THE SECURITY THREAT THAT BINDS US

THE UNRAVELING OF ECOLOGICAL AND NATURAL SECURITY AND WHAT THE UNITED STATES CAN DO ABOUT IT

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THE CONVERGING RISKS LAB

an institute of

COUNCIL ON STRATEGIC RISKS

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February 2021

Cover Photo:
Top Row: (1) Heaps of overfished mackerel minnows near Andaman Sea (Tanes Ngamson/ Shutterstock), (2) Demonstrators protest over ongoing drought in La Paz, Bolivia 2017. (David Mercado/Reuters). (3) Dead bee, killed by pesticide. (RHJ Photo and illustration/Shutterstock); Bottom Row: (1) Rhino dehorned to prevent its killing, South Africa (John Michael Vosloo/ Shutterstock); (2) Malaysian and Vietnamese fishing boats destroyed by Indonesia for illegal fishing. (M N Kanwa/Antara Foto, Reuters). Background image: Aerial drone view of tropical rainforest deforestation (Richard Whitcombe/ Shutterstock). Composition by Rod Schoonover.

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I. EXECUTIVE SUMMARY

KEY FINDINGS

Global ecological disruption is arguably the 21st Century's most underappreciated security threat. Human societies are producing rapid, novel, and foundational changes across multiple Earth systems with concomitant—and sometimes severe—consequences for people, societies, and security worldwide. These changes are significant and globally consequential, and include the transformation of the atmosphere's composition, overloaded and depleted soils, toxified and acidified oceans, and reconfigured freshwater systems. Due to human activities, the biosphere—the Earth system that encompasses all living entities—is destabilizing rapidly and fraying the ecological fabric on which human society depends. Many scientists warn that Earth is entering a sixth mass extinction, a period of rapid loss of biodiversity so consequential that it affects the fate of the majority of multicellular organisms on the planet.

Humanity's alteration of the Earth's climate, driven primarily by the discharge of greenhouse gases into the troposphere, is now receiving well-deserved and long-overdue attention from the media, governments, security institutions, and publics worldwide. Broader activities related to ecological or natural security—ones that more directly alter ecosystems and transform the biosphere—have been no less dramatic or consequential but have been absent from most of these discussions. Further, both climate and broader ecological security risks continue to be under-recognized as issues with tangible and present consequences for safety, security, and U.S. strategic interests.

The national security structures and agencies of the United States and many other countries were designed to protect their respective citizens against malign nation-state actors, having shifted over the past few decades to also recognize threats from non-state actors. Actorless security threats, or threats without "proximate" actors or explicit actor intention, such as infectious disease outbreaks, pandemics, and intensified natural disasters that harm people and infrastructure, present threats to which national security structures and agencies in the U.S. and elsewhere must adapt, and restructure where necessary, in order to meet their missions in the coming years and decades.

This summary uses the term ***ecological security*** to describe the elements of human, national, and global security that arise from ecological destruction and disruption, and the collapse of ecosystems. This term includes water and food security, trafficking and exploitative use of wildlife, protection from natural disasters, and the threats to U.S. economic interests from illegal timber trade and fisheries—the focus of the ongoing *Natural Security* campaign[1]—as well as those arising from other forms of ecological disruption such as species and population extinctions, zoonotic disease, and threats to critical ecological processes.

This report describes our ecological predicament and analyzes the security implications arising from decades of ecological disruption. We take a deep dive into several pillars of *natural security*, which span water, food, wildlife, forest, and fisheries systems. Finally, we offer recommendations for how the U.S. and other nations and multilateral institutions can proactively mitigate and address both ecological disruption and its impacts on national and human security.

ECOLOGICAL DISRUPTION IS UNDERWAY

Human activities greatly influence how many and what types of organisms exist, where they live, what they live on, and the nature of their interactions between other organisms and with their habitats. These human activities are driving what some ecologists call an ongoing "biological annihilation," in which species are becoming extinct at rates far higher than the natural pace, and healthy and functional populations of organisms disappear even more quickly. Habitats are changing, life is redistributing and mixing in new ways, and many ecosystems are shifting to new baseline states. The impacts on health, safety, security and prosperity are manifold, from crop failures and infectious disease outbreaks to conflict, instability, and erosion of livelihoods.

ECOSYSTEM SERVICES ARE DEGRADING

Ecosystem services—the suite of benefits that natural systems provide to humanity—range from "regulating" services affecting air, water, and soil quality, the severity of the impact of natural disasters and extreme events, pollination, and disease and pest control; to "material" services such as food, water, and fiber production, energy provision, and medicinal resources; and finally to "nonmaterial" services including recreation, tourism, heritage protection, and symbolic, spiritual, and psychological services to people.

While economists often employ the concept of ecosystem services to quantify the monetary loss arising from the degradation of natural systems, the impacts of large-scale losses are likely to extend well beyond mere economic valuation. The incipient damage could potentially lead to catastrophic circumstances and outcomes for human life and complex human systems, including the nation-state system and the global order that depends on it. There is growing evidence that the consequences of amassed losses of ecosystem services may compare to those of other better-known global change stressors, such as climate change—itself a major contributor to the losses of ecological services.

PANDEMIC RISK GROWS AS NATURE DEGRADES

Pandemics and large-scale epidemics are becoming more frequent. The last two decades have seen significant outbreaks of previously identified pathogens such as H5N1 (avian flu), dengue fever, cholera, and Ebola. These outbreaks are part of a broad acceleration of infectious disease emergence, with many of the most damaging cases now caused by the zoonotic "spillover" from animals to humans. SARS, H1N1, MERS, Chikungunya,

Zika, and COVID-19 emerged during this same period, three of which were caused by novel coronaviruses. It is clear that ecological degradation—especially loss and fragmentation of habitat—significantly increases the likelihood of zoonotic "spillover" pathogens by increasing the frequency of people and their systems interacting with wildlife (among other mechanisms driven by the loss of wildlife habitat and other processes).

As evidenced by the impacts of the COVID-19 pandemic, global infectious disease outbreaks, especially when unaddressed or poorly managed, can disrupt social order, undermine economic stability, depress trade, decimate public health capacity, intensify food insecurity, erode public confidence in government, and worsen social and political inequalities.

ENVIRONMENTAL CRIME IS AMPLIFYING ECOLOGICAL STRESS AND SOCIAL INSTABILITY

Although sometimes dismissed as victimless transgressions against nature, environmental crime carries significant repercussions for individuals and societies worldwide. The illegal procurement and trade of live wildlife, ivory, rhino horn, pangolin, rosewood (a trade term that describes a wide range of tropical hardwood), and fish harvested through illegal, unreported, and unregulated (IUU) fishing have helped criminal networks generate profits and establish steady financial flows, with some of the benefits accruing to criminal and terrorist networks and other bad actors. Corruption, a facilitator of environmental crime, is an acute threat to the rule of law and a nation's stability.

The economic damage is immense, with revenues diverted from national treasuries into informal economies and both terrorist and criminal networks, thereby depriving countries of the benefits from their natural wealth. Illegal trade in these natural resources also poses multifaceted risks to a country's social and political capital. Over the past decades, crime has globalized like other industries, spurring a fundamental change in the nature of environmental crime. As with other transnational organized crimes, environmental crime is driven primarily by market forces, which suggests that approaches that focus narrowly on groups or individuals will have limited efficacy.

THE *NATURAL SECURITY* CAMPAIGN HAS ELEVATED ATTENTION TO SPECIFIC DRIVERS OF INSECURITY

Water. Water stress is a major threat for much of the world's population., posing a number of risks to human health and security and becoming a factor in some forms of international conflict, such as disputes over transboundary water resources. The number of water conflicts has been increasing at the subnational level. To date, interstate tensions over water are most often defused before escalating to conflict. Still, many analysts project that this may change in the future as water stresses increase due to climatic changes and other social and political dynamics. Water stress, and the failure of governments to adequately address it, can contribute to political instability, social disruption and state instability and conflict, while serving as an impetus or accelerant for human migration and population displacement. Some insurgent groups "weaponize" water by targeting critical water resources or attempting to benefit from providing needed water to build patronage with locals. Water stress also poses a number of risks to human health.

Food. Securing food resources has long been an important issue for national security. Food insecurity can be a factor in conflict, instability, social unrest, and migration. The prospect of feeding the planet's burgeoning population has regional and global geopolitical and geostrategic overtones, which are increasingly exacerbated by climate change stresses. After largely disappearing from the world, famine has commingled over the past few years with other humanitarian crises, such as COVID-19, conflict, and locust outbreaks. Losses of insect and other pollinators pose a perilous risk to some parts of food production. Meanwhile, industrialized countries depend critically on the global food network, which is becoming increasingly vulnerable to concurrent acute shocks.

Wildlife. Dramatic numbers of habitats have been transformed to meet people's natural resource demands, but these pressures have contributed to precipitous declines in wildlife. The risk of pandemics and infectious disease outbreaks grows as the human-wildlife interface deepens, and many forms of legal and illegal wildlife trade continues. Global economic losses from the illegal wildlife trade are substantial, which also threatens many local people and communities' livelihoods. The low risk, high reward nature of wildlife trafficking is an appealing factor for insurgent groups or non-state actors that struggle with financing. In some places, the rapidity and violence of poaching activities have overwhelmed the response capacity of local wildlife enforcement agencies. Heightened militarization of wildlife areas increases the risk of heavy-handed anti-poaching efforts and nonparticipants being caught in the crossfire as collateral damage.

Forests. Illegal forest activities, including illegal logging and poor governance, contribute to regional unrest and conflict in some areas. Revenue from the illegal timber trade finances violent conflicts in many countries and creates havens for illicit drug activities that can proliferate in forested regions without oversight. Illegal logging undermines legitimate forest activities, robs governments of revenue, and poses threats to sustainability by crippling the resource wealth of a state. Deforestation and forest degradation, particularly in the tropics, is a primary driver of both biodiversity loss and climate change, which has concomitant risks for humans and societies. Between 1950 and 2000, over 80 percent of all armed conflicts occurred in forested regions and other biodiversity hotspots. The rapid pace of forest conversion can cause the severe dislocation of people and contribute to migration and loss of social cohesion. Whether driven by global timber markets or happening by necessity, the increased human activity at these ecosystem boundaries increases risk of zoonotic pathogen transfer.

Fisheries. Development and competition of fisheries resources underpin several security concerns, including geopolitical clashes over fisheries, conflicts over natural and artificial land, increasing incidences of maritime piracy, and armed interactions over fish stocks. Disputes over ocean and inland freshwater fisheries have been associated with conflict, at times elevating to militarized interstate disputes over fisheries and raising the specter of future intensified conflicts as fish stocks dwindle or move. Dams can substantially affect fisheries on inland rivers and their estuaries by blocking fish migration and changing sediment flow patterns in major rivers. Illegal, unreported, and unregulated (IUU) fishing is a major human-driven stress undermining all fishery management efforts because of the difficulty of tracing it, particularly in nations with weak maritime governance. A minority of IUU fishing takes place in international waters, meaning that coastal nations shoulder the burden disproportionately via their coastal exclusive economic zones.

POLICY RECOMMENDATIONS

This report offers recommendations based on **three fundamental precepts**:

1. Only **centrally-appropriated and coordinated funding, programs, and structures through the U.S. Congress** combined **with effective interagency coordination in the Executive Branch** can directly and effectively address ecological disruption at scale. This can be done by elevating ecological security in U.S. national security policy-making, promoting international conservation, combating environmental crime, enhancing water and food security, strengthening pandemic preparation, and building local capacity.

2. The **infusion of science and scientific expertise** into the defense, diplomatic, and intelligence communities **will be critical** for comprehending and responding to the problem. This requires leaning heavily on science and engineering fields atypically engaged in national security such as conservation biology, disease ecology, forest science, soil science, hydrology, and agricultural engineering.

3. The U.S. government must **reboot its national security doctrine and architecture** to tackle the modern threats presented by a changing planet and the degradation of its embedded socio-ecological systems.

Based on these three precepts, we recommend the following **8 pillars of action** to address the security implications of ecological disruption:

1. <u>Promote International Mechanisms that Aim to Reverse and Reduce the Drivers of Ecological Disruption,</u> which include:

- 1.1. Ratify the UN Convention on Biological Diversity
- 1.2. Ratify the UN Convention on the Law of the Sea
- 1.3. Infuse Ecological and Natural Security into Climate Change Efforts
- 1.4. Integrate Sustainable Agriculture and Food Supply into Policy and Science
- 1.5. Promote Actions that Combat Overexploitation of Natural Resources

2. <u>Promote Methods that Protect and Expand Critical Systems and Services,</u> which include:

- 2.1. Counter Harmful State Actions Towards Critical Resources
- 2.2. Expand Protected Areas
- 2.3. Better Manage and Protect Protected Areas
- 2.4. Protect Critical Ecosystem Services that Span Geographies

3. <u>Build and Strengthen International Alliances,</u> which include:

- 3.1. Assert Global Leadership on Climate and Ecological Security
- 3.2. Bring together Ecological Security Communities
- 3.3. Increase International Communication on Ecological Risks
- 3.4. Develop, Share, and Collaborate on Ecological Defense Frameworks

4. **Treat Environmental Crimes as Serious Crimes,** which include:
    - 4.1. Prioritize Anti-Corruption Efforts
    - 4.2. Target Transnational Criminal Networks over Localized Criminal Groups
    - 4.3. Move Beyond Seizures and Promote Effective Prosecutions and Deterrent Penalties

5. **Reduce Pandemic Risk at Point of Origin,** which include:
    - 5.1. Enhance Monitoring, Understanding of Pathogen Space, and Pathogen Early Warning
    - 5.2. Increase Assistance for One Health Efforts
    - 5.3. Address Pandemic Risk in the Wildlife Trade

6. **Amplify Ecological and Natural Security Issues in the U.S Government,** which include:
    - 6.1. Create a Deputy Assistant to the President for Environmental Security and an Office of Environmental Security Within the National Security Council
    - 6.2. Infuse Ecological and Natural Security into White House Strategic Planning
    - 6.3. Increase Capacity for Analyzing Ecological and Natural Security Issues Within the Intelligence Community
    - 6.4. Elevate International Water Security Issues (including their climate dimensions) Within the Foreign Policy and National Security Enterprise, including at the Department of State, Department of Defense, and the National Security Council
    - 6.5. Add More Ecological and Natural Security Issues to Military-Military and Intelligence-Intelligence Engagements
    - 6.6. Augment Ecological and Natural Security in U.S. Defense and Intelligence Academic Curricula

7. **Initiate an Ecological and Natural Security Research Agenda, which include:**
    - 7.1. Deepen Understanding of Linkages Between Ecological Disruption and Security
    - 7.2. Develop Early Warning Indicators for Impactful Ecological Regime Shifts
    - 7.3. Bring Ecological Forecasting to Maturity
    - 7.4. Foster More Research on Insect Declines

8. **Engage the Public on Ecological and Natural Security Issues,** which include:
    - 8.1. Deploy Effective Advocates
    - 8.2. Convene High-Level Ecological and Natural Security Conferences, with the Participation of Security, Foreign Policy and Intelligence Leaders
    - 8.3. Expand the Aperture of *Natural Security* to Include the Broader Ecological Security Framework Described In This Report

II. NATURAL SYSTEMS AND SECURITY

"Few problems are less recognized, but more important than, the accelerating disappearance of the Earth's biological resources. In pushing other species to extinction, humanity is busy sawing off the limb on which it is perched."

— Paul R. Ehrlich

"Give me trees now, so I don't have to ask for tanks later."

— Public Remarks by [Unnamed] Senior U.S. Government Official
Munich Security Conference, February 2020

OVERVIEW

Global ecological disruption is arguably the 21st Century's most underappreciated security risk. Humans and their activities are producing rapid, novel, and substantial changes across multiple Earth systems with concomitant—and sometimes severe—consequences for people and societies worldwide. People have transformed the atmosphere's composition, overloaded and depleted soils, toxified the oceans, and reconfigured freshwater systems. The biosphere—the Earth system that encompasses all living entities—is destabilizing rapidly and fraying the ecological fabric on which humanity depends.

Ecological stresses add pressure on people, communities, governments, institutions, and norms that have not evolved to adequately address the changing threat landscape. Without substantial and transformative mitigation policies, dangerous fallout is increasingly likely for the vulnerable—and unlucky. Some facets of the ecological security threat will resemble traditional security outcomes, like conflict and crime. As ecological pressures amalgamate, the mismatch between how the national security enterprise is organized and what threats people face will be increasingly striking.

Weaknesses in U.S. national security strategy and policy have already been exposed by shortfalls in addressing ongoing climate change impacts and the COVID-19 pandemic. Fatalities of U.S. citizens from

Avenue C in Manhattan after flooding caused by Hurricane Sandy on October 29, 2012. David Shankbone/Wikimedia Commons

the coronavirus SARS-CoV-2 have surpassed those from both the Civil War and World War II, while causing tremendous economic harm and social disruption. Meanwhile, supercharged wildfires and tropical storms are destroying massive quantities of infrastructure personal property in addition to deaths. The risks from ecological disruption, which are simultaneously apart from and connected to climate change and pandemic risk, are serious enough for consideration alongside other critical transnational security concerns.

This report was written with a wide range of audiences in mind, to include policymakers, scientists, security experts, and the general public. It aims to frame and demonstrate the ongoing problem of ecological disruption (Section III); take a deeper dive into five key ecological domains that are primary foci of international conservation groups, and the *Natural Security* campaign in particular (Section IV); share a novel matrix supporting analysis in this space (Section V); summarize the policy landscape and trajectory of the problem (Section VI); and finally, provide recommendations for addressing the security implications of ecological degradation (Section VII).

This report uses the term *ecological security* to describe the elements of human, national, and global security that arise from ecological disruption. This term includes water and food security, wildlife trafficking, protection from natural disasters, and the threats to U.S. economic interests from illegal timber and fishing—the focus of the *Natural Security* campaign—as well as those arising from other forms of ecological disruption such as species and population extinctions, zoonotic disease, and threats to critical ecological processes. In some ways, *ecological security* is a natural successor to *environmental security*, but with a greater emphasis on threats to the integrity of the biosphere.

NATIONAL SECURITY MUST ADAPT TO AN ERA OF ECOLOGICAL STRESS

The January 2020 World Economic Forum report on global risk perceptions identified, for the first time,[i] biodiversity loss as one of its Top 5 Global Risks in terms of both likelihood and impact over the next ten years.[2] The same report also identified the failure of climate action, extreme weather, natural disasters, human-made environmental disasters, and water crises as top risks. Those who closely monitor the global risk landscape increasingly recognize the deepening relevance of ecological and environmental stressors.

But ecological disruption affects people and societies in the context of other dynamic risks. Biophysical pressures from climate change, ocean acidification, and toxification intermingle with social stress factors such as economic instability, national and global governance failures, pervasive inequality, and the retrenchment of both information integrity and expertise. Unmitigated, these compounding factors portend a worrying period of global turbulence and shocks with high geographic variability. The complexity of the Earth, and the deep interconnectedness of its living and nonliving components, will stymie efforts to address any of these stressors in isolation.

Ecological factors can contribute to a number of outcomes that most experts would recognize as "traditional" security threats. These include state conflict, political instability, resource disputes, and transnational organized crime. However, the amalgamated risks that nations face over the next several decades are arguably more diffuse, obfuscated, and actorless than those experienced by previous generations. The changing nature of the risk landscape argues for a doctrinal reboot that infuses ecological concerns into security to better anticipate and address the challenges ahead.

What constitutes "national security" has evolved since World War II, especially in the aftermath of the Cold War. This is especially true as the United States has grappled with a number of threats that stemmed not from conflict or Cold War rivalries, but that still challenged the nation at the strategic level, such as those arising from energy and economic crises, and drug trafficking concerns.[3] In a groundbreaking 1974 *Foreign Affairs* article, former Chairman of the Joint Chiefs of Staff Gen. Maxwell D. Taylor[ii] warned that "the most formidable threats to this nation are in the nonmilitary field."[4] Indeed, the systemic shock arising from COVID-19 throughout 2020 and likely beyond is a brutal illustration that nations can incur mass casualties, economic devastation, and social disruption that surpass violent conflicts.

