adapt to present climate impacts, building sea walls and changing building codes to recognize the reality of rising sea levels and increased storm surge.

But this adaptation may come at a price: Some farmers in Midwest counties, for instance, may suffer economic losses shifting to new crops (with required new equipment and expertise), if they can afford to shift at all. Meanwhile, coastal states and cities are being forced to adapt to climate realities without adequate financial support from the federal government.¹² These public sector adaptation costs will only grow as the private insurance industry continues

its exodus from the business of insuring coastal real estate and the bond market begins to wake up to the vulnerability of key infrastructure investments to climate change.¹³

Investor Adaptation: Incorporating risk assessment into capital expenditures and balance sheets.

Another area where today's business investments have a direct relationship to tomorrow's climate impacts is in long-term capital expenditures, which will live well into the middle of the century and beyond. Today, ratings agencies are evaluating infrastructure projects with a multi-decade lifespan. Utilities are making investments in new power plants and pipelines, and signing long-term power purchase agreements that rely on those investments. And real estate investors are making multiple bets on residential and commercial properties. These investments must be evaluated in terms of the actual climate risk specific regions face as we approach the middle of this century. In 2010, recognizing this reality, the Securities and Exchange Commission (SEC) issued Interpretive Guidance on climate disclosure, giving companies some idea of how to consider their "material" risks from climate change; unfortunately, as of 2013, over 40% of companies listed on the Standard & Poor's 500 Index were still not voluntarily disclosing climate risks.¹⁴

Public Sector Response: Instituting policies to mitigate and adapt to climate change.

Ultimately, climate change is not just an issue for specific sectors and regions: It is a global issue that demands an effective policy response from the U.S. According to the latest Intergovernmental Panel on Climate Change report, the world may have as little as 15 years to "keep planetary warming to a tolerable level," through an aggressive push to bring down carbon emissions.¹⁵

In the Risky Business Project, we focused primarily on modeling our current

economic path and the attendant climate risks. Because this is the path we're now following as a nation, we need to better understand the potential risks it poses and decide how to respond to those risks—especially those that are already embedded in our economy because of decisions we made decades ago.

But the path we're on today does not have to be the path we choose to follow tomorrow. Our analysis also looks at alternate pathways that include investments in adaptation and policy efforts to mitigate climate change through lowering greenhouse gas emissions. These alternate pathways could significantly change the climate impacts we discuss above. For example, modest global emission reductions can avoid up to 80% of projected economic costs resulting from increased heat-related mortality and energy demand.

Our goal in this risk assessment is not to dictate those policy pathways. However, we do strongly urge the American business community to play an active role in the public discussion around climate mitigation and preparedness, which we believe is the single most effective way for businesses to decrease the risks we have identified in this project.

Conclusion

With this project, we have attempted to provide a common language for how to think about climate risk—built upon a common language of risk that is already part of every serious business and investment decision we make today. If we have a common, serious, non-partisan language describing the risks our nation may face from climate change, we can use it as the springboard for a serious,

non-partisan discussion of the potential actions we can take to reduce those risks.

Our goal with the Risky Business Project is not to confront the doubters. Rather, it is to bring American business and government—doubters and believers alike—together to look squarely at the potential risks posed by climate change, and to consider whether it's time to take out an insurance policy of our own.

ENDNOTES

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International News

International Wood Culture Society

*World Wood Day USA Celebration
in Bethesda, Maryland*

The first World Wood Day USA celebration, sponsored by the International Wood Culture Society (IWCS), was held in Bethesda, Maryland on March 21-22, 2014. The event examined the growing value of wood as a natural resource and a medium for cultural expression under the theme: the melting pot of American culture and how it has impacted the use of wood. This event coincided with the larger Second International World Wood Day activities in Fujian Province, China.

Several technical presentations followed by demonstrations of Native American woodcarving, wood turning, basket making, musical instrument craftsmanship, and fish decoy carving were held on the first day of the event. The second day consisted of children's programming with wooden toys and

games, followed by a tour of a private wood art collection.

Additional information on World Wood Day is available online at <http://www.worldwoodday.org/2014>.