Calls for the security establishment to pay greater attention to ecological threats are not new. Lester Brown, prolific author and founder of the Worldwatch Institute, wrote in 1977 that the "failure to arrest the deterioration of biological systems threatens not only the security of individual nations, but the survival of civilization as we know it."[5] In her influential 1989 article "Redefining Security," Jessica Mathews, former Director of the Office of the Global Issues at the National Security Council and future President of the Carnegie Foundation for International Peace,[iii] argued that "ignorance of the biological underpinning of human society blocks a clear view of where the long-term threats to global security lie."[6] Two years later, in his administration's 1991 National Security Strategy, President George H.W. Bush cited biodiversity, deforestation, food security, water supplies, and climate change as critical issues of concern.[7]

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i Biodiversity loss appeared in the Top 5 Global Risks in the 2011 report, but only on the Likelihood scale.

ii Although controversial to some military historians for his role in Vietnam-era decisionmaking, Taylor remained a national security thought leader as Chairman of the Foreign Intelligence Advisory Board and President of the Institute for Defense Analyses.

iii A biophysicist, Mathews was also founding Vice President of the World Resources Institute.

Despite such calls to widen the security aperture, attention to environmental and ecological threats nearly always lags attention compared to more traditional security frameworks. In 2019, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) released an exhaustive global-level assessment report by 145 authors from 50 countries that clarified the unprecedented degree and pace of ongoing ecological damage, with startling details about species extinctions, population declines, land degradation, overexploitation of resources, and overall degradation of ecological processes worldwide.[8] Despite its disquieting implications for humanity itself, the release of the IPBES report seemingly made no waves within the U.S. security community, where it remains essentially unknown. Further, despite the Director of National Intelligence citing threats from some aspects of climate and ecological disruption in the 2019 Worldwide Threat Assessment,[iv] their mention appears well towards the back of the document (in the last subsection of the last section of a chapter devoted to global threats).[9] Recognition of these issues is growing, but there is currently little indication that the scale of the threat is broadly understood or that mitigating policy actions are likely to follow without a change in course.

To better understand and articulate the connections between ecological disruption and security, this report offers an analytic starting point through the development of an ecological security matrix (see Page 97 and Appendix I). This effort employs an expert elicitation method to investigate the degree of crossover between different factors of ecological stress and potential security outcomes. The initial results establish a baseline as well as possible avenues of future research for ecological security analysis.

Members of the New York National Guard help build food packages as part of a Joint Task Force mission in Fonda, NY on June 19, 2020. Residents of Montgomery County and surrounding areas have been adversely impacted by the health and economic stresses caused by the COVID-19 outbreak. The National Guard / Flickr

iv The U.S. intelligence community did not release a 2020 Worldwide Threat Assessment.

III. ECOLOGICAL DISRUPTION IS UNDERWAY

Decades of evidence point to an expansive human footprint that has fundamentally transformed the planet's physical, chemical, and biological composition and processes and, because species extinctions are irreversible, the evolutionary trajectory of the biosphere. Humanity has developed into such a dominant force that many scientists argue the Earth has entered a new geologic epoch called the Anthropocene.[10] [11] [12] The discussion is more than academic. Indeed, the finiteness of the Earth, and the complexity of its processes, point to dynamic, interconnected, nonlinear, large-scale thresholds and tipping points with ominous significance for human prosperity and wellbeing.

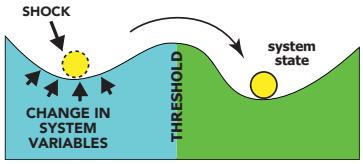
Scientists have developed theories to better characterize a safe operating space for global human activities that don't endanger our development, wellbeing, and safety. For example, the Planetary Boundaries Framework endeavors to quantify dangerous thresholds of nine planetary domains: climate change, biosphere integrity, land-system change, freshwater use, biogeochemical flows, ocean acidification, atmospheric aerosol loading, stratospheric ozone depletion, and introduction of novel entities (such as new substances or life forms).[13] A subsequent 2015 article singled out climate change and biosphere integrity as the two core boundaries[v] that, if transgressed, have the potential to independently drive the Earth into a new state.[14] Concerningly, the authors argue that—along with excessive nitrogen and phosphorus biogeochemical flows—the threshold for biosphere destabilization has already been surpassed.[15] The very notion that a safe operating space for biodiversity even exists has been a recent topic of scientific debate, however.[16]

MANY ECOSYSTEMS ARE SHIFTING TO NEW BASELINE STATES

Policymakers at the international level are finding utility in the Planetary Boundaries Framework.[17] Still, its global focus is generally too expansive to be useful in discussions on the impacts of ecological change on national and human security. Further, compounding stresses will almost certainly undermine stability and human wellbeing well before the global thresholds are reached. Arguably more relevant for thinking about effects on people and societies is the concept of the *ecological regime shift*, which is a large, sudden, long-lived, and largely irreversible change in a natural or manmade ecosystem (see Figure 1). A system in one regime will overcome a critical threshold and enter a new regime through either a shock or change in underlying system variables. Such shifts have been recorded in oceans, freshwater, forests, woodlands, drylands, rangelands, and agroecosystems and can cause tremendous disruption to societies and economies.

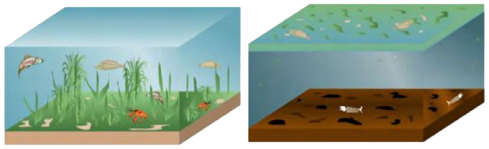
v The security implications of climate change have been well studied and articulated, but less so for biosphere integrity. Hence, an added impetus for this report.

Figure 1. Many Systems Undergo Ecological Regime Shifts



Regime shifts occur when a shock or change in system variables, or some combination of both, induce a system to cross a critical threshold into a new regime.

Example: Freshwater Eutrophication



Low nitrogen, phosphorus
Clear water
Sparse phytoplankton
Fish thrive

High nitrogen, phosphorus
Murky water
Phytoplankton canopy
Fish suffocate

OBSERVED TYPES

	REGIME 1	REGIME 2	
Freshwater Eutrophication	Clear water	Murky water	AQUATIC
Submerged to Floating Plants	Submerged plant dominance	Floating plant dominance	
Coastal Marine Eutrophication	Low nutrients	High nutrients	
Hypoxia	Normoxia	Hypoxia, anoxia	
Fisheries Collapse	High abundance of commerical fish	Low abundance	
Marine Food Webs	Predator dominated	Lower trophic group dominated	
Bivalves Collapse	High abundance of bivalves	Low abundance	
Coral Transitions	Coral-dominated reefs	Macroalgae, sponges, urchins	
Kelp Transitions	Canopy-forming algae	Turf-forming algae, urchins	
Seagrass Transitions	Seagrass	Algae, Sediments	
Soil Salinization	Low-salinity soils	High-salinity soils	TERRESTRIAL
Savannization	Forest	Savanna	
Bush Encroachment	Grass-dominant savanna	Shrub- or tree-dominant	
Coniferous to Deciduous Forest	Coniferous forest	Deciduous forest	
Tundra to Boreal Forest	Tundra	Boreal forest	
Steppe to Tundra	Steppe grassland	Tundra	
Thermokarst Lake	Thermokarst lake	Terrestrial ecosystem	LAND-WATER
River Channel Position	Old channel course	New channel course	
Peatland Transition	Low productivity, high carbon	High productivity, low carbon	
Salt Marsh to Tidal Flat	Salt marsh	Tidal or subtidal flat	
Mangrove Transitions	Mangrove forest	Ponds, marshes, coasts	
Indian Summer Monsoon	Strong monsoon	Weak monsoon	CLIMATE
Thermohaline Circulation	Strong thermohaline	Weak or collapse of circulation	
West Antarctic Ice Sheet	Permanent ice sheet	No permanent ice sheet	
Greenland Ice Sheet	Permanent ice sheet	No permanent ice sheet	
Arctic Sea-Ice Loss	Permanent ice sheet	No permanent ice sheet	

Source: Regime Shifts Database, Stockholm Resilience Centre

It is possible for an ecological regime shift to bring net benefits to people, such as increased productivity in a terrestrial or marine system. An unwelcome example is the widespread collapse of kelp canopies to sea-urchin dominated barren grounds.[18] Kelp are large, brown macroalgae that form underwater towers in shallow, temperate waters and occupy roughly 25 percent of the world's coastlines. Kelp forests play a crucial ecological role by providing food and ecological infrastructure for thousands of fish, invertebrate, and marine mammal species.[19 20] Ecological and climatic drivers can tip a kelp forest into one dominated by sea urchins that feast on algae. For example, in 2014, a combination of warm ocean waters and a persistent illness in one of its key predators, the sea star, led to a population explosion of sea urchins off the United States' west coast. The subsequent collapse of commercially important fisheries cost millions of dollars, with similar damage experienced in Australia and Japan.[21]

Another critical ecological regime shift is the transformation of a densely-wooded forest region into a savanna, characterized by grassland and few trees. Fires, deforestation, and forest degradation from extreme climate conditions are important drivers of this savannization process, while invasive grasses that accompany agricultural expansion are potential catalysts.[22] Recent upticks in Brazilian deforestation have many experts worried about the Amazon crossing the forest-savanna tipping point, with dangerous consequences for people and security at local, regional, and global scales (also see Forests, Page 56).[23] [24] [25]

The ecological regime shift concept is not uncommon to academics but is essentially absent from policy and security discussions. Efforts to understand the ecological components of national and human security would benefit from robust analyses of the magnitude of these shifts' socioeconomic and human costs and how to anticipate where and when they may transpire. Many international conservation programs either directly or indirectly impede a number of perilous regime shifts, supporting the notion that financing these efforts is a cost-effective safeguard against dangerous ecological outcomes.

A BIOSPHERE TRANSFORMED

Humanity's alteration of the Earth's climate, driven primarily by discharge of greenhouse gases into the troposphere, has received attention from the media, policymakers, and publics worldwide that is well-deserved and long-overdue (given that physical chemist Svante Arrhenius first identified the problem in 1896[vi]). More direct transformation of the biosphere has been no less dramatic or consequential. Human activities greatly influence how many and what types of organisms exist, where they live, what they live on, and the nature of interactions between other organisms and their habitats.

EXTINCTIONS OF SPECIES AND POPULATIONS ARE RAPID AND ACCELERATING

Most indicators that measure the state of the biosphere point to a destabilizing global ecological network that both supports and includes humans. The rapid loss of biological diversity, or biodiversity, spans all scales of the biosphere, from ecosystems and populations to species and genes.[26] The rate of disappearance has intensified over the last few decades, under conditions that some scientists call an ongoing "biological annihilation."[27] [28] The drivers of extinction and other forms of biodiversity loss include habitat change, overexploitation, direct exploitation of organisms, toxification, invasive species, and climate change.

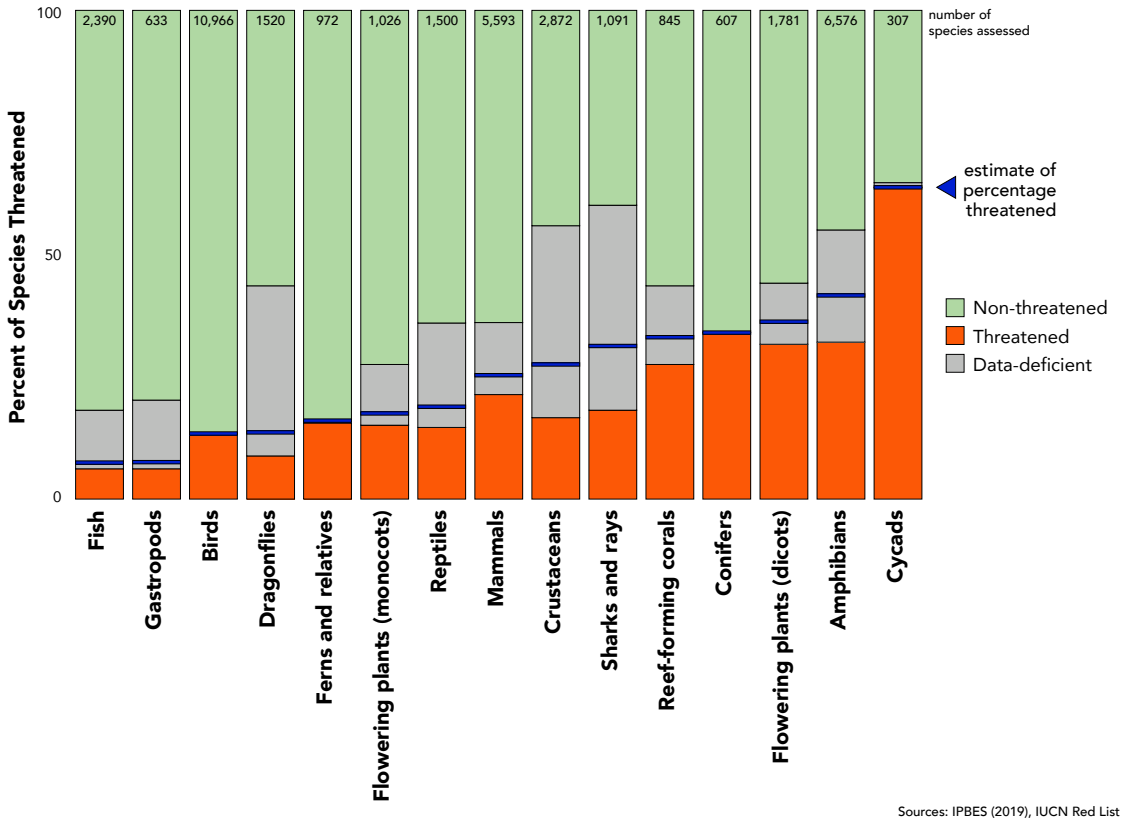
The most direct quantification of global extinction rates and extinction risk is derived from ongoing species assessments by the International Union for the Conservation of Nature (IUCN). As of 2020, the IUCN has assessed the status of 120,372 species of animals, plants, and fungi, representing a small fraction of the estimated total number of species (2,140,958). Global inventories differ greatly for major groups of organisms, with much greater knowledge of mammals, birds, amphibians, reptiles, and flowering plant species than for fungi and other plants.[29] (See Figure 2). Invertebrate animals, such as insects, arachnids,

vi Arrhenius's work built on other 19th century scientists like Joseph Fourier, Claude Pouillet, Eunice Newton Foote, Samuel Langley, and Arvid Högbom. By the 1960s, the phenomenon of global warming had become established, appearing in the 1965 landmark report "Restoring the Quality of Our Environment" by Lyndon B. Johnson's Science Advisory Committee and a 1968 study commissioned by the American Petroleum Institute.

mollusks, and crustaceans, are underrepresented in such databases compared to more charismatic terrestrial vertebrates.[30] Some scientists have made urgent pleas for a more vigorous and systematic assessment of invertebrates, which account for 75 percent of all species and countless ecological processes.[31]

Detailed analysis suggests that the current rate of species extinctions is currently as much as 1,000 times that of the background (natural) extinction rate,[vii] and accelerating.[32 33 34] Put another way, the time it would take for species to naturally go extinct over 10,000 years has been compressed by human influence to about 100 years. This rate would be on the order of those experienced during Earth's five mass extinctions, although there is some debate about the comparison.[35 36] Irrespective of its conclusion, the very discussion about whether or not our current ecological predicament represents the onset of a sixth mass extinction should be a matter of great concern, because the prior five radically transformed the biosphere, including the elimination of most dominant species (See Appendix II).[37 38 39]

Figure 2. Animal and Plant Species in Decline



Sources: IPBES (2019), IUCN Red List

Extinction risk for a sample of animal and plant species, taken from the IUCN Red List. The threatened category refers to critically endangered, endangered, and vulnerable species, while non-threatened refers to species that are near-threatened or those of least concern.

When looking beyond species-level estimates, and setting aside science's reticence to declare any species extinct, other indicators of biodiversity loss point to even more serious declines.[40] Extirpations (geographically-localized extinctions) of populations and declines of population abundance are also rapidly occurring, and

vii Although species extinctions occur naturally, the rate is comparatively slow. Current estimates of the mammalian extinction rate are around 2 extinctions per 10,000 species per 100 years, or 2 extinctions per million species-years (2 E/MSY).

their ecological impacts are likely to obstruct a number of ecological processes well before species extinction occurs (or is declared).[41] In a 2020 scientific article, researchers found 515 of 29,400 terrestrial vertebrate species fewer than 1,000 individuals, indicating that these species are likely to become extinct soon.[42] Ongoing anthropogenic pressures, geographic clustering of vulnerable species, and deep interactions with other organisms raise the risk of extinction cascades with consequent adverse effects for people.

SPECIES POPULATION CRASHES AND EXPLOSIONS

Rapid changes in the population of a particular species have long been part of Earth's ecological and evolutionary dynamics. Changing environmental conditions, pathogens, food source availability, and changes in competitors or predators can lead to boom or bust cycles. The deep connectedness of ecological trophic (food) networks raises the possibility that some extreme population shifts might have damaging and cascading effects for people.

Scientists have detected a recent shift in the occurrence, cause, and magnitude of animal mass mortality events, the rapid, catastrophic die-offs of populations of a single species.[43] A few recent examples are the mass deaths of koalas and other animals in Australia[44], saiga antelopes in Kazakhstan[45], menhaden fish in North Carolina[46], elephants in Botswana[47], sea stars in California[48], oysters in Japan[49], cuttlefish in Chile[50], and a wide variety of sea life in Far East Russia[51]. The magnitudes of mass mortality events are likely increasing, as measured by the number of animals killed per event, with the strongest pattern seen for fish, birds, and marine invertebrates such as lobsters and clams.[52] Most causes of mass animal die-offs have been infectious diseases, human perturbation, biotoxicity, and climate stresses.[53]

A wide range critically important reef-building coral species are experiencing mass die-offs across the world. Massive bleaching events of coral reefs have dangerous implications for global food security.[54] NOAA has recognized coral reefs as the "rainforest of the sea," with nearly a quarter of all fish relying on the reefs for shelter, food, and breeding grounds. The long-term sustainability of reef fisheries is at risk as coral reefs diminish, fish populations decline, and reef fish communities experience biotic homogenization. A report from the UN estimates that the net economic value of healthy coral reefs in Mesoamerica and South Asia combined is approximately $71.3 billion per year.[55] Damage to coral arises primarily from destructive fishing practices, pollution, plastics, and warming and acidifying oceans.[56 57 58]

Coral reefs also provide natural coastal protection. Damages from floods would double, and from storms would triple, without coral reefs, according to one study.[59] In the United States and its territories, coral reefs protect more than 18,000 coastal citizens and $1.8 billion worth of coastal infrastructure, according to the U.S. Geological Survey.[60] Coral reefs protect coastlines from storms and erosion acting as breakwaters reducing the energy of waves by as much as 97 percent.[61] The global reduction of coral cover has caused parallel declines in fish biodiversity and a loss of shoreline protection from waves and storms.

A few recent scientific studies showing sharp declines in local insect abundance, particularly in parts of Europe and North America, triggered a number of headlines about the "insect apocalypse" and incipient "ecological Armageddon."[62 63 64] Indeed, substantial insect declines would damage some critical ecological functions important to people, such as pollination and decomposition (although insects also destroy crops and spread disease). Large losses of insects would trigger unpredictable, and almost certainly unwelcome, ecological shock waves through numerous food webs. A 2020 scientific meta-analysis found that terrestrial insect abundance had declined about nine percent per decade globally, with considerable regional variability,

Dead staghorn coral killed by bleaching on the northern Great Barrier Reef, November 2016.
Greg Torda /ARC Centre of Excellence for Coral Reef Studies / Flickr

and an 11 percent increase in freshwater insect abundance.[65] (The authors speculate that the upward trend in freshwater ecosystems may result from improvements in water quality and increased nutrient runoff from agriculture.) A recent scientific article appealed for "urgent actions to close key knowledge gaps and curb insect extinctions," warning that more work is needed to "conserve insect diversity for our own survival."[66]

While abrupt declines can have dire consequences, population explosions of organisms can also wreak havoc. Since 2014, colossal blooms of sargassum seaweed, fueled by fertilizer runoff and warming sea temperatures, have battered the tourism and fisheries sectors of Mexico and several Central America, and Caribbean countries.[67] Jellyfish blooms are known to cause severe disruptions to fishing, tourism, infrastructure, power, and shipping, although the causes of their population explosions are still under debate.[68 69] Swarms of several billion desert locusts have recently plagued the Middle East, North Africa, South Asia, and South America (see Food, Page 45).[70]

Rapid growth of harmful algae, such as dinoflagellates (red tide) and cyanobacteria (blue-green algae), can cause detrimental and sometimes severe economic, political, and social consequences. Some harmful algae excrete some of the most potent neurotoxins ever discovered, which can kill or impair most animals, through direct consumption or bioaccumulation.[71] Acute masses of harmful algae can severely deplete dissolved oxygen levels, leaving aquatic dead zones in their wake and, as a leading cause of biotoxicity, pose a compounded threat to fisheries and populations that depend on them. Economic and social disruptions from harmful algae have been reported worldwide. In 2014, Toledo, Ohio's water system that supplied 400,000 citizens was shut down for three days from red tide, and harmful algae killed 25 million fish in Chile in 2016, which pushed up salmon prices globally and fueled local unrest.[72 73 74] Harmful algal blooms have increased in range and frequency in coastal areas since the 1980s, probably fueled by marine heatwaves, eutrophication (nutrient oversaturation), and pollution.[75]

LIFE IS REDISTRIBUTING

The biosphere is undergoing a substantial geographic redistribution of organisms on Earth. As a result of climate change, many species are finding their habitats increasingly unsuitable, prompting a sizable fraction to move.[viii] Human activities, often unintentionally, promote the introduction of species into non-native environments with few natural competitors, with great economic and ecological ramifications.

SPECIES ON THE MOVE, AND MIXING

Climate change is affecting terrestrial, marine, and freshwater organisms worldwide as well as their ecological processes. Warming temperatures can influence a population's phenology (the timing or seasonality of ecological events), such as flowering, insect emergence, and animal migration, which can desynchronize important interactions with other organisms.[76] Individual organisms often exhibit climate-driven alterations in morphology (body size and shape) and physiology. There is growing evidence that evolutionary adaptation to climate change is occurring, which could propagate species-wide.[77] [78] [79] A 2016 scientific article assessed that 82 percent of all ecological processes have now been impacted, either positively or negatively, by climate change.[80]

Shifts in the geographic distribution of species are expected to keep pace with shifting climates, with a general tendency towards higher latitudes and elevations. Scientists have developed the climate velocity[ix] index (see Figure 3) that represents, on each particular point on a map, the speed and direction necessary to maintain constant conditions (usually temperature, for simplicity).[81] [82]

Range shifts are likely to have substantial ramifications for systems important to people. Species of marine fish and invertebrates are expected to move poleward and to deeper waters, with associated geopolitical implications (see Fisheries, page 63), and some scientific reports have observed this shift.[83] [84] Elevated temperatures are likely to exceed stress thresholds for many crops, especially at night, which is likely to push agriculture in the Northern Hemisphere northward; agricultural pests are sure to follow, perhaps at faster speeds. Global health security will almost certainly be undermined by the range shifts of organisms—and the pathogens they carry.[85] In addition to infectious disease vectors and pathogens pushing into more zones that are climatically suitable, differential climate velocities will enhance new forms of biotic mixing, leading to new opportunities for zoonotic pathogen spillover.[86] [87] Some scientists argue that pathogens are already evolutionarily predisposed to take advantage of new hosts shifted geographically by climate change.[88] [89]

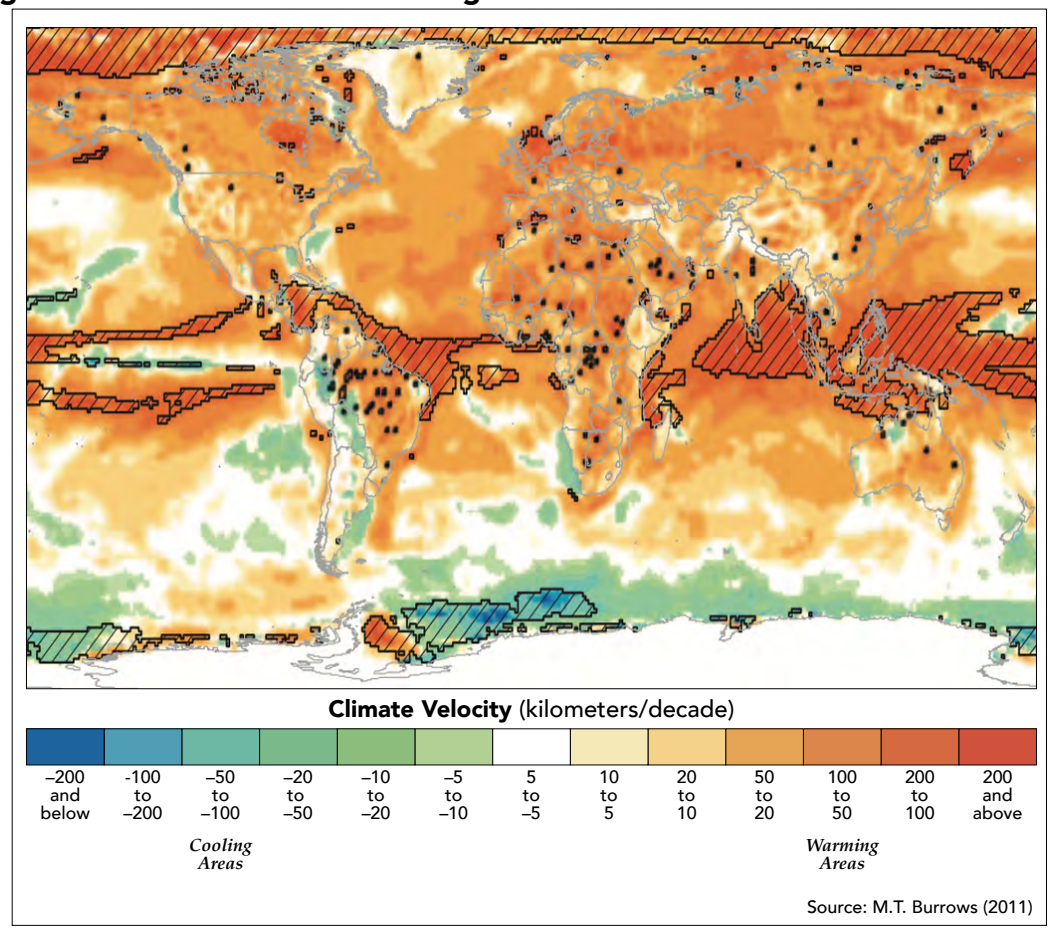
INVASIVE ALIEN SPECIES THREATEN ECONOMIC PROSPERITY AND SOCIAL WELFARE

Thousands of species have been introduced and established in new geographies in which they are non-native, and such alien invasive species are a growing economic and social threat.[90] Although geographic drift of species has long occurred naturally, comparatively recent human-facilitated introductions of species into new ecosystems have greatly intensified the rate, scale, and geographic range of such biological invasions.[91]

viii Options for species undergoing climate pressure typically fall in the range of move, adapt by evolution, adapt by plasticity, or hunker down.

ix The term *climate velocity* often causes confusion because it refers to how fast an entity must move to experience constant conditions and not how fast the climate is changing.

Figure 3. Terrestrial and Marine Organisms Under Differential Thermal Pressures



Climate velocity (km/decade) is the velocity at which subregions would need to move to experience constant temperature; positive values are for warming areas and negative are for cooling areas. Climate velocities are generally greater where the temperature gradient is small. Cross-hatched regions exhibit small differences in seasonal temperatures but where future seasonal shifts may be large.

According to the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), nearly one-fifth of the Earth's surface is at risk of plant and animal invasions. Some key allies, such as Australia and New Zealand, view combating and preventing invasive species as priorities important to their respective national security.

Invasive species are a problem on every continent and, according to a recent scientific report, the rate of newly emerging invasive species is higher than ever.[92] There have been approximately 30 times more recorded invasions cumulatively in high income countries than low income countries as a result of connected trade networks, human mobility, and globalization, although detection capabilities is also a factor.[93] Island nations and coastal regions are particularly vulnerable, and the wealthier nations of North America, Europe, and Oceania are also considered invasive species hotspots.[94]

The economic impacts of invasive species are difficult to narrow down and precise calculations are complicated by the wide range of sectors affected, such as public health. Some introduced species even have economic benefits, like many of the major food crops. Estimates of global net economic losses, in terms of damage and management costs, arising from biological invasions is about $1.4 trillion annually, or roughly 5 percent of the aggregate sum of global national products.[95] [96] The United States alone is estimated to incur

annual economic losses of $120 billion, with the agriculture sector being particularly affected.[97] Developing countries with high risks of agricultural pest importations and whose GDP is disproportionately dependent on crop production, such as several Sub-Saharan Africa nations, are particularly prone to destabilizing economic damages incurred by invasive species.

Invasive species are an immense threat to the food security of many nations. Probably arriving in 2016 as eggs in imported produce from the Americas, fall armyworms have decimated corn crops in many countries in southern Africa, notably South Africa, Zambia, and Zimbabwe.[98] The khapra beetle's appetite for wheat and its ability to survive extreme conditions typical of international transit, makes the insect a major threat to wheat producing countries the United States, Canada, Russia, and Australia.[99] Asian carp, once native to Russia and China, have displaced and preyed on other fish in freshwater systems of North America and Europe. The risk to agriculture is heightened by the fact that only nine species of plants account for 66 percent of the world's crop production.[100]

Invasive species also pose substantial threats to human health. Invasive mosquitos are some of the most well-known transmitters of vector-borne disease. Mosquitos have encroached into almost every part of the world, spreading infectious diseases from invasive pathogens, such as West Nile virus in North America. In aquatic environments, invasive marine species ingested raw or undercooked can infect humans with transmitted pathogens or flatworms, such as the Chinese mitten crab which can transmit the lung fluke.[101] Poisonous, stinging, or allergenic invasive species, most notably invasive plants, can impact human health if touched or ingested by inducing harmful psychological effects, discomfort, skin irritations, or death. Invasive species that reduce biodiversity can limit the availability of medicinal plants used in natural remedies.[102] Global health researchers predict that invasive species will increasingly threaten human livelihoods if not controlled.

The synergistic effects of climate change and invasive species, both already significant stressors to ecological stability, are likely to bring new types of risk. For example, new shipping routes may bring unwanted species to previously inaccessible regions, while changing climate conditions may favor their establishment in the arrival destination.[103] While some of these trends are at least partially predictable after more than twenty years of study, there are almost certainly surprising and unwelcome socioeconomic impacts ahead.

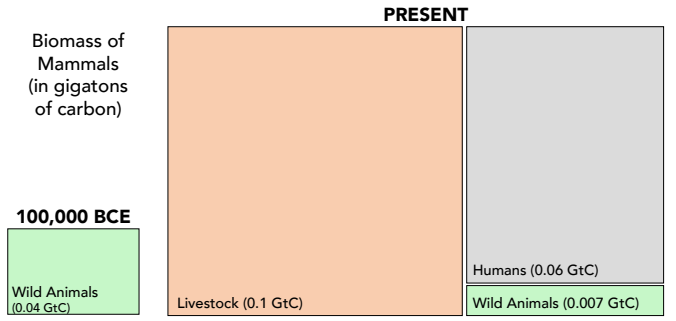
HABITATS ARE CHANGING

Land-use change has occurred throughout human history, but its expansiveness is increasingly affecting many Earth systems, including the biosphere. By some estimates, over half of Earth's land surface has been transformed by human activities, including croplands, pasture and rangelands, and urban areas.[104] Patterns of land degradation, desertification, and habitat fragmentation pose serious risks for food security and ecological stability.

Global demand for agricultural products is a major driver of habitat conversion, and is expected to increase by 50 percent by 2050. From 1980 to 2000, over 55 percent of the more than 100 million hectares converted in the tropics came from intact forests.[105] The greatest conversion of forests in Latin America was for cattle pastures, with an increase of 35 million and 7 million hectares in South and Central America, respectively.[106] In Southeast Asia, most agricultural land is devoted to tree plantations, with oil palm responsible for over 80 percent of the expansion by the 1990s.[107] [108] During the past 40 years, there has been a 70 percent increase in irrigated croplands and a 700 percent increase in global fertilizer use.[109]

Beyond possessing an enormous land-use footprint, the industrial domestication of animals for human purposes has also radically altered the biosphere. A 2018 scientific article estimated that domesticated livestock comprise 60 percent of mammalian biomass, humans comprise 36 percent, and wild mammals just 4 percent (see Figure 4).[110] This occurred as 83 percent of wild mammal biomass disappeared from the Earth. Meanwhile, 70 percent of global avian biomass today is represented by domestic poultry stocks.[111]

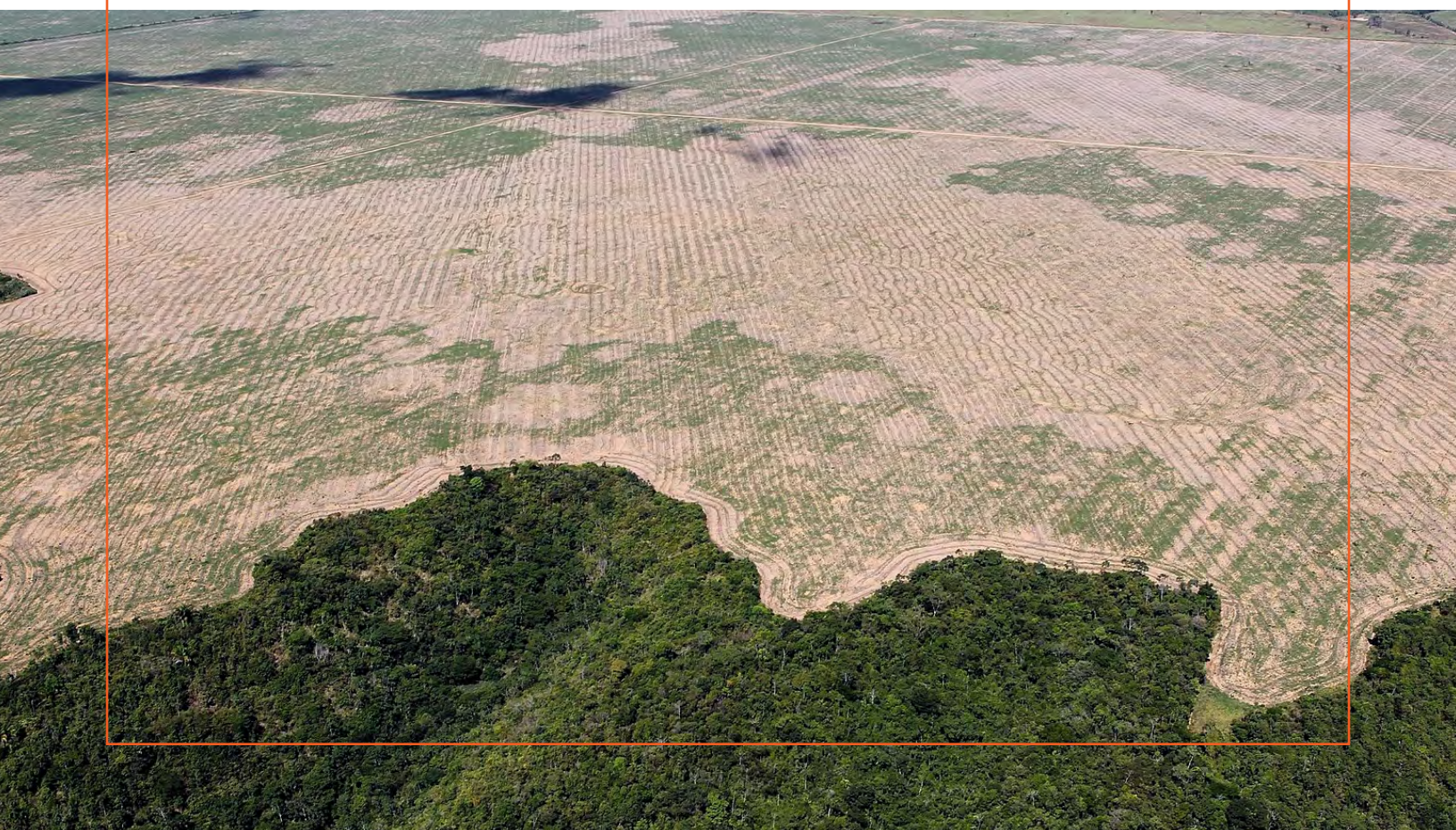
Figure 4. Livestock are the Predominant Mammals on Earth



Source: Y.M. Bar-On, The Biomass Distribution on Earth (2018)

Urbanization also drives habitat conversion. The largest percent increase in land use change over the past 40 years has been associated with urban areas, and city areas doubled from 1992 to 2015.[112] Since 1950, the world's urban population has grown almost sixfold, from 751 million to 4.2 billion in 2018.[113] Urban consumption patterns typically require productive land areas many times greater than the city's political area.

Deforestation in Gurupi Biological Reserve and the Caru and Alto Turiaçu Indigenous Lands, in Maranhão. July 2016.
Felipe Werneck / Ascom / Ibama.



Land degradation, the loss or reduction of productivity of land, is a serious global stressor affecting croplands, rangelands, forests, woodlands, and wetlands. About 25 percent of the Earth's land has been degraded, by some estimates. Soil health is maintained by a wide range of soil organisms under pressure from pollutants, intensive activity, and climate change. Soil erosion, often undetected on an annual basis, can lead to a complete collapse in agricultural function over decades.[114] An estimated 24 billion tons of soil are degraded each year, far outpacing rates of soil formation.[115] Long-term exposure to atmospheric pollutants and overuse of fertilizers has led to damaging soil acidification in North America, Central and Northern Europe, and Southern China.[116]

Habitat conversion often leads to fragmentation, the division of habitat into smaller, more isolated areas separated by transformed land. For example, roads have divided the Earth into over 600,000 fragments, with more than half occupying an area less than a square kilometer.[117] Fragmentation alters animal migration patterns, increases the edge effect where species live closer to modified environments, and in some instances, can lead to complete habitat isolation.[118] Scientists have observed that fragmentation negatively impacts biodiversity, reproduction rates, old-growth forests, and ecosystem dynamics.[119] As human populations expand and encroach habitats, fragmentation will persist, further exacerbating extinctions, risk of novel disease spread, and damage to ecosystem services.