U.S. Department of State Hosts Our Ocean 2014 Conference

On June 16-17, the Department of State hosted the "Our Ocean" Conference, which brought together Heads of State, Foreign Ministers, policy makers, environmentalists, scientists and entrepreneurs from nearly 90 countries with the goal of developing strategies for protecting oceans from marine pollution, acidification and overfishing.

The conference aimed to raise ocean conservation as a critical foreign policy issue and resulted in commitments from government and private sources valued at more than \$800 million to conserve the ocean and its resources for future generations. In addition, Norway announced it will allocate \$1 billion to

climate change mitigation and adaptation assistance.

In a video presentation, President Obama announced that his Administration will immediately consider ways to expand protections near the Pacific Remote Islands Marine National Monument in the south-central Pacific Ocean. The President also outlined a new comprehensive program aimed at deterring illegal fishing, addressing seafood fraud and preventing illegally caught fish from entering the U.S. marketplace.

In his closing remarks, Secretary Kerry outlined an action plan of policy goals, best practices, and benchmarks aimed at translating the initiatives developed at the conference into a unified global ocean policy. In addition, participants announced commitments for the protection of more than 3 million square kilometers of the ocean—an area slightly larger than India.

Additional information on the Our Ocean conference is available online at <http://ourocean2014.state.gov/>.

Meetings

See <http://www.rnrf.org> for additional meetings

Submit Meeting Notices to: info@rnrf.org

October 2014

IUFRO World Congress. Sustaining Forests, Sustaining People: The Role of Research. October 5-11, 2014, Salt Lake City, UT. <http://iufro2014.com>

Society of American Foresters National Convention. October 8-11, 2014, Salt Lake City, UT. <http://www.xcdsystem.com/saf/site14/>

Natural Areas Conference. October 15-17, 2014, Dayton, OH. <https://naturalareas.org/conference/2014-natural-areas-conference>

Geological Society of America Annual Meeting. October 19-22, 2014, Vancouver, British Columbia, Canada. <http://www.geosociety.org/meetings/2014/>

Water for Food Global Conference. Harnessing the Data Revolution: Ensuring Water and Food Security from Field to Global Scales. October 19-22, 2014, Seattle, WA. <http://waterforfood.nebraska.edu/wff2014/>

NOAA's 39th Climate Diagnostics and Prediction Workshop. October 20-23, 2014, St. Louis, Missouri. <http://www.cpc.ncep.noaa.gov/products/outreach/CDPW39.shtml>

International Symposium on Weather and Climate Extremes, Food Security and Biodiversity. October 20-24, 2014, Fairfax, VA. <http://iscefs.org>

Urban Land Institute Fall Meeting. October 21-24, 2014, NYC, NY. <http://www.uli.org/events/fall-meeting/>

Together Toward Tomorrow - Conservation, Partners, and Landscapes. October 23-24, 2014, Washington, DC. <http://www.largelandscapenetwork.org/2014-national-workshop/>

The Wildlife Society Annual Conference. October 25-30, 2014, Pittsburgh, PA. <http://www.wildlife.org>

BioCycle East Coast Conference 2014. October 27-30, 2014, Baltimore, MD. <http://www.biocycle.net/conferences/biocycle-east-coast-conference-2014/>

November 2014

American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America International Annual Meeting. November 2-5, 2014, Long Beach, CA. <https://www.acsmeetings.org/>

American Water Resources Association Annual Water Resources Conference. November 3-6, 2014, Vienna, VA. <http://www.awra.org/meetings/Annual2014/>

SETAC North America 35th Annual Meeting. November 9-13, 2014, Vancouver, British Columbia, Canada. <http://vancouver.setac.org/>

American Society of Landscape Architects Annual Meeting and Expo. November 21-24, 2014, Denver, CO. <http://www.asla.org/annualmeetingandexpo.aspx>

December 2014

RNRF Congress on Adapting Food Production to a Changing Climate: Identifying Strategies and Establishing Priorities. December 9-10, 2014, Washington, DC. <http://www.rnrf.org/2014cong>

National Groundwater Association Expo. December 9-12, 2014, Las Vegas, NV. <http://groundwaterexpo.com/>

American Geophysical Union Fall Meeting. December 15-19, 2014, San Francisco, CA. <http://fallmeeting.agu.org/2014/>

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