Ocean habitats are increasingly hostile to many forms of life. As oceans absorb carbon dioxide from the atmosphere, they have become more acidic, at a pace roughly 50 times faster than historical rates.[120] Many parts of the ocean are rapidly losing dissolved oxygen content, which has serious implications for marine life. Marine plastic pollution has grown at least tenfold since 1980, and plastics have been found at every scale, from patches observable by satellites to nanoplastics lodged inside microbial cells.[121] [122] Current estimates project about 12,000 megatons of plastic accumulating in the environment by 2050, most of it winding up in the ocean and its marine foodwebs.[123] Longer and more frequent marine heatwaves incurred from climate change have severe negative impacts on many marine organisms and ecosystems, including commercially important fisheries.[124] [125]

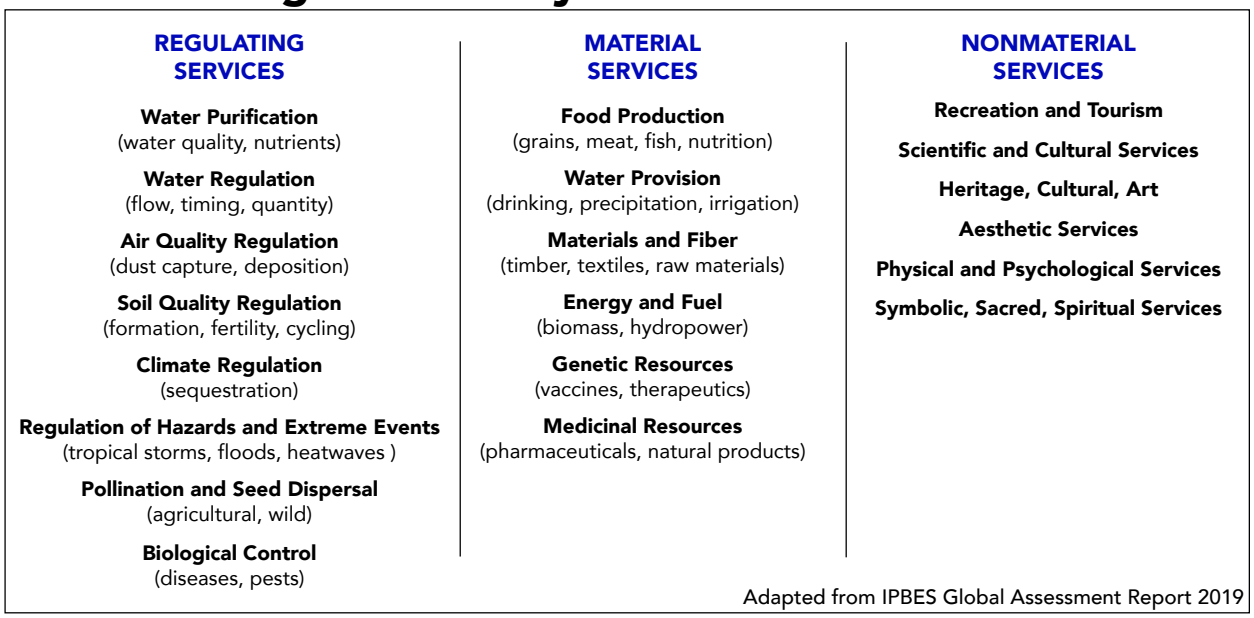
ECOSYSTEM SERVICES ARE DEGRADING

If an ecosystem could be likened to a large piece of machinery--such as an airplane as Erlich and Erlich once offered--the loss of a species or population might amount to a small bolt that appears to be of no major consequence to day-to-day operations. Over time and across all ecosystems globally, the accumulated impact of those missing parts adds up, ultimately leading to a structural failure of operations.[126]

In 2012, a landmark paper published on the 20th anniversary of the 1992 Earth Summit summarized the known impacts that biodiversity loss poses for ecological processes important for humanity.[127] An important finding of the report was the unequivocal evidence that reductions in the number of species, populations, and genes reduce the efficacy of a number of key ecological processes.[128] Further, the article establishes that the impact of biodiversity loss on an ecosystem is nonlinear, and the disruption accelerates as biodiversity loss increases. Perhaps most worrisome is the paper's suggestion that the impacts from biodiversity loss on ecological processes is sufficiently large to rival those of other global change stressors, such as climate change.[129]

The ongoing feedback loop between biodiversity loss and habitat degradation threatens *ecosystem services*, the suite of benefits that natural systems provide to humanity. The framework's partitioning of services into different categories also provides a convenient conceptual springboard to assess potential societal and security outcomes. The set of ecosystem services are often partitioned into those that perform *regulating* functions (such as water regulation), *material* services (such as irrigation water), and *nonmaterial* services (such as water for recreation) (see Figure 5).

Figure 5. Ecosystem Services at Risk



Ecosystem services are the suite of benefits that natural systems provide to humanity. Ecological economists use the concept to estimate monetary equivalents to ecological damage, such as loss of coastal protection from coral reefs. Security analysts would greatly benefit from integrating the concept into their research.

Gauging the risk arising from damage to ecosystem services by human activities is nontrivial and complicated by the existence of underlying thresholds, tipping points, and inertia. Collapse and regime shifts (see Page 16), for example, are pervasive in ecological systems, with the abrupt crash of the Atlantic cod population in 1992 as perhaps the textbook example of a catastrophic event arising from linear stresses.[130] [131]

While there has been limited research in establishing early warning indicators of collapse, there are presently no reliable methods to predict such outcomes in most ecosystems.[132] Unfortunately, societies have generally failed to prioritize addressing obvious and perilous declines in ecosystem services, which portends a troubling pattern of crossing thresholds before their significance is appreciated. Large-scale losses of ecosystem services, especially to regulating and material services, are probably beyond economic valuation and could potentially lead to catastrophic circumstances for human life.

The sections below discuss just two of the myriad ecosystem services. Further analysis assessing the societal stresses incurred from potential degradation of the larger set of ecosystem services is badly needed.

That said, one conclusion can be drawn without further analysis: Relying narrowly on purely monetary valuations of the benefits of ecosystem services as the prime metric and driver of action, both governmental and private, is itself a negative factor that undercuts many dimensions of human, national, and global security.

REDUCED PROTECTION FROM NATURAL DISASTERS

Natural disasters can produce acute shocks to weak or fragile institutions and challenge human security and regional stability. Their impacts can aggravate food and water stress, themselves recognized drivers of conflict, political instability, loss of social cohesion, and economic disruption. Governments at all scales that have not implemented adequate measures towards resilience enhancement, vulnerability reduction, and early warning systems may face increasingly dire conditions from compound or sequential disasters.

Many nations, including the United States, have military installations currently or potentially vulnerable to natural disasters. A 2019 Department of Defense report indicated that 25 Air Force bases, 17 Army bases, and 16 Naval bases were at risk from coastal or river flooding over the next twenty years.[133] The same report listed 48 military installations at risk from drought, 43 at risk from wildfires, and 6 at risk from desertification.[134] Embassies and other State Department facilities abroad presumably have vulnerabilities to the same types of natural disasters, but relevant quantitative estimates are not available.

Extreme weather events have increased by an average 44 percent between 2001 to 2015, compared to the 1994-2000 average.[135] Wetlands, forests, and coastal ecosystems provide natural protections, but damage from droughts, tropical storms, earthquakes, and other natural disasters are amplified when these ecosystems are degraded. Deforestation, soil erosion, and water mismanagement can increase both hazard intensity and frequency. The links between deforestation and slope stability are especially noteworthy, as are the erosion rates from storm surges along unprotected coastlines.

Developing countries are disproportionately affected. In many, poor regulation and management policies can accelerate the loss of naturally protective ecosystems while the absence of a nationalized support system can leave fewer resources for recovery. This increases the likelihood and severity of the effects of disaster events, and makes those states more susceptible to civil unrest and radicalization by driving the diffusion of local power centers to non-state actors. Rapidly changing conditions in the response phase to natural disasters can enable or enhance corruption. Organized crime or terrorist organizations have an opportunity to leverage the critical needs of an under-supported community.

Floodwaters causing extensive damage to the manufacturing industry, in Ayutthaya Province, Thailand, 2011.
US Marine Corps photo by Cpl. Robert J. Maurer.Service / Flickr

Local industries have incurred damages from natural disasters, some with global repercussions. Some events, such as tsunamis and major flooding, have impaired global supply chains with knock-on effects for U.S. companies. For example, the 2011 earthquake and tsunami that struck major car suppliers in Japan caused a massive disruption to automaker supply chains and forced an overhaul of the industry.[136] In 2012, Hurricane Isaac shut down 93 percent of oil production in the Gulf of Mexico. This storm not only drove up the cost of oil futures, but dredged up and washed residual oil from the 2010 Deepwater Horizon disaster onto Louisiana coastlines.[137]

Population-dense coastal regions face major risks from the sea. Rapidly growing urban areas are vulnerable to storms, storm surges, and flooding, increasing the risk for mass casualties or large-scale social disruption. In 2019, Karachi's mayor stated that in the ten years since the 2005 Pakistan earthquake, the country had incurred more than $18.5 billion in damages from subsequent natural disasters.[138] In Africa's most populous nation, more than a hundred Nigerians perished in 2018 when the country's two major rivers flooded, calling immediately for sweeping humanitarian action and $8.2 million in relief funds.[139] In early 2020, the nearly ten million residents of Jakarta faced the city's most severe flooding event since 2013, pushing Indonesia's leaders to plea for infrastructure projects that could curb future flooding.[140] In late 2020 Goni, one of the strongest typhoons of the decade, slammed into the Philippines, narrowly missing densely-populated Manila. Emergency evacuations were complicated by ongoing COVID-related capacity and infrastructure shortfalls.[141] On average, 26.5 million people have been displaced by natural disasters annually since 2008, driving refugee crises all over the world.[142]

The rising human, social, and economic costs from natural disasters has thus far failed to spur substantial investments in pre-disaster mitigation and preparedness, however. According to a 2013 NGO report, less than 13 percent of an estimated $107 billion dollars allocated to disasters over a twenty-year period was targeted towards pre-disaster risk reduction measures, with the remainder spent on disaster response, reconstruction, and rehabilitation.[143] In the U.S. alone, every $1 spent on mitigation funding could save the nation $6 in future disaster costs, according to a report by the National Institute of Building Sciences.[144] Meanwhile, global flooding disasters from 2000 to 2019 have more than doubled compared to the 1980 to 1999 period, and storm disasters have grown by 50 percent, according to a 2020 UN report.[145]

POLLINATION SERVICES ARE IN JEOPARDY

Animal pollination of flowers is a critically important regulating ecosystem service, providing the foundation for plant reproduction and fruits and seeds production. Insects, such as bees, butterflies, moths, flies, and beetles, are by far the most important animal pollinators of cultivated and wild plants, but some vertebrates, such as birds and bats, also contribute.[146] In particular, the roughly 20,000 species of bees frequent more than 90 percent of the leading 107 crop types worldwide.[147] Populations of many insect species are declining (see Page 18), although nailing down whether these are regional effects or a global phenomenon remains a matter of debate.[148] [149] Global implications for economic livelihoods and food security renders the question of decreasing populations of insects, particularly bees, an urgent one to address.

Nearly 75 percent of global food crops depend, at least in part, on insects and other pollinators, estimated to be worth $235 to $577 billion[x] per year.[150] [151] Economic benefits are distributed unevenly, however, with

x On the basis of 2009 market prices, adjusted to 2015 inflation levels.

southern and eastern Asia and Mediterranean Europe benefiting most. Many high-value cash crops, such as cocoa, coffee, and almonds, are highly dependent on insect pollination.[152] Livelihoods have become more reliant on pollinators as the production volume of pollinator-dependent agriculture has increased 300 percent over the past five decades.[153] Animal pollination is also increasingly important for biofuel crops. Growth in Europe, for example, was 32 percent between 2005 and 2010.[154] The demand for, and consumption of, animal pollinated crops is currently rising at a greater rate than managed honeybee colonies.[155]

DECLINES IN POLLINATORS POSE A SIGNIFICANT THREAT TO HUMAN HEALTH

Pollinator-dependent crops account for about 40 percent of the global nutrient supply for people.[156] A 2015 *Lancet* study estimated that pollinator collapse would cause new deficiencies for vitamin A and folate, essential to the human diet, in 71 million and 173 million people, respectively.[157] The same study estimated that a 50 percent decline in pollinators would lead to 700,000 annual deaths annually.

A dead bee hive at Bradshaw Honey Farms in California. BBC World Service / Flickr

Box 1. State Fragility and Projected Exposure to Select Ecosystem Service Declines

The connection between state fragility trends and declines in ecosystem services is an important analytical question, but little systematic research has been conducted on the matter. This is especially true for regulating ecosystem services, such as water purification, protection from coastal hazards, and pollination. Countries that already exhibit state fragility are presumably especially vulnerable to declines in natural capital, although this hypothesis would need to be tested explicitly to elucidate possible deeper linkages. Some countries appear on multiple lists which may indicate they may be at risk of disruption from compound stresses, irrespective of their state fragility rank.

Highest Exposure to Water Pollution (a)

	Country	State Fragility (d)
1	**Zimbabwe**	99.2
2	**Haiti**	97.7
3	**Eritrea**	95.8
4	Burma	94.0
5	**Kenya**	90.3
6	**Liberia**	90.0
7	**Angola**	87.3
8	Egypt	86.0
9	**Bangladesh**	85.7
10	Lebanon	84.7
11	Malawi	84.0
12	Eswatini	83.0
13	Equatorial Guinea	83.0
14	Timor-Leste	82.7
15	Papua New Guinea	82.3
16	**Sri Lanka**	81.8
17	Philippines	81.0
18	**Cambodia**	80.3
19	Solomon Islands	79.7
20	**Guatemala**	79.2
21	Turkey	79.1
22	Lesotho	78.3
23	**Nicaragua**	77.1
24	Laos	76.9
25	**Honduras**	76.8

Highest Exposure to Coastal Hazards (b)

	Country	State Fragility (d)
1	**Yemen**	112.4
2	Somalia	110.0
3	**South Sudan**	110.8
4	**Cameroon**	97.9
5	**Haiti**	97.7
6	**Nigeria**	97.3
7	Guinea	97.2
8	**Guinea Bissau**	92.9
9	**Republic of Congo**	92.1
10	Pakistan	92.1
11	**Kenya**	90.3
12	**Liberia**	90.0
13	**Angola**	87.3
14	**Bangladesh**	85.7
15	Sierra Leone	84.4
16	Iran	83.4
17	**Sri Lanka**	81.8
18	**Cambodia**	80.3
19	**Guatemala**	79.2
20	Tanzania	78.1
21	**Nicaragua**	77.1
22	**Honduras**	76.8
23	Colombia	76.6
24	India	75.3
25	Senegal	74.6

Highest Exposure to Pollination Declines (c)

	Country	State Fragility (d)
1	**Yemen**	112.4
2	**South Sudan**	110.8
3	Democratic Republic of Congo	109.4
4	Central African Republic	107.5
5	Chad	106.4
6	**Zimbabwe**	99.2
7	**Cameroon**	97.9
8	**Nigeria**	97.3
9	Mali	96.0
10	**Eritrea**	95.8
11	Niger	95.3
12	Libya	95.2
13	**Ethiopia**	94.6
14	**Guinea Bissau**	92.9
15	Uganda	92.8
16	**Republic of Congo**	92.1
17	Mozambique	91.7
18	Venezuela	91.2
19	**Kenya**	90.3
20	North Korea	90.2
21	**Liberia**	90.0
22	Cote d'Ivoire	89.7
23	Mauritania	88.7
24	**Angola**	87.3
25	Burkina Faso	85.9

Countries appearing in two lists
Countries appearing in three lists

Notes: Countries with over 90% of population (a) impacted by future nitrogen-export water pollution, (b) very impacted by future coastal hazards, or (c) impacted by future pollution-dependent crop declines, (SSP3). No other regulating ecosystem services were analyzed in the source document, but declines in others, such as soil quality regulation and biological control, are likely to be additional destabilizing factors. Data for projected exposures to declining ecosystem services were obtained from R. Chaplin-Kramer et al "Global modeling of nature's contributions to people," Supplementary Materials, Science (2019)

State Fragility score (d) was taken from The Fragile States Index 2020, The Fund for Peace.

PANDEMIC RISK GROWS AS NATURE DEGRADES

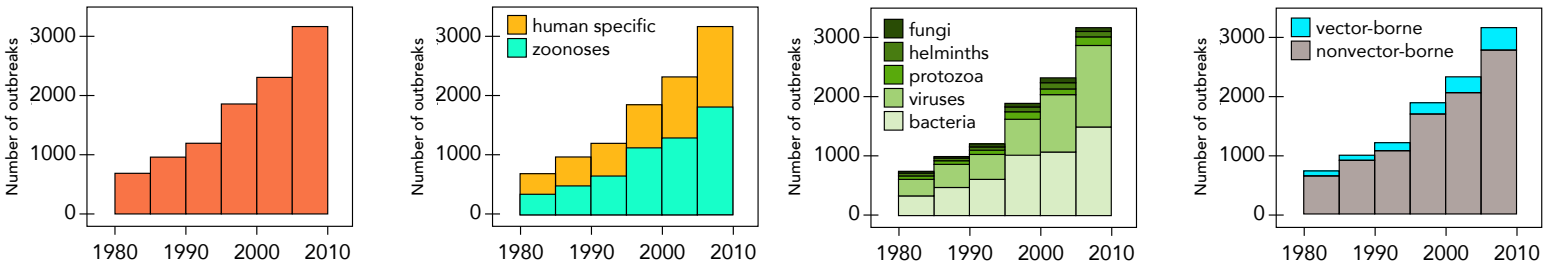
Pandemics pose a critical threat to the stability of nations, including the United States. Global infectious disease outbreaks, especially when unaddressed or poorly managed, can disrupt social order, undermine economic stability, depress trade, decimate public health capacity, intensify food insecurity, erode public confidence in government, and worsen social and political inequalities. The deadliest pandemics kill far more people than war, and recovery is long, costly, and often shambolic. Minimizing or eliminating pandemic risk before outbreaks occur is one of the most effective pathways to bolster human, national, and global security.

Pandemics[xi] and large-scale epidemics have occurred sporadically throughout human history, but are now becoming more common.[158] In the last two decades alone, the world has witnessed the emergence of Severe Acute Respiratory Syndrome (SARS) in 2003, H1N1 (swine flu) in 2009, Middle East Respiratory Syndrome (MERS) in 2012, Chikungunya in 2014, Zika in 2015, and COVID-19 in 2019.[159] [160] About 70 percent of emerging infectious diseases and nearly all pandemics are zoonotic, meaning they are caused by microbes hosted by animals that "spillover" into humans. Notably, three pandemics came from the emergence of novel coronaviruses in just seventeen years.

The last two decades have also seen significant outbreaks of previously identified pathogens, such as H5N1 (avian flu), dengue fever, cholera, bubonic plague, rift valley fever, Japanese encephalitis, Ebola, Nipah, and measles. At the same time, the world's global health capacity has strengthened, although improvements are geographically uneven and struggle to keep pace with the most acute outbreaks.[161]

Human activities are increasingly exposing populations worldwide to the tremendous microbial diversity found in natural systems. Most of the drivers of ecological disruption, such as habitat conversion, globalization, overexploitation, and climate change, also bring wildlife, livestock, and people into closer contact. Greater exposure to mammals and birds brings people in closer proximity to the estimated 1.7 million undiscovered viruses that these animals harbor; as many as 850,000 of these viruses could infect humans, according to IPBES.[162] Scientists believe the most important wildlife reservoirs with pandemic potential are mammals, especially bats, rodents, and primates, and waterfowl birds, such as ducks and geese.

Figure 6. Human Infectious Diseases are Increasing



Source: K.F.Smith, Global Rise in Human Infectious Disease Outbreaks (2014)

xi The general definition of 'pandemic' is an infectious disease epidemic that spreads across multiple continents. The World Health Organization is the international body with the authority to officially declare an outbreak to be a pandemic, but its criteria are opaque and somewhat political.

Livestock, especially pigs, poultry, and camels, are additional sources of zoonotic transmission to people. Densely packed assemblages of closely related animals are a well-documented cause of pathogen crossover into domesticated animal species, and the expansion of livestock production, in terms of acreage and animal populations, has increased the risk of transmission to people.[163] For example, the brain affliction variant Creutzfeld-Jakob disease ("mad cow disease") is believed to originate from beef production, while novel strains of avian influenza probably emanate from unusual groupings of poultry flocks and wild birds, particularly in Asia.[164] Although the coronavirus responsible for MERS probably originated in bats, it likely jumped into the human reservoir through domesticated dromedaries, camels now known to be infected with MERS-like coronaviruses throughout the Arabian Peninsula.[165]

The continued extinction of organisms is poised to rob future generations of undiscovered medicinal and pharmaceutical treatments. Humans evolved comparatively recently into a biosphere in which millions of years of natural selection had already shaped the countless offensive and defensive biological and chemical processes between animals, plants, fungi, and microbes. Currently, the majority of drugs used in humans and animals, particularly antibiotics, are derived or inspired by natural products.[166] New biochemical and computational technologies are already well-positioned to usher in a resurgence of natural product-derived medicines. Organisms that have been largely untapped include many plant species, lichens, insect-associated fungi and bacteria, and microbes found in the guts (microbiomes) of complex animals, according to a 2019 scientific report.[167]

Evidence is growing that ecological degradation fuels antimicrobial resistance, the ability of microorganisms to nullify the effects of drugs. The high use of antimicrobial medicines in livestock and aquaculture, coupled with inadequate water treatment, has led to increasing concentrations in terrestrial, marine, and freshwater environments worldwide.[168] Microbes exposed to these drugs can develop resistance through evolution or those already genetically predisposed to resistance may grow in numbers. Antimicrobial resistance in soils can be transmitted through plants and into the food chain, or through runoff into other ecosystems.[169] Hundreds of thousands of deaths worldwide per year are already attributable to antimicrobial resistance and scientists expect the number to climb dramatically[xii] without substantial biomedical breakthroughs.

Ongoing ecological disruption and its intensifying impacts on the human-wildlife-livestock-pathogen nexus puts an additional burden on national and global security. The world has entered an "era of pandemics, newly emerging infectious diseases, and the return of old contagious foes," as a June 2020 scientific article put it.[170] Continued increases in the factors that drive emerging infectious diseases raises the specter of future compound pandemics. Meanwhile, antimicrobial resistance threatens to remove some of the tools that have helped nations prosper over the last century, while increasingly aggressive disinformation programs help derail effective responses.

These critical risks argue for deeper engagement of the security community with and reliance on experts from scientific fields that too many security professionals and policymakers rarely encounter, such as animal science, epidemiology, disease ecology, forestry, and soil science.

xii Some articles cite 10 million possible deaths by 2050 but sourcing that figure has proven difficult.

ENVIRONMENTAL CRIME AMPLIFIES ECOLOGICAL STRESS AND SOCIAL INSTABILITY

Environmental crime,[xiii] once dismissed as a set of victimless transgressions against nature, carries significant repercussions for people and societies worldwide. The illicit procurement and trade of ivory, rhino horn, pangolins, rosewood, and ill-gotten fish products have helped criminal networks generate profits and establish steady financial flows, with some benefits accruing to bad actors. For some nations, the role of corruption in all aspects of environmental crime is an acute threat to stability and the rule of law.

The economic damage from environmental crime is immense. In 2019, a World Bank report estimated that the net economic value from illegal logging, illegal fishing, and illegal wildlife is in the range of $48 billion to $216 billion per year.[171] These revenues are diverted from national treasuries into informal economies and criminal organizations, thereby depriving source countries of the benefits of their natural wealth. Beyond causing ecological and economic damage, illegal trade in these natural resources pose multifaceted risks to natural, financial, social, and political capital, according to the same report (see Figure 7).[172]

Figure 7. Capital Risk from Illegal Trade in Wildlife, Timber, and Fisheries

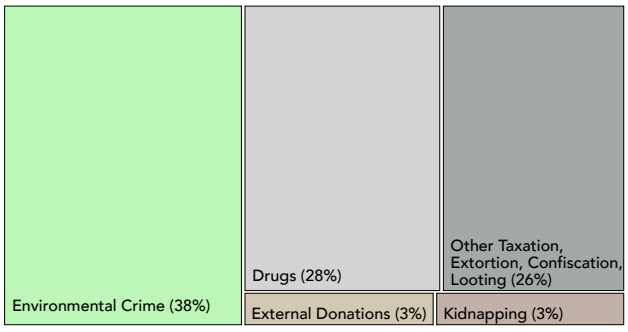
NATURAL CAPITAL*	FINANCIAL CAPITAL	SOCIAL CAPITAL	POLITICAL CAPITAL
Forests (Flood Retention, Water, Soil Erosion, Carbon Sequestration, Pollination, Wildlife Reduction)	Government Revenue	Jobs and Livelihoods	Governance (Corruption, Land Rights)
Fisheries (Bycatch Reduction)	Evasion (Tax, Non-Tax, Fees)	Crime and Conflict	Reputation
Wildlife (Biodiversity)	Economy (Size, Productivity, Profitability)	Health (Mortality, Morbidity)	Social Investments
	Investments		
	Macro/Fiscal (Trade Balance/ Payments)		

*Ecosystem Services

Source: The World Bank (2019)

Environmental crime is widely recognized as a major funder of bad actors. According to a 2018 report prepared for INTERPOL, the largest source of income for non-state armed groups and terrorist organizations are proceeds derived from environmental crime, which includes wildlife crime, forest crime, fisheries crime, as well as the illicit mining of gold, diamonds, and other minerals (see Figure 8).[173] (More discussion can be found in Wildlife, Page 49)

Figure 8. How Non-State Actors Fund Their Operations



Source: Nelleman,World Atlas of Illicit Flows (2018)

xiii This report focuses primarily on wildlife, forest, and fisheries crime. Other forms of environmental crime, such as illegal dumping, electronic waste mismanagement, illegal mining, and smuggling of ozone-depleting substances, are also important, but not treated herein.

CORRUPTION IS THE DARK FACILITATOR OF ENVIRONMENTAL CRIME

The systematic enabling, enhancement, and propagation of corruption is arguably the most calamitous aspect of environmental crime. Corrupt activities corrode political, economic, and criminal justice systems and, if prevalent enough, become normalized in a state's institutions.[174] Corrupt public servants may use official cover to engage in bribery, patronage, or permit abuse. When uncovered, corruption can invoke public resentment and fury, contributing to distrust in government and social unrest.

Corruption poses a number of systemic risks to a nation's security and self-determination. In extreme cases, corruption can divert activities away from running a state which, according to the Carnegie Endowment for International Peace, should be viewed "not as a failure or distortion of government but as a functioning system in which ruling networks use selected levers of power to capture specific revenue streams."[175] It promotes mutualistic interconnections between legal activities and illegal transnational crime, provides funding streams for insurgent and terror groups, and severely limits a country's ability to advance up the development spectrum.[176] Further, studies examining the role of corruption within the context of environmental policy have demonstrated links to political instability and state failure.[177]

Western policies often deprioritize addressing corruption in environmental crime, despite the damages it causes and the co-benefits that would accrue if it were diminished. Strategies that narrowly target illegal extraction and demand reduction of illicit products—both aspects necessary but insufficient—are likely to be greatly hampered without a commensurate focus on the corruption that facilitates all nodes of environmental crime networks.

Figure 9. Corruption Facilitates All Nodes of Environmental Crime

Poaching	Transport	Processing	Trading
Guides	Border Guards	Inspectors	Shopkeepers
Rangers	Inspectors	Government Officials	Traders
Police	Police		Police
Military	Military		Government Officials
Judges	Diplomats		
Goverment Officials	Government Officials		

Source: van Uhm, Corruption Within the Wildlife Trade, (2018)

TRANSNATIONAL ORGANIZED ENVIRONMENTAL CRIME IS WIDESPREAD

Environmental crime's multifaceted and interwoven nature has left governments struggling to adequately respond to interwoven types of crime. An important, oft-asked question is whether organized crime overlaps with or participates in environmental crime. For many, the term "organized crime" connotes groups of people, often with an ethnicity attached, such as the Italian mafia or the Russian mob. From that perspective, organized criminal activities are the criminal activities that these groups engage in—the criminal activities may change but the involved groups remain roughly the same. Law enforcement agencies implicitly adopt this group-centric framework because criminal justice systems are designed to apprehend specific individuals who commit specific crimes.[178]

Over the past few decades, however, the crime business has globalized just like other industries, spurring a fundamental change in the nature of organized crime. Many scholars argue that organized crime groups are now much less important than the illicit markets in which they engage. As the UN Office on Drugs and Crime states: "Today, organized crime seems to be less a matter of a group of individuals who are involved in a range of illicit activities, and more a matter of a group of illicit activities in which some individuals are presently involved. If these individuals are arrested and incarcerated, the activities continue because the illicit market, and the incentives it generates, remain."[179]

Criminologists have pondered the linkages between transnational crime and organized crime. One scholar posits that transnational crimes have three objectives: provision of illicit goods, provision of illicit services, and the infiltration of business or government operations.[180] By this definition, most forms of environmental crime fit the definition, including wildlife crime, forest crime, and fisheries crime (see Figure 10).

Figure 10. Environmental Crime as Transnational Crime

	Objectives of Transnational Crime		
Environmental Crime	**Provision of Illicit Goods**	**Provision of Illicit Services**	**Infiltration of Business or Government**
Illegal Wildlife	Wildlife Products	Poaching Smuggling	Park Rangers Law Enforcement
Illegal Logging	Timber Products	Timber Laundering Timber Fraud	Civil Servants Forestry Sector
Illegal Fishing	Fish Products	Fish Laundering Forced Labor	Licensing Agents Tax Collectors

Source: J.S. Albanese (2012)

Much, if not most, environmental crime in renewable natural resources is transnational crime. Further, many environmental crime activities fit the UN Convention Against Transnational Organized Crime's definition of "organized crime": Any serious offense that is committed by a group of three or more people with the aim of making money.[181] Positioning environmental crime firmly as transnational organized crime, which is driven by market-forces, suggests that law enforcement approaches that focus largely on groups or individuals will have limited efficacy. Using instruments that target the illicit activity itself, such as anti-corruption measures and international agreements, are more likely to have positive results.

IV. A CLOSER LOOK AT NATURAL SECURITY

The following sections lay out the security pathways that can arise from the ecological disruption and the degradation of nature across a number of domains. The topics—water, food, wildlife, forests, and fisheries—correspond to the major pillars of the ***Natural Security campaign***, a combined effort of four[xiv] leading international conservation organizations.[182] The arguments in these sections underscore the importance of international conservation efforts abroad as an important element of bolstering the security interests of the United States.

Water provision in Ali Addeh camp in Djibouti. The number of people at risk of hunger has increased since the 2011 drought, accelerating the rural exodus to urban areas. A combination of high food prices, water scarcity, climate change and reduced pasture has increased food insecurity. EU Civil Protection and Humanitarian Aid / Flickr

xiv Conservation International, The Nature Conservancy, Wildlife Conservation Society, and World Wildlife Fund

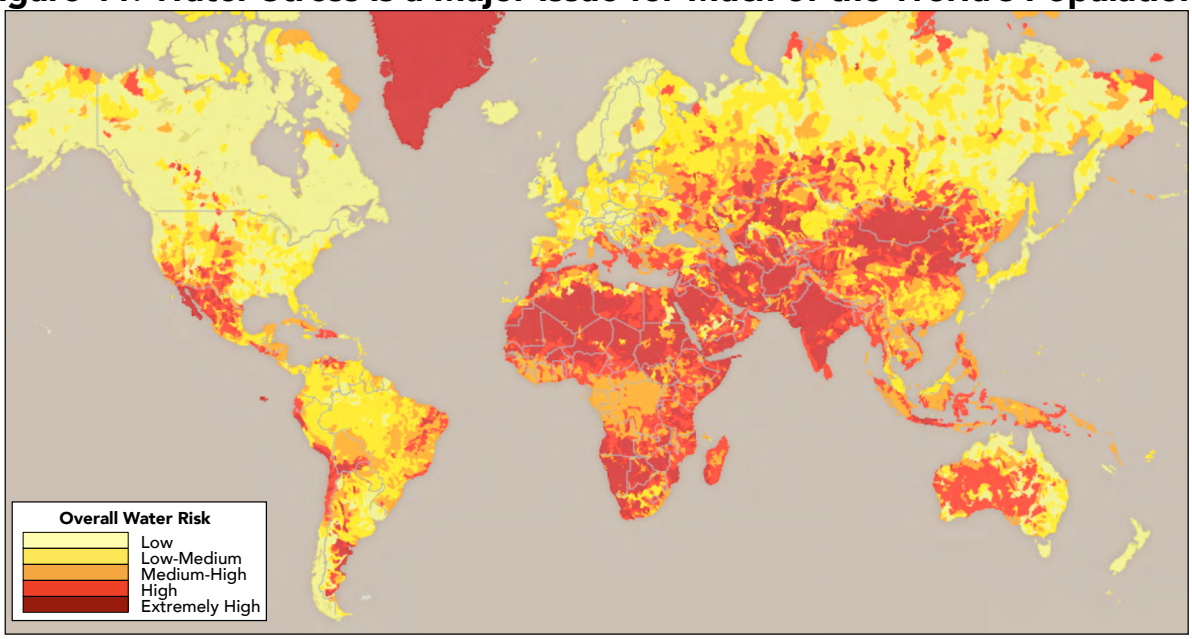
WATER

Water resources are integral to essentially every social and economic sector. However, those resources are under constant stress from population growth, changing demographics, urbanization, and climate change, and the impacts range from water scarcity and pollution to overabundance and flooding. Many governments worldwide are under pressure to meet the needs of society by ensuring adequate water resources and conditions, while simultaneously addressing the demands arising from the interconnected energy and food sectors.

WATER STRESS

Water stress occurs when water demand exceeds the amount available at a given time, or when poor quality impedes its use. Roughly 25 percent of the world's population resides in the 17 countries now experiencing extremely high water stress, according to the World Resources Institute (see Figure 11).[183] Twelve of those countries—Qatar, Israel, Lebanon, Iran, Jordan, Libya, Kuwait, Saudi Arabia, Eritrea, UAE, Bahrain, and Oman—are concentrated in the Middle East and North Africa region. India and Pakistan, the world's 2nd and 5th most populous nations, also suffer from extremely high-water stress.[184] Climate change is expected to intensify water stress in many of the countries already experiencing critical water problems.

Figure 11. Water Stress is a Major Issue for Much of the World's Populations



Source: World Resources Institute AQUEDUCT Database

World map of baseline water stress, the ratio of water withdrawals to total renewable supply in a given region.

Groundwater resources, which make up just 0.6 percent of all water on Earth, support roughly half of the world's population and have been decreasing since at least 1960.[185] In some regions, rates of extraction, often for agricultural and municipal uses, greatly outpaces natural recharge rates. Much of those recharge rates are dependent on the seasonal melt of glaciers, which represent the largest terrestrial store of freshwater. But heatwaves and volatile weather conditions disrupt those cycles, accelerating snowpack loss and potentially even increasing recharge rates before glacier storage is permanently lost.[186]

The 2002 to 2016 Gravity Recovery and Climate Experiment (GRACE) twin-satellite NASA mission has recently quantified the health of difficult-to-monitor underground aquifers, with stark implications for some countries.[187] Northern India, northern China, the Middle East, the western United States, and countries bordering the Caspian Sea are regions whose aquifers are already experiencing severe groundwater pressures, according to analysis of GRACE measurements.[188]

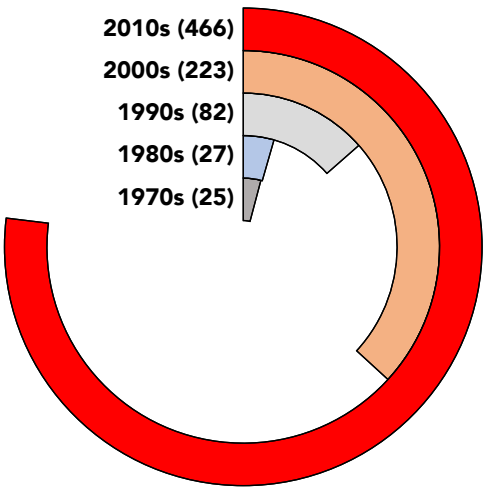
Water quality degradation is a global issue fueled predominantly by human pollution. Untreated discharge of pollutants and runoffs—80 percent of which goes untreated globally—threaten freshwater resources, human security, food security, and contributes to the release of methane.[189] About one third of all rivers in Latin America, Africa, and Asia are contaminated with bacterial and other pathogenic microorganisms, according to a UN report.[190] The number of affected rural residents of these countries may be in the hundreds of millions, according to the same report. Many groundwater sources are at a growing risk of salinity pollution from saltwater intrusion driven by rising sea levels and overpumping.

Another intensifying global threat to water quality is increased eutrophication. This ecological regime shift (see Page 16) occurs when algae grows rapidly in a body of water that has become overly enriched in nutrients, such as agricultural run-off of nitrogen and phosphorus compounds used for fertilizer. Algae can also greatly reduce dissolved oxygen that all marine life requires and, in extreme cases, produce hypoxic (low oxygen) or anoxic (no oxygen) conditions leading to dead zones. Eutrophication plagues over half of the lakes in Asia and Europe with somewhat smaller incidences in Africa and the Americas.[191]

CONFLICT

A common cliché in water policy circles, even among experts, is that water disputes generally do not escalate to violence. There are certainly many modern examples of cooperation prevailing over armed conflict between states (the 1964-1967 violence over control of Jordan River water resources between Israel and its Arab neighbors a notable exception).[192] [193] Policymakers should be wary, however, of extrapolating the *cooperation-over-conflict* narrative too far into the 21st century, as competition over scarcer and less reliable water supplies is almost certain to intensify in many already-stressed regions.

Figure 12. Number of Water Conflicts Per Decade



Source: Water Conflict Chronology Database Pacific Institute, October 2019 Update.

At the subnational level, the number of water conflicts has actually been increasing (see Figure 12), according to the Pacific Institute's Water Conflict Chronology database.[194] These conflicts over water include violence that results in injuries or death or threats of violence, such as military maneuvers, verbal threats, or other shows of force.

Armed conflict is not required for disrupting regional or global stability, as illustrated by the decades-long Cold War between the United States, the Soviet Union, and their respective allies. Transboundary water resources--such as rivers and groundwater that cross political boundaries—are often the sources of contentious disputes between nations. Indeed, some disputes, such as that between Egypt and Ethiopia over the Nile (and India and Pakistan over the Indus), possess several Cold War characteristics. In such circumstances, both sides of a dispute employ diplomatic, economic, and security levers, often in proxy conflicts, to garner support from influential third-party nations as hostilities spillover into geopolitical and propaganda domains. A 2020 article even opined that an Egyptian-Ethiopian war over water has already begun in cyberspace, with armed soldiers being replaced by hackers and social media influencers.[195]

Water stress, and the failure of government to adequately address it, can contribute to social disruption and political instability. Water-sharing agreements between riparian (river-sharing) states must navigate questions of access to water, sovereignty, development, and national identity. Roughly 300 of such agreements exist, mostly leading to functional relationships between countries.

But governments erode public faith in institutions when they fail to adequately address tensions, which in turn contribute to social disruption and political instability. Populations that depend on these water agreements will be impacted as environmental stresses drive changes in water availability over time. Destabilization risk grows when the afflicted populace concludes that those in power have caused or worsened the problem, such as through poor governance, unequal access between the wealthy and the poor, or the use of water as a coercive tool. Many experts point to Syria, Iraq, and Yemen as nations in which water insecurity has contributed to recent political instability or state failure.[196] [197] [198]

HEIGHTENED TENSIONS OVER DAMS

Unilateral dam construction is an especially important irritant of already acrid relations between countries due to the influence that upstream nations can gain through the construction and control of water infrastructure (see Figure 13). Many water infrastructure projects ignore or avoid environmental impact assessments, prioritizing large financing contracts or influential interests within a state or region over more efficient or sustainable solutions. As populations grow and demands to access critical water resources go unmet, increased competition and political strife can follow.

Figure 13. Selected Dam Disputes on Transboundary Water Basins

Dam	River Basin	Upstream	Downstream
Grand Ethiopian Renaissance Dam	(Blue) Nile	Ethiopia	Egypt, Sudan
Ilusu	Tigris	Turkey	Iraq
Don Sahong	Mekong	Laos	Cambodia, Vietnam, Thailand
Xayaburi	Mekong	Laos	Cambodia, Vietnam, Thailand
Roghun	Amu Darya	Tajikistan	Uzbekistan
Gilgel Gibe III	Omo	Ethiopia	Kenya
Kamal Khan	Helmand	Afghanistan	Iran

China's massive long-term dam-building program on several Southeast Asian rivers has brought Beijing considerable international scrutiny and condemnation. For example, eleven immense dams span the Mekong River, one of the most socio-ecologically important waterways in the world, before it crosses the Chinese border into Burma, Laos, Thailand, Cambodia, and into the South China Sea. Ecologists point to potentially calamitous consequences for food security and biological diversity downstream arising from impeded fish migrations and interrupted sediment flows.[199] Severe droughts experienced over the past year by downstream Mekong nations, even during the traditional wet seasons, were probably due in part from China's dams, according to a 2020 report commissioned by the Lower Mekong Initiative.[200] Beijing has disputed the findings of the report, claiming that the battery of Mekong dams provides positive benefits to the region.

WATER AS A TARGET

Terrorist and extremist organizations sometimes target critical water resources to destabilize governments and threaten communities. As recently as 2014, Al Shabaab in Somalia and ISIS in Iraq have captured dams in attempts to cut off or assert control over downstream populations.[201] Dams, and other high-publicity water infrastructure projects, are especially attractive targets for terrorist operations. In 2017, the Taliban, backed by Iranian support since roughly the middle of that decade, destroyed a dam in the southern Kandahar province

A man stands in a dry field in the Mishkhab region, 25 kilometres from Najaf, Iraq. July 2018. AFP

of Afghanistan and have reportedly tried to impede the construction of the Kamal Khan Dam as recently as this year.[202] Other terrorist and extremist groups that have either targeted or used water to further their objectives include the Revolutionary Armed Forces of Colombia (FARC), Shining Path (SL), Kurdistan Workers' Party (PKK), Tehrik-i-Taliban (TTP), and Boko Haram.[203] Desalination plants may emerge as future targets, especially in the Middle East, because of their centrality in providing water in parched, conflict-prone regions.

DISPLACEMENT

Water stresses can serve as an impetus or accelerant for human migration and population displacement. Water scarcity, severe drought and pollution reduce a community's safe water access. Storm surges and flooding alter landscapes, potentially rendering properties unsafe and unlivable. Oftentimes dams such as the Lesotho Highlands Water Project will permanently flood or disrupt inhabited lands as its reservoirs are filled. Persistent water stress contributes to rural-to-urban migration that can undermine domestic stability, and insecurity can spill over to neighboring states through migration or disease. In turn, rapid human migration from other countries can contribute to water scarcity in the host country, as recently experienced in Jordan and Lebanon from the influx of Syrian refugees.[204] [205]

WATER AND HEALTH

Water stress poses a number of risks to human health. Pathogens, such as viruses, bacteria, and protozoa, can concentrate in both groundwater and surface water when rainfall decreases. Acute respiratory and gastrointestinal illnesses spread more easily between people when water quantities are insufficient for handwashing. Shortfalls in hygiene greatly amplify the risk of the spread of infectious diseases.[206]

CASE STUDY: THE GRAND ETHIOPIAN RENAISSANCE DAM

Sharing of Nile River water resources is one of the greatest challenges to regional security in North Africa. Ten countries share the Nile River Basin: Burundi, the Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, South Sudan, Tanzania, and Uganda. For decades Nile hydropolitics have been infused with mistrust, secrecy, and bluster, worsened by holdover treaties dating back to colonial times. Recent squabbles have been most pronounced between Egypt, Ethiopia, and Sudan, the three countries that share the Blue Nile, one of the Nile's main tributaries.

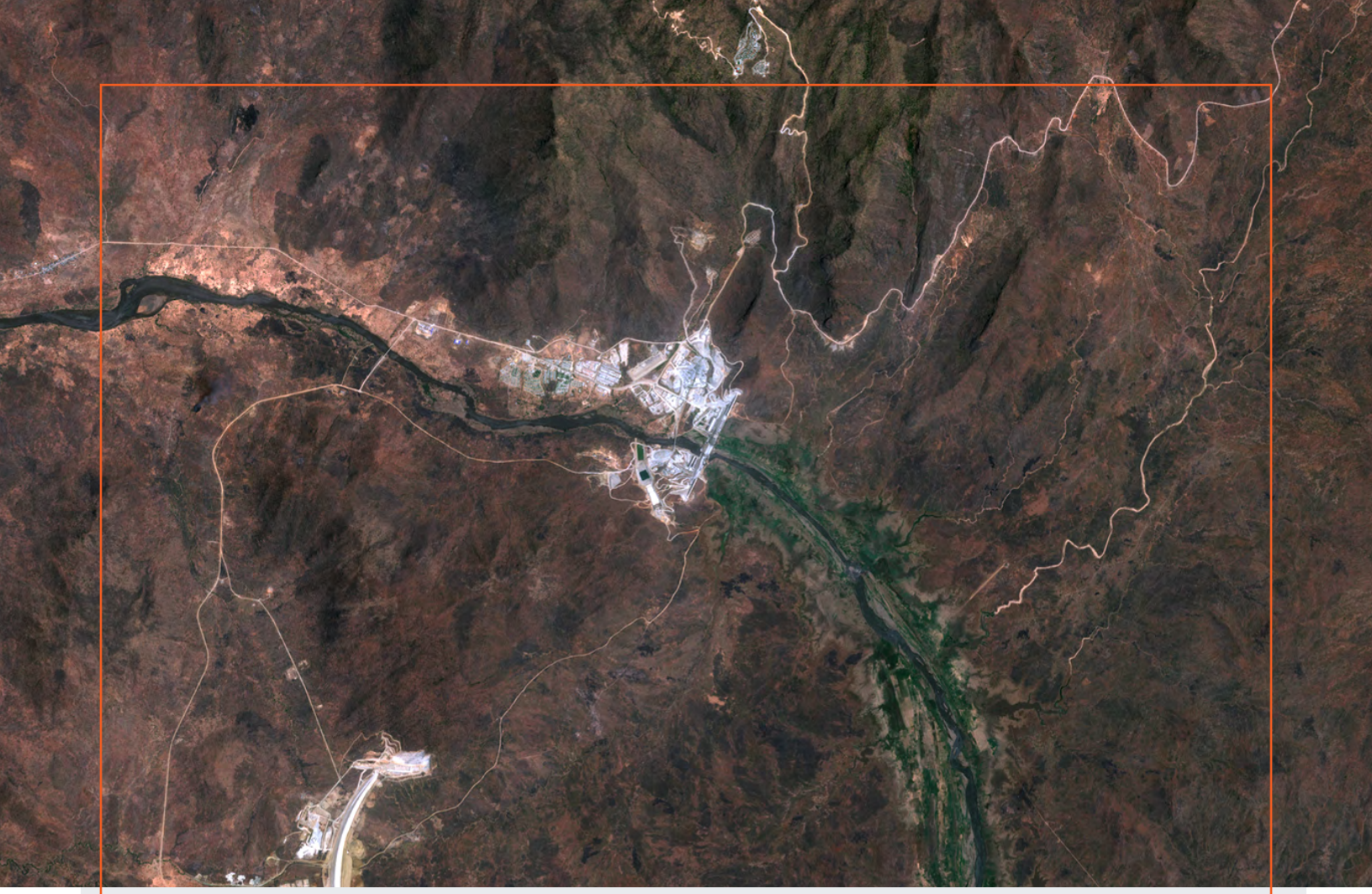
Tensions have escalated precipitously since Ethiopia's 2011 announcement of its intent to construct the Grand Ethiopian Renaissance Dam (GERD), a massive hydropower project that is the largest in Africa and the seventh largest in the world. Water scarcity already looms large in Egypt's political stability and any shortfall of Nile flow, essentially the country's only freshwater source, is characterized by Cairo as a threat to Egypt's national security. Meanwhile, Addis Ababa seeks to use the Nile, which originates from Ethiopia's Lake Tana, to generate electrical power and drive much-needed development.

Dam benefits come from creating reservoirs that provide reliable irrigation sources, while also providing more constant flow rates for flood prevention and hydropower production. Dam projects have historically been pursued largely on the assumption that economic and developmental benefits outweigh other costs, although institutions such as the World Bank have greatly influenced dam-builders to consider environmental downsides.[207] However, many rivers are overly sedimented, land corridors are flooded, and water quality and chemistry is altered due to changes in drainage, toxic runoff, and reservoir formation. People that live in nearby communities are likely to be adversely affected by altered flow rates, and potentially forced to migrate as reservoirs are created and submerge landscapes.

Comprehensive environmental and social impact assessments are generally necessary to understand a dam's long-term impacts. When such studies are abbreviated or incomplete, critics often argue that the process is tainted by vested special interests and the large contract budgets of such projects. In the case of the GERD, critics argue that a robust impact assessment was either never performed or not made available, despite the site originally being identified as far back as the 1950s.[208] Ethiopia has self-funded nearly all of the $4.8 billion project, although China has contributed some ancillary equipment. China has mostly kept a light touch with the GERD, as several Chinese-funded projects in Africa have faced international criticism for their disregard of environmental impacts and use of their own labor. Also, Beijing almost certainly does not want to be caught in a geopolitical dispute between two countries it has transactional relationships with.[209]

The United States has long-standing strategic interests in the region, heightened in the past two decades by its global anti-terrorism efforts. In 2018 the U.S. restored financial assistance to Egypt, a country that borders Israel and the strategically important Suez Canal, after withholding assistance over human rights violations.[210] After Israel, Egypt is the second largest recipient of foreign assistance from the United States. In the past four years Ethiopia has received $4 billion in U.S. aid, and more than $13 billion in the past two decades, as an ally in fighting terrorism.[211] Sudan has also received foreign assistance, such as an $81 million package in 2020 earmarked for humanitarian aid and efforts to normalize Israeli-Sudanese relations.[212]

In July 2020, after many years of design, construction, and frequent diplomatic impasses, Ethiopia began filling the reservoir of the GERD, which is purportedly about 70 percent complete.[213] The filling rate is a central theme of ongoing negotiations, with Egypt demanding a 12 to 20-year fill period to spread out flow



The Grand Ethiopian Renaissance Dam in North West Ethiopia near the border of Sudan as captured by Sentinel-2 satellite on April 4, 2020. EU Earth Observation Programme / Flickr

reductions while Ethiopia insists on a more rapid 5 to 7 years to maximize benefits. The filling rate is also subject to regional hydrological conditions, where periods of extreme drought and flooding have occurred over the past decades.

Negotiations over the GERD continue to be tense. Ethiopian officials have long insisted dam operations will cause no harm to downstream Egypt and Sudan. The rhetoric has even cooled somewhat, compared to prior years when Egyptian politicians spoke publicly of sabotaging the construction site and Ethiopia announcing military countermeasures.[214] The United States has historically sought to thread a diplomatic needle by providing technical assistance to secure peace in the region while not taking sides in the dispute.

In September 2020, the Trump administration paused Ethiopian foreign assistance after its decision to begin filling the GERD reservoir, despite pledging $230 million to the country earlier in the year. Although the suspension was temporary, Ethiopia was exasperated by Washington's apparent decision to take sides in the dispute. Ethiopia offered little to assuage concerns about regional peace when it began preventing flights over the dam in October 2020, citing security concerns.[215]

FOOD

Securing food resources has long been an important issue for national security. The prospect of feeding the planet's anticipated 9 billion people by 2050 has regional and global geopolitical and geostrategic overtones, especially as the effects of climate change begin to factor into agricultural outputs and geographies. Famine, once thought largely vanquished, has commingled with other humanitarian crises over the past few years. Meanwhile, food insecurity can be a factor in conflict, instability and migration.

FOOD STRESS

After decades of steady decline, the number of people worldwide affected by hunger has been slowly increasing since 2014, according to the UN.[216] For example, in 2019 close to 750 million people, roughly one in ten people in the world, were exposed to severe levels of food insecurity.[217] An estimated 2 billion people did not have access to safe food of sufficiently nutritious quality.[218] Preliminary estimates indicate that the COVID-19 global pandemic will move between 83 and 132 million people into a state of undernourishment in 2020.[219] Meanwhile, economic barriers to healthy consumption patterns persist as estimates show that healthy diets are, on average, five times more expensive than those that are inferior in nutritional quality.[220]

FAMINE

The global number of deaths by famine--an extreme, sustained shortage of food that endangers life--has been steadily declining since the 1970s. This trend has been aided by technical developments in agriculture, healthcare, food trade, and early warning capabilities, which have also reduced the relative importance of natural triggers of famine.[221] Hence, over time, famines have become increasingly human-caused, arising largely from government shortcomings and poor policies.[xv]

xv The compound effects of climate change are likely to increase the importance of natural factors, like drought, in future famines.

Africa continues to experience sporadic famines, with drought and armed conflict primary contributors. In 2005-2006, nearly 3.5 million people in Niger were pushed into food insecurity by grain shortages and high food prices. Many countries in the Sahel region experienced famine in 2010, from a drought that was at least partly fueled by overgrazing, deforestation, and climate change.[222] In 2011, East Africa experienced its worst drought in 60 years and caused severe food shortages across Somalia, Djibouti, Ethiopia, and Kenya.[223] In 2017, famine returned yet again, putting about 20 million people at risk of starvation in Nigeria, Somalia, South Sudan, and Yemen.[224]

LOCUSTS, EXTREME WEATHER, AND PANDEMICS

Cascading plagues of desert locusts, beginning in mid-2019 and lasting through 2020, have decimated food supplies on three different continents. Heavy rains from unusual Arabian Sea cyclones fueled the initial locust outbreak in June 2019 in Yemen and Saudi Arabia.[225] Swarms crossed the Red Sea a few months later into East Africa, a region that soon experienced unusually intense rainfall from a rare late season cyclone, causing severe food insecurity in Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, and Uganda.[226] At the same time, locust swarms had spread into Asia, affecting India, Iran, and Pakistan. South America was also impacted as crop-destroying swarms formed in Paraguay, spread to Argentina, and threatened to enter Bolivia and Brazil.[227]

Extreme weather events, agricultural pests and diseases can trigger crop failures and drive spikes in food prices. In addition, oil price shocks affect grain prices through corresponding increases in transportation, irrigation, and fertilizer costs. High demand from emerging markets and economic shocks also contribute to food price spikes.[228]

The COVID-19 pandemic has worsened global food insecurity even further. Travel restrictions and lockdowns hampered locust control efforts in many countries by disrupting supply chains important for the distribution of personnel, insecticides, and equipment.[229] The economic and public health consequences of the pandemic may push as many as another 132 million people into food insecurity, according to the UN.[230]

Meager crops in rural indigenous Guatemala. Years of below average rainfall have created a cycle of seasonal hunger in the Dry Corridor. S. Billy / EU Civil Protection and Humanitarian Aid / Flickr

FOOD-RELATED INSTABILITY

Food-related social unrest has been well-documented in history.[231] [232] After a comparatively quiet period dating back over a hundred years, the mid-1970s witnessed a resurgence of global food unrest, with 146 food riots spanning 39 countries.[233] [234] The nature of unrest had changed, evolving from mostly angry rural populations targeting farmers and businessmen over bad harvests to almost exclusively urban unrest focusing their ire on supermarkets and government institutions.

A 2015 study of urban unrest in major cities in Africa and Asia from 1960-2010 showed a robust relationship between instances of protests or rioting and global food prices, particularly for democratic or partially-democratic countries.[235] The period 2007-2008 saw unrest over food prices in Afghanistan, Bangladesh, Burkina Faso, Cameroon, China, Côte d'Ivoire, Egypt, Ethiopia, Haiti, Indonesia, Mauritania, Morocco, Pakistan, the Philippines, Senegal, Thailand, Trinidad and Tobago, UAE, Uzbekistan, and Yemen.[236] Three years later, high food prices sparked another pattern of global unrest, probably contributing to the 2011 Arab Spring in the Middle East and North Africa.[237]

TERROR AND INSURGENT GROUPS

Terrorist groups, such as Boko Haram, Al Shabaab, and the Islamic State in Iraq and Syria (ISIS), are known to exploit food insecurity to further their ambitions of establishing parallel states.[238] Their tactics include using ill-gotten financial resources to obtain and distribute food in vulnerable areas to garner public support, degrade government legitimacy, create sympathizers, and recruit fighters. The terrorist groups have also been involved in the blockade or diversion of foreign food aid during humanitarian crises.

FOOD AND DISPLACEMENT

Conflict, forced migration, and food insecurity can create compound stresses for rural populations as one challenge abets another. Insecurity and conflict are the main drivers for displacement while food security together with social networks and stronger livelihood opportunities can incentivize populations to remain in their community.[239] High levels of food insecurity generally lead to increased levels of migration across borders, according to a 2017 report from the World Food Program.[240] The same report also argued that "one percentage increase in food insecurity in a population compels 1.9 percent more people to migrate per 1000 population."[241]

When displaced populations settle in a new area or country in response to food insecurity, tensions often form in their new settlements over a lack of or newly-shared food resources. In Ethiopia's Omo Valley, the development of villages for pastoralists led to the forced displacement of Bodi settlers and food insecurity from faulty irrigation systems.[242] In Nigeria, desertification, instability, and a loss of grazing land forced nomadic herders to migrate into Southern territory where they clashed with sedentary farming communities.[243] A vicious cycle appears as conflict exacerbates food insecurity, leading to displacement, which in turn fuels conflict.

GLOBAL FOOD SUPPLY VULNERABILITIES

Nearly a billion people worldwide depend on the global food system, which is underpinned by trade in a handful of crops and fertilizers. The increased efficiencies throughout the complex supply chains that stretch across the world have also made them vulnerable to acute shocks. A 2017 Chatham House report identified several types of chokepoints critical to global food security, such as maritime corridors like straits and canals, and coastal and inland infrastructure in major crop-exporting regions.[244] Sudden losses in food production or transportation can arise through ecological pressures, such as crop failures, livestock fatalities, fisheries collapse, or extreme weather, or through social factors, such as policy changes and armed conflict.190 Several studies suggest that global food networks and food prices may be unusually vulnerable to multiple system stresses.[245] [246] [247] Intentional sabotage of the integrity of the global food supply system is probably within the capabilities of some malign actors, especially if other systemic stresses are already present.

CASE STUDY: COFFEE AND MIGRATION IN CENTRAL AMERICA

Northbound migration from the Central American "Northern Triangle" countries El Salvador, Guatemala, and Honduras has been an important influence on U.S. foreign and domestic policy since 2014.[248] Although U.S. media reports initially linked these migration pulses to regional violence, later studies showed that food insecurity and lack of economic opportunities from crop failures were often the most important factor for many households.[249] [250] [251] Erratic weather patterns and agricultural pests are thought to be largely responsible for the agricultural failures.[252]

The effects of erratic weather on Northern Triangle agriculture and food reserves have been devastating. The 2019 harvest of corn and beans marked the fifth consecutive year that extreme weather led to poor crop production.[253] In 2018, several Central American governments reported that the delayed start of the rainy season in the Dry Corridor ruined up to 70 percent of subsistence farmers' first harvest while too much rainfall damaged up to 50 percent of the second harvest.[254] The 2018 and 2019 droughts and flooding especially affected regional coffee growers. For the poorest residents of Central America, coffee production is the key part of their livelihoods who depend on this income as small producers and cutters.

Central America has endured a series of outbreaks of coffee leaf rust, a plant disease that attacks the coffee plant leaves and whose spread has been linked to a changing climate. From 2012 to 2014, a cluster of epidemics of coffee leaf rust, collectively described as the Big Rust, caused enormous hardship to coffee producers and laborers in the region, with repercussions across the coffee commodity chain throughout Central America.[255] [256] Some farmers experienced extended periods of zero output leading many to destroy their remaining trees. Impoverished farmers tried to find employment on neighboring coffee farms, but the epidemic had obliterated the demand for labor. According to some estimates, coffee leaf rust displaced over 373,000 people across Central America.[257] [258]

For Northern Triangle countries, most producers are small and don't have access to resources or credit to invest in projects to mitigate crop diseases. Many are still in debt from previous outbreaks, especially from the Big Rust epidemic.[259] The loss of economic opportunities and associated food insecurity are likely to continue prompting increasingly more farmers and associated families to migrate northward.

WILDLIFE

The complex, dynamic relationship between humans and animals has existed throughout our evolutionary history, but has been fundamentally changed through developmental inventions like agriculture, domestication, and industrialization. Dramatic numbers of habitats have been transformed to meet the natural resource demands of expanding and more affluent populations, driving humans and wildlife into greater proximity. Increasing globalization and levels of prosperity have helped fuel high demands for wildlife and its products, for food, ornaments or pets. Globalization has also increased the probability for organisms to be transported to new geographies, heightening the risks of alien invasive species.

DEFAUNATION

An immensely damaging consequence of modern human activities is the high rate of global defaunation—the extinction of animal species or populations, or the decline in abundance of individual organisms within a population (see Figure 2, Page 19). Driven by habitat loss, invasive species, pollution, overexploitation, and legal and illegal direct harvest of organisms, defaunation occurs at differential rates dependent on ecosystem type. For example, freshwater fauna are dying at higher rates than those in terrestrial and marine systems, almost certainly due to their closer proximity to human activities.[260] [261] [262] The geographic distribution of defaunation is likewise highly variable; terrestrial vertebrates, for example, are at a comparatively higher risk in Southeast Asia, South America, and central Africa.[263]

High rates of species extinction are notable because of the rapid and irreversible loss of evolutionary history to the planet. The current rate of animal species extinctions has been estimated at 11,000 to 58,000 species lost per year worldwide, out of an estimated 5 to 8 million species total.[264] According to the International Union for the Conservation of Nature (IUCN) 2020 Red List, best estimates of the number of threatened species are 14 percent of birds, 26 percent of mammals, and 41 percent of amphibians.[265] A recent study suggested that 35 billion years of cumulative evolutionary history of ecological interactions have been lost from defaunation.[266]

INCREASING HUMAN-WILDLIFE INTERFACE

As humans encroach into regions that historically harbor wildlife, and as some wildlife move because of ecological pressures, the interface between human and wildlife populations will increase with implications for both. Human and economic security are affected both by impacts on global health and human-wildlife conflict.

GLOBAL HEALTH

Infectious diseases, particularly those that emerge from pathogens not experienced before by humans, have serious repercussions for global health and economic security. As illustrated by COVID-19, pandemics can cause social disruption and fatalities that rival or surpass armed conflict. The encroachment of human activities into regions previously dominated by wildlife increases the risk of zoonosis, in which a pathogen hops from an animal to a human host. Since the 1970s, at least three dozen infectious diseases have emerged from human contact with animals, including Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola, Zika, Chikungunya, Nipah, and several variants of swine and avian influenza.

Anthrax, tuberculosis, and other zoonotic diseases were once dominated by transmission to humans from domesticated animals like dairy cows, but 70 percent of all emerging infections are now thought to arise from a growing human-wildlife nexus. This is particularly true of international wildlife trade that presents viral spillover opportunities that would never occur naturally, posing risks at every stage of the commercial supply chain, from border crossing to restaurants. Hence, global wildlife trade, both legal and illegal, poses a serious risk as a transmission mechanism for zoonotic pathogen spillover into humans.[267]

The illicit importation of exotic species poses an additional biosecurity risk to the integrity of native fauna and flora. Smuggled organisms could become established in the wild and cause ecological and economic damages. Alternatively, they could carry seeds, parasites, and pathogens that could adversely affect important sectors, such as agriculture, horticulture, and aquaculture.[268]

HUMAN-WILDLIFE CONFLICT

Habitat loss and fragmentation aggravates conflicts between people and wild animals, which can involve direct attacks from predators on humans and their domesticated animals or the destruction of crops.[269] Human-wildlife conflict poses dangers to human lives and livelihoods and can result in retaliatory actions that undermine local conservation efforts.[270] Once viewed as a problem affecting mainly rural populations, human wildlife conflict is increasingly urban, and expected to intensify as urbanization grows.[271]

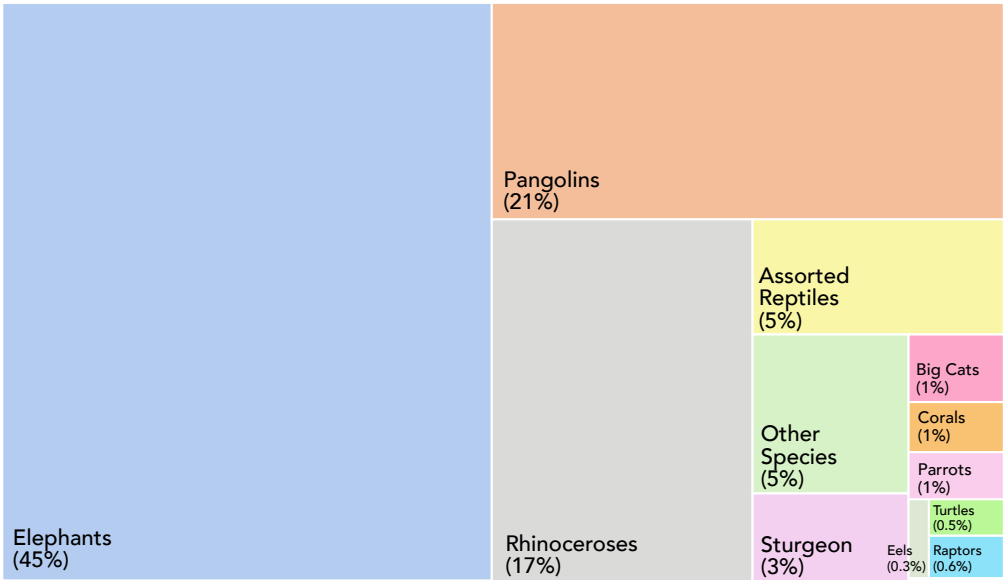
WILDLIFE TRAFFICKING

Wildlife crime is the illegal trade in specific animals or animal products.[xvi] The term *wildlife trafficking* is often used to refer to the entire multi-stage illegal wildlife chain: planning, poaching, distribution, transportation, processing, selling, and laundering. This chain is not exclusive to wildlife: groups and networks that traffic guns, drugs and humans are often participating in wildlife crime as well. No country is untouched by wildlife crime, which the UN has labelled "serious, organized crime."[272]

ECONOMIC DAMAGE

Global economic losses from the illegal wildlife trade are substantial. An October 2019 World Bank report estimated the economic value of the illegal wildlife trade (excluding illegal logging and illegal fishing) at $7 to $23 billion per year.[273] As measured as a percentage of total wildlife seizures, elephants, pangolins, and rhinoceros are the most trafficked types of wildlife or wildlife products, according to the UN (See Figure 14).[274] Growing regional government strategies, technology enhancements, and regional corporations have applied strong pressure to the supply side. Thus, even as demand for elephant ivory, rhino horn, and other products have climbed, poaching of elephant and rhinoceros have declined since 2011 and 2015, respectively, as have the monies paid for their products. Meanwhile, poaching of pangolins has increased tenfold in just five years.[275]

Figure 14. Share of Wildlife Among Seizures (2014-2018)



Source: UNODC Worldwide Wildlife Crime Report (2020)

The most trafficked types of wildlife, as measured by seizures, from 2014 to 2018.

xvi Other definitions of wildlife crime include illegal trade in plants and timber, but this report uses the term primarily in the context of illicit trade in animals (not including fish).

Illegal wildlife trade also threatens the livelihoods of many local people and communities who depend on wildlife. This is especially for those with jobs associated with the tourism industry, as it erodes economic growth, particularly in countries for which tourism provides major revenue.

Much wildlife criminal activity has moved online, with social media being a thriving market. However, the dark web, the balkanized part of the internet where a number of illegal activities transpire, does not appear to be a major source of wildlife cybercrime, according to a 2018 report.[276] More than 5,000 advertisements spanning over a hundred easily-accessible online marketplaces and social media platforms were discovered in 2018, according to a report by an environmental NGO.[277] Close to 12,000 wildlife products were discovered, all found in searchable parts of cyberspace, valuing almost $4 million dollars.

POLITICAL INSTABILITY

Wildlife trafficking has direct implications for global political and economic stability. This is in part because the trade tends to be a relatively lucrative and low risk endeavor. Penalties tend to be low while relevant laws are murky and less stringent than other criminal activities. Illicit trade, already a black market in which few criminal prosecutions are made, compromises a state's political, economic, and criminal justice system in addition to the private sector. At the same time, corruption is a critical facilitating factor that permeates the illegal wildlife enterprise, from poaching to transit to destination (see Environmental Crime, Page 34).

For some countries, the illegal wildlife trade contributes to a greater risk of political instability by undermining government effectiveness, degrading the economic base, and providing resources for insurgent groups. When wildlife trafficking impacts local food security and livelihoods, blame often falls on inadequate policies and actions and is exacerbated when other enablers of illegal wildlife trade receive little or no punishment. Yet some heavy-handed anti-poaching policies, such as shoot-to-kill orders, are perceived as acts of brutality or repression, particularly when locals poach out of necessity. In both cases, poor governance that fails to assess the nature of threats from wildlife trafficking poses risks to stability through weakened governmental legitimacy or increased resentment.

Park rangers display tusks recovered in eastern Congo's Garamba National Park, 2012. Nuria Ortega / African Parks Network / Flickr

TRANSNATIONAL ORGANIZED CRIME

As discussed in Section III (Page 16), there is a large overlap between environmental crime and transnational crime. Transnational criminal networks participate heavily in the illegal wildlife trade in particular, although such entities may not resemble stereotypical mafia-type groups.[278] [279] Transnational organized crime transcends borders, rejiggering financial and shipping networks to avoid interdiction while actively obstructing justice and the rule of law. Only organized crime can pull off the logistical requirements necessary to traffic some forms of wildlife products, such as elephant ivory.

Transnational criminal networks break down into three sometimes-overlapping categories, according to a recent study.[280] First, organized crime groups, such as those believed to be involved in illicit ivory and totoaba trafficking, possess comparatively high levels of structure and longevity and are likely to use violence and corruption to attain their goals. Second, corporate crime groups consist of one or more corporations, from family-owned small businesses to multinational entities, that participate in illegal wildlife activities for their own benefit.[281] These groups may transport illicit wildlife or engage in wildlife laundering, concealing the illegal origin of wildlife. Third, disorganized criminal groups are characterized by temporary and fluid networks of opportunistic individuals, such as couriers, border officials, and other intermediaries.[282]

CONVERGENCE WITH INSURGENCY

Similar to the criminal enterprise, the low risk, high reward nature of poaching is an appealing factor for insurgent groups or non-state actors that struggle with financing. A number of credible sources, including INTERPOL and the UN, have identified at various times the involvement of several non-state armed groups, such as the Lord's Resistance Army, Sudanese Janjaweed, AQIM, and insurgent actors in Mali, Mozambique, and the Democratic Republic of Congo, in some aspects of the illegal wildlife trade.[283] [284] [285] It remains difficult to assess the degree to which these actors participate in the illicit wildlife enterprise, but it is unlikely to be either very large or nonexistent.

HEIGHTENED MILITARIZATION

In some places, such as Sub-Saharan Africa, the rapidity and violence of poaching activities have overwhelmed the response capacity of local wildlife enforcement agencies. Groups in pursuit of elephant ivory and rhino horn, for example, often employed sophisticated weapons and equipment. To confront them, park rangers, police forces, and soldiers have needed to similarly arm themselves in kind. The resultant militarization of wildlife areas increases the risk of heavy-handed anti-poaching efforts and nonparticipants being caught in the crossfire as collateral damage.[286]

WILDLIFE CRIME AND GLOBAL HEALTH

Most efforts to combat wildlife crime are directed at anti-poaching or other steps in the supply chain, and rarely is the disease risk addressed.[287] Much of the demand comes from high-income, educated and industrialized

Western countries. For example, between 2000 and 2009, the United States was the leading importer of both legal and illegal animals, with more than 1.5 billion live animals imported.[288] When wildlife product shipments are refused, the reason is predominantly due to the protective status of the endangered animal rather than an assessment of potential risks of infectious disease transmission the shipments may pose.[289] Many critics argue that from a disease perspective it does not matter whether wildlife trade is legal or illegal.

CASE STUDY: WILDLIFE AND COVID-19

The COVID-19 pandemic has prompted scientists worldwide to search for the animal intermediary responsible for the transmission of SARS-CoV-2, the strain of coronavirus newly identified in late 2019. Identifying wild reservoirs of zoonotic pathogens and the spillover chain is critical in order to prevent future introductions into the human population. Recent research exposes weaknesses in our knowledge of viruses in wildlife and human activities are greatly amplifying risk of future pandemics.

Bats are a reasonable starting point for virus hunters as they host several hundred known strains of coronavirus, in addition to other viral classes. Bats have developed the ability to harbor many different viruses with no signs of disease, though these same pathogens are often very virulent in other mammals.[290] The spillover of a virus directly from bats to humans would require several factors, including a mode of transmission, molecular compatibility between the coronavirus and human host cells, and an impeded human immune response. Scientists quickly converged on the conclusion that while bats were the natural reservoir for SARS-CoV-2 an intermediate host was probably the source of indirect transmission to humans.[291]

An intermediate host provides more than a secondary chain of contact, but also a genetic factory where viruses can potentially evolve characteristics for successful spillover into other organisms, including humans. Its genetic structure places SARS-CoV-2 in the same coronavirus family as SARS-CoV, which caused the Severe Acute Respiratory Syndrome (SARS) epidemic in 2003, and MERS-CoV, which caused the Middle East Respiratory Syndrome (MERS) epidemic in 2013.[292] [293] Scientists believe the intermediate hosts for SARS and MERS are civet cats and dromedary camels, respectively. These outbreaks helped put coronaviruses prominently on the watchlist of viruses with pandemic potential.

Investigations of early COVID-19 cases uncovered an apparent connection to the Huanan Seafood Wholesale Market in China's Wuhan Province. This wet market is a community resource that sells fish, meats and perishable goods, in addition to a variety of wild animals. Shortly afterward, researchers also identified a high genomic match between SARS-CoV-2 with coronaviruses carried by the pangolin, a mammal that has in recent years become the most trafficked wildlife in the world and is often sold in wet markets.[294] The pangolin was initially suspected as the intermediate host but, thus far, the evidence has been weak. Further, there are indications of early COVID-19 cases recorded before the Wuhan outbreak in people who have no obvious connection with the market.[295]

The search for a better understanding of COVID-19 has revealed a number of worrying issues. Early research uncovered genetic sequences of almost 800 coronaviruses in bats in China, nearly a third of which had been

Ducks and geese in cages at a wet market in Shenzhen's Luohu District, China, 2013. Daniel Case / Wikimedia Commons

unreported, which revealed a sizable knowledge gap in wildlife virology research.[296] Other studies have shown that human-to-wildlife transmission of SARS-CoV-2 is likely. Field studies have measured SARS-related antibodies in about 3 percent of people in China who lived near caves, indicating that virus spillover to humans is not a rare event.[297] These and other findings indicate that increased contact between humans and some types of wildlife brings more pathogenic exposure than previously believed.

A 2020 study argues for an alternative model of zoonotic disease emergence into humans. Rather than viruses spilling over into humans when the right conditions are met, the authors argue that some viruses are constantly being transmitted between species, including humans.[298] After infection, the virus then can become pathogenic for the host, through mutation or reassortment of the viral genetic material.[299] As supporting evidence, the authors point to the lack of reported animal diseases in civet and dromedary populations before SARS and MERS appeared in humans, and that people have been exposed more frequently to many viruses without subsequent epidemics.[300]

Regardless of model, the more frequently that humans and wildlife interact, the more opportunities exist for viral transfer to occur. These interactions include hunting, trading of animal foods, animal husbandry, wet markets, and the handling of animals or exotic pets. Cataloging numbers of novel animal-derived viruses is almost certainly necessary, but insufficient to gauge the exposure that humans incur from an intensifying human-wildlife interface; understanding how they interact with human physiology is needed as well. Focusing solely on wildlife rather than the human activities that heighten the risk of zoonotic spillover is unlikely to be successful for reducing the risk of future pandemics.[301]

FORESTS

Forests are critical ecological domains that maintain the conditions that support life on Earth. Forested areas cover almost a third of the planet's total land area, although a little more than half of the world's forests fall within the political boundaries of just five countries--Russia, Brazil, Canada, the United States, and China.[302] Forests house enormous biodiversity on Earth, help with hydrologic and heat cycles, and act as sinks that sequester carbon from the atmosphere. Their destruction poses regional and global risks to climate regulation, watershed stability, flood control, and soil stability. The benefits of forests—and the potential security risks inherent in their degradation, from economic to health to even armed conflict—have not been extensively assessed and are inadequately reflected in today's policies and decision-making practices.

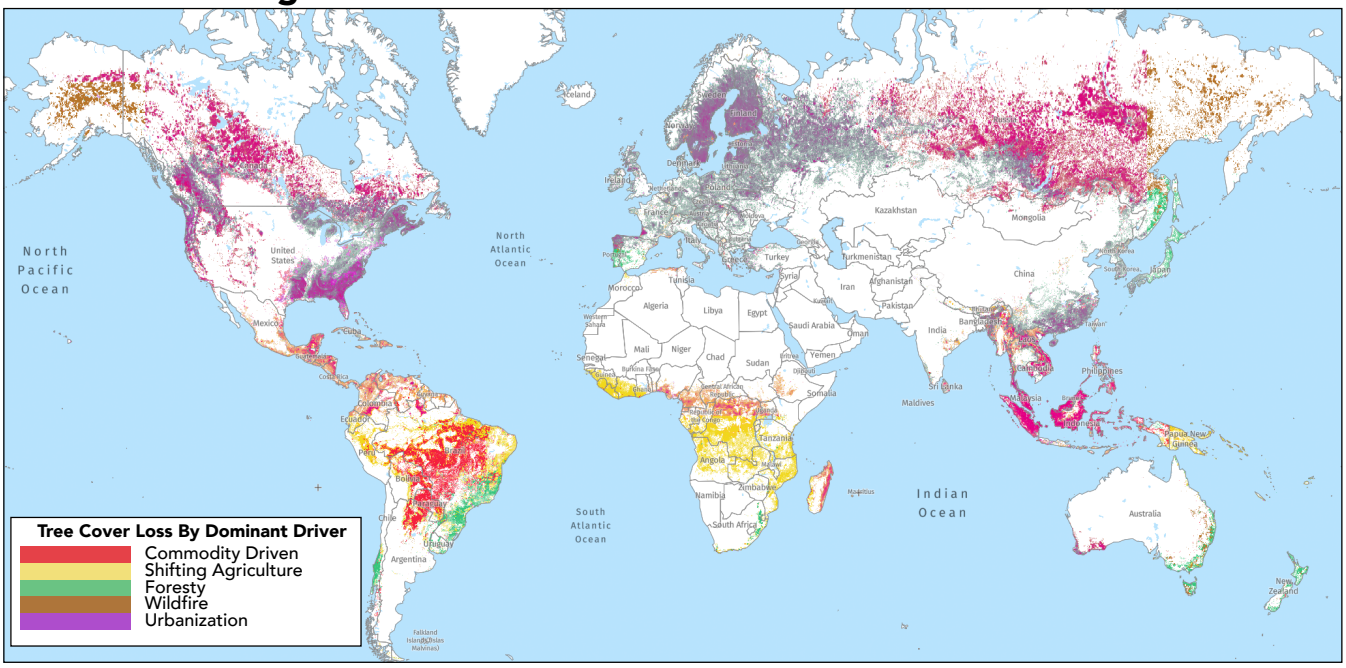
DEFORESTATION

The world's net forested area has decreased for several decades, although the loss rate has decelerated significantly since 2010, according to the UN.[303] An estimated 10 million hectares of forests per year on average have been deforested between 2015 and 2020, and despite forest regrowth—over 90 percent of it occurring naturally—the last decade has still seen a net loss of roughly 4.7 million hectares per year. While these rates are an improvement from the 1990s, they still have alarming implications for the biodiversity that is critical for the health, agriculture, and livelihoods of hundreds of millions of people.[304]

However, global statistics mask regional forest decline trends. Since 2010, Africa and South America have witnessed large net losses of forest area, while Asia and Europe have experienced net gains in forest area. North America and Oceania, meanwhile, have hovered close to net zero forest loss.[305] Brazil, Indonesia, Sudan, Burma, Zambia, Tanzania, Nigeria, the Democratic Republic of the Congo, Zimbabwe, and Venezuela face the highest rates of deforestation in the world.[306]

Deforestation differs from other forms of forest disturbance because it represents a permanent conversion of forests to other land use. A 2018 study indicates that 27 percent of global forest loss over the period 2001 to 2015 can be attributed to permanent land use change for production of commodities, such as agriculture, mining, or energy.[307] Commercial and subsistence agriculture practices drive over 70 percent of deforestation.[308]

Figure 15. Global Tree Cover Loss from 2001 to 2019



Source: World Resources Institute Global Forest Watch

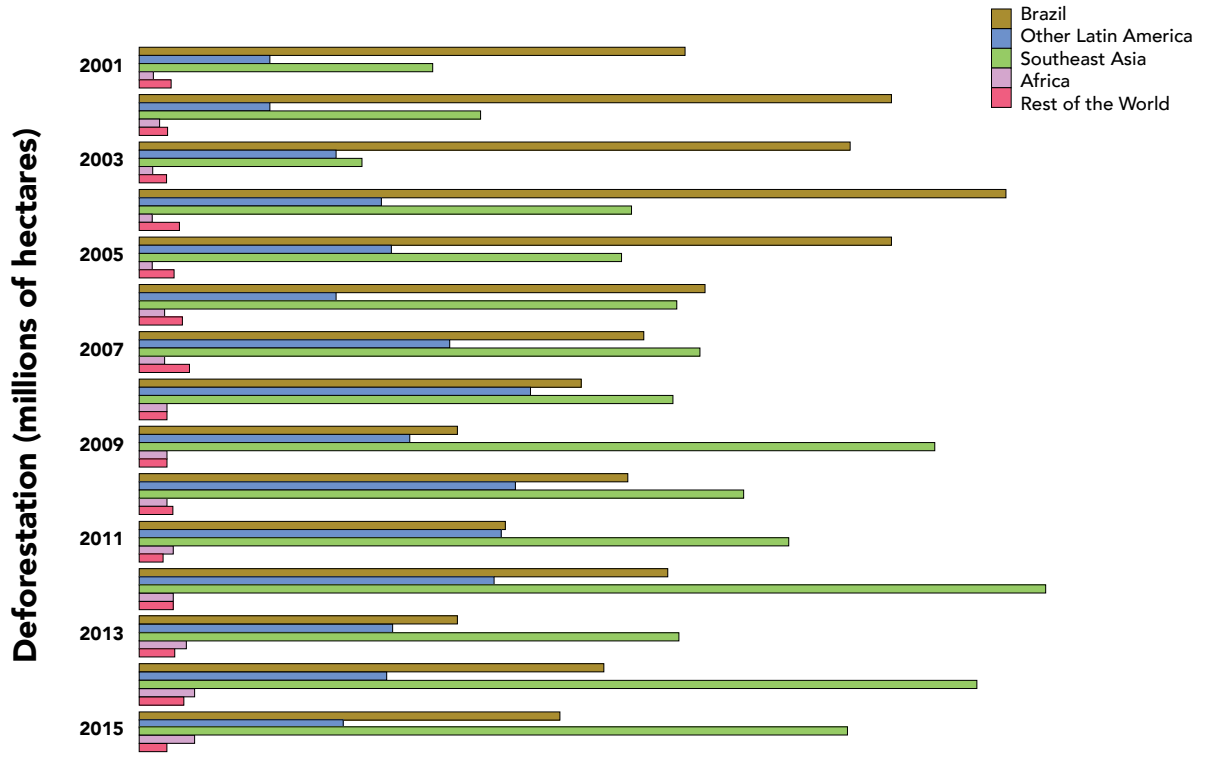
Despite being tied to only seven percent of deforestation, mining creates some of the most long-lasting and damaging incidents of forest damage.[309] High quantities of acids, organic compounds, sulfates, cyanides, and inorganic substances, such as mercury and arsenic, all have harmful effects on forest systems, especially when unmitigated. Parts of Africa and Asia have become hot zones for extensive illegal mining practices, which are difficult to monitor. Many such illegal mines pump silt and heavy metal contamination directly into rivers and water sources.[310] An analysis of roughly 500 satellite images from 2017-2018 showed that gold mining had destroyed almost 23,000 acres of the Amazon, according to a 2019 NGO report.[311]

Commodity-driven deforestation is concentrated in Latin America, primarily for cattle grazing and crop production, and Southeast Asia, where palm oil cultivation is a primary cause, according to a 2018 scientific article.[312] Other drivers of forest loss are forestry activities (26 percent), shifting agriculture (24 percent), wildfire (23 percent), and urbanization (less than 1 percent), according to the same study.[313]

ECOLOGICAL REPERCUSSIONS

The Amazon has undergone extensive ecological change. Scientific models suggest two possible "points of no return", either of which could drive the forest ecosystem towards a new ecological state (see savannization, Page 18): A warming of 4°C or deforestation that exceeds 40 percent.[314] The economic production of this cleared land for farming is not high, however, especially when compared to the high-value products and irreplaceable ecosystem services that the same acreage of forest provides when left intact. Forest degradation in the tropics is a primary driver of biodiversity loss, which has concomitant risks for humans and societies.

Figure 16. Commodity-Driven Forest Losses 2001-2015



Adapted from Curtis, Science (2018)

Forests also contribute to hydrological cycles. Deforestation in the Amazon rainforest has reduced inland vapor transport contributions, such as atmospheric rivers, by 40 percent or more; this has extended dry spells in the immediate region and shifted global water patterns, creating a wetter southern hemisphere and a drier North America.[315] A 2013 survey of North American forests indicated that for every 10 percent increase in forest cover in a water supply catchment, water treatment costs decreased by approximately 20 percent.[316] Forest cover both increased security of supply and led to reduced pollutants in the water.

FORESTS AND GLOBAL HEALTH

A growing body of scientific evidence indicates that forest loss and declines in forest integrity drive increases in some human infectious diseases. For example, two years before the beginning of the COVID-19 pandemic, a 2018 scientific article predicted that long-term deforestation patterns in Asia could spark an emergent bat-coronavirus disease.[317] Brazilian bats are known to harbor over 3200 types of coronavirus, suggesting that the high rate of Amazon forest loss may prompt the region to emerge as another deforestation-coronavirus nexus.[318] The probability of an Ebola outbreak is increased substantially by recent deforestation, while many mosquito-borne diseases, such as malaria and dengue fever, are similarly favored by forest loss.[319] [320]

DISPLACEMENT

The rapid pace of forest conversion can cause severe dislocation of people and contribute to migration and social disruption. In Indonesia, for example, palm tree plantations have displaced millions of indigenous people who rely on the provisioning services of the forest, according to a Human Rights Watch report.[321] In the Amazon, wildfires and deforestation have restricted indigenous peoples' access to ancestral lands and their ability to hunt which encourages migration to more urban areas. While migration can offer new livelihood and education opportunities, indigenous groups can experience discrimination as both migrants and indigenous peoples are forced to move to a new area.[322]

As large corporations consolidate and expand land for commercial agriculture, rural small-scale farmers are also being pushed out by high land costs and soil exhaustion from high-intensity farming.[323] In the Ecuadorian Amazon pressure over land has led to deforestation where agricultural output is eventually exhausted, causing out-migration to other rural and pristine forest areas, which then creates more deforestation in a feedback loop.[324]

CHARCOAL AND CONFLICT FINANCE

Charcoal, a concentrated energy source obtained from burning wood in a low-oxygen environment, contributes to deforestation. From 2000 to 2010 charcoal production was the leading cause of forest degradation in Africa, followed by timber logging.[325] The charcoal and fuelwood industries generated $33 billion USD in 2011 and employed over 40 million people commercially (with nearly 900 million people involved in a non-commercial capacity).[326]

Extortionate taxing of charcoal provides a source of revenue to militias and terrorist groups across Africa. As late as 2018, Al Shabaab's primary revenue source was charcoal, funding numerous violent attacks in Somalia and Kenya, according to the UN.[327] Militia and terrorist groups in the Central African Republic, Democratic Republic of Congo, Mali, and Sudan also derive substantial revenues from illicit charcoal, according to the same source.[328]

NARCO-DEFORESTATION

The illegal narcotics trade has likely fueled deforestation in some regions.[329] Starting around 2007, cocaine traffickers reportedly escaped increasingly vigorous U.S. counter-narcotic efforts in Mexico and moved southward to Guatemala, Honduras, and Nicaragua, where forests were cleared for clandestine airstrips and roads, according to a 2014 scientific report.[330] Further, forests were converted into agricultural businesses in order to launder drug profits, according to the study's authors. Similar patterns of forest loss were not found in Costa Rica, El Salvador, and Panama because, according to the report, money laundering through hotels and banks was more accessible.[331]

Ibama confiscates 7,387 logs illegally extracted from the Pirititi Indigenous Land, in Roraima (Brazil). Felipe Werneck/Ibama via Flickr

ILLEGAL LOGGING

Illegal logging is the harvesting of wood in contravention of national and international regulations. These activities included obtaining timber from protected areas, logging protected species, or exceeding quotas of legal timber. Illegal logging activities have been documented wherever there are forests, but most often occur in countries with weak governance and law enforcement capabilities. Tropical rainforests, such as those found in the Amazon and Southeast Asia, and the boreal forests of Russia's Far East, are noteworthy illegal logging hotspots.

Figure 17. Illegal Logging Spans the Globe

Africa	Asia	Europe	South America
Angola	Burma	Estonia	Bolivia
Cameroon	Cambodia	Latvia	Brazil
Democratic Republic of Congo	Indonesia	Romania	Colombia
Gabon	Laos	Russia	Guyana
Ghana	Malaysia		Paraguay
Liberia	Papua New Guinea		Peru
Republic of Congo	The Philippines		
South Sudan	Thailand		
Tanzania	Vietnam		
Zambia			

Source: Adapted from Wyatt, Environmental Crime and Social Conflict (2015)

Incidents of illegal logging have been reported in many countries across the world.

ECONOMIC DAMAGE

The exact scale and scope of illegal logging is difficult to assess. Confounding factors include the clandestine nature of illegal activities, the isolated nature in which forest crimes tend to occur, and the lack of experience or desire to monitor illicit timber shipments. Freely available satellite imagery has greatly enhanced and democratized the ability to monitor logging activities, although there are some indications that illegal loggers cut down smaller forest patches to thwart overhead detection. Reports of illegal logging in many forested countries (see Figure 17) lead to some estimates that the global percentage of illicit timber may be between 50 to 90 percent.[332] The top consumers of international illegal logging products are China, India, Japan, the United States, and countries with the European Union.[333]

Illegal logging causes enormous economic damage. A 2019 World Bank report estimated that the market losses from illicit timber were $30 to $157 billion dollars annually and lost tax revenues from $6 to $9 billion dollars annually.[334] The economic valuation of the global loss of regulating services, such as carbon sequestration, and cultural services, such as tourism, from illegal logging were estimated at $838 billion to $1.74 trillion dollars annually.[335] Some studies indicate that illegal logging suppresses global timber prices by 7 to 16 percent, which would deprive legal timber companies of substantial revenues. In the United States, for example, this translates to an estimated $460 million to $1 billion lost per year.[336]

Illegal rosewood and other tropical hardwoods are increasingly entering legal supply chains. Around 2011, Chinese demand for rosewood (a trade term that describes a wide range of tropical hardwood and is not a botanical category) drove huge market surges, according to a scientific study.[337] Quantifying trade in illicit rosewood is complicated because their entry into legal markets obfuscates possible illicit origins. Lines have been further blurred in ways that have allowed market loopholes to be exploited, such as a Convention on International Trade in Endangered Species (CITES) amendment to permit trade of musical instruments made of rosewood.[338] Still, from 2014 to 2018, rosewood comprised 31.7 percent of all illegal wildlife seizures, the largest percentage of all species.[339] CITES permits have been forged or questionably issued in a sophisticated laundering scheme of Nigerian timber, according to a 2017 NGO report.[340]

POLITICAL INSTABILITY

Illegal forest activities, including illegal logging, result from failed management policies and poor governance, which have been a well-documented influence on the regional unrest and conflict in forested regions of Africa, Asia, and Latin America. A consistent theme of illegal exploitation of forests is that corruption and trade hurt national economies, but the burdens fall disproportionately on local forest communities and indigenous people that rely closely on the ecosystem services for their livelihoods.[341] Between 1950 and 2000, over 80 percent of all armed conflicts occurred in forested regions and other biodiversity hotspots. In addition to ecological damage in the immediate conflict zones, state resources are funneled away from conservation and other initiatives to support military efforts.[342]

Illegal timber trade revenue finances violent conflicts in many countries, and creates havens for illicit drug activities that can proliferate in forested regions that lack effective governmental oversight. These markets shift power to non-state forces involved in organized crime and corruption, which in turn drives widespread violence that further renders any fledgling conservation or forestry practices ineffective.

Illegal logging and deforestation have prompted protests and violence towards forest defenders in some countries. In the past few years, Romania has seen thousands of citizens protesting rampant illegal logging in the Carpathians, believed to be the most extensive in Europe, leading to associated violence.[343] The country's forestry service has counted nearly 200 assaults on its staff, including six murders.[344] Murders and violence associated with defending forest land have also been reported in Brazil, Cambodia, Colombia, Costa Rica, Democratic Republic of Congo, Honduras, Indonesia, Malaysia, Papua New Guinea, Peru, the Philippines, and Russia.[345] [346] [347]

When looking at post-conflict regions, forest integrity often suffers when governments allow timber extraction and land conversion practices to return. After a 2016 peace deal was secured with the Revolutionary Armed Forces of Colombia (FARC), deforestation in Colombia increased 44 percent in the first year.[348] Illegal logging also undermines legitimate forest activities, robs governments of revenue, and poses threats to sustainability by crippling a state's resource wealth.

CASE STUDY: THE TIMBER MAFIA OF PAKISTAN

Fuelwood, a critical component of Pakistani domestic energy needs, has been a primary factor for the country's rapid rate of deforestation, estimated in the early 2000s to be the second highest rate in the world. Despite legal protections of certain forested areas when commercial harvesting began in the 1970s, government permits were not reflected in official harvest reports. Also, during this time, an unofficial "timber mafia" emerged that dominated markets, initially by collecting dead timber and later to harvest trees subsequent to the commercial ban in 1987.[349] Commercial harvesting has eroded the forests to the point where even small-scale activities are detrimental.[350]

From 2000 to 2010 Pakistan lost roughly 43,000 hectares of forest annually, reducing forest coverage to just 2 percent of the country. The converted land was often illegally transformed from floodplains to farming, straining irrigation systems as landlords and government officials profited or turned a blind eye.[351] These circumstances are particularly precarious since climate change is already expected to strain the heavily agriculture-dependent economy of an important U.S. strategic partner. Pakistan ranked fifth on the list of countries most vulnerable to climate change in Germanwatch's Global Climate Risk Index 2020.[352]

The threat posed by extensive deforestation went largely unnoticed for decades, but the 2010 monsoon season drove catastrophic destruction that the riverine forests could no longer diffuse, resulting in the storm surges and that swept away more than 60,000 miles of natural and human landscapes.[353] In 2018, Pakistani Prime Minister Imran Khan began the 5-year Plant4Pakistan project.[354] The program, which promises to plant ten billion trees in that time, was halted at the beginning of the COVID-19 pandemic, but then resumed in a job creation movement that employed over 60,000 people and prioritized women and young people in rural areas. The project's $46 million in funding pales in comparison to the $3.8 billion lost in the previous two decades of extreme weather events, doubling as an economic stimulus and a mitigation against rising temperatures and future flood events.[355]

FISHERIES

Fish and its derivatives are a critical source of protein, comprising approximately 20 percent intake of animal protein for approximately 3 billion people globally.[356] At an average annual rate of 3.1 percent per year, the global growth rate of fish consumption is almost twice the rate of population growth.[357] Bangladesh, Cambodia, the Gambia, Ghana, Indonesia, Sierra Leone, Sri Lanka, and several small island states are particularly dependent on fish, consuming 50 percent or more of their protein through fish products.[358]

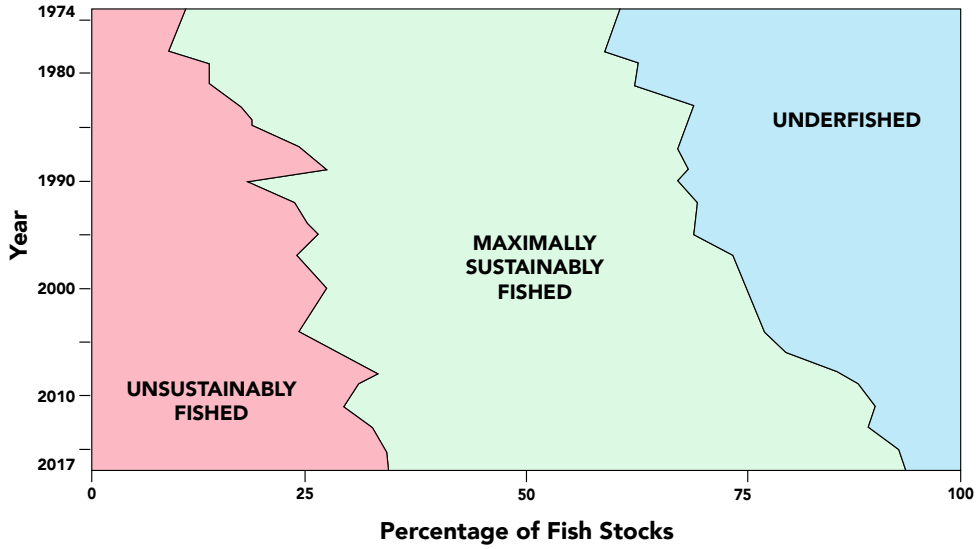
Many people derive their livelihoods through various parts of the fishing industry. In 2018, nearly 39 million people were engaged, to some degree, as fishers while over 20 million people were fish farmers (aquaculture). The vast majority of people dependent on fisheries for employment are in Asia, at 85 percent, while 10 percent worked in Africa and 4 percent in Latin America and the Caribbean.[359]

OVERFISHING

Global overfishing has increased steadily over the past decades, as measured by the percent of marine fish stocks extracted beyond sustainable limits, according to the UN. At the same time, underfished stocks in which yields could be safely expanded has dropped to under 10 percent of global stocks (See Figure 18).[360] Some scientists paint a much bleaker picture of overfishing through reconstruction of unaccounted catches (see IUU fishing); these estimates indicate that marine fisheries have been declining rather than plateauing since the mid-1990s.[361] Overfishing is especially prevalent in some oceanic regions, such as the Mediterranean and Black Sea, Southeast Pacific Ocean, and Southwest Atlantic Ocean.[362]

Overfishing has been catalyzed by the increasing industrialization of fishing vessels and methods. Approximately 3.2 million fishing vessels operate in marine waters, with greater numbers of trawlers, long-liners, and dredgers being used.[363] Technological improvements in gear design, fish finding and catch handling produce large increases in fishing effectiveness, particularly when they are implemented throughout a fleet in a short period of time.[364]

Figure 18. Sustainability Trends in Marine Fisheries



Adapted from State of the World's Fisheries and Aquaculture, UNFAO (2020)

The sustainability of marine fish stocks is declining as the number of underfished stocks decreases and the number of unsustainably fished stocks increases. Ideally, the number of maximally sustainably fished stocks would increase with time but has instead remained essentially constant since 1974.

FISHERIES AND CONFLICT

Militarized interstate disputes over fisheries raise the specter of future intensified conflicts as fish stocks dwindle or move. Since 2007, Iceland, Norway, the EU, and the Faroe Islands have been tangling in the so-called 'Mackerel War', prompted by Atlantic mackerel stocks shifting northward by warming waters.[365] [366] Disputes over inland freshwater fisheries have also been associated with conflict, such as reductions in Nile perch sparking violence between Kenya and Uganda on Lake Victoria in the late 2000s.[367]

In recent years, international tensions have simmered over dwindling fish stocks in the South China Sea, an increasingly militarized maritime region responsible for about 12 percent of the global fish catch and more than 50 percent of fishing vessels.[368] Aggressive and sometimes violent fishing disputes are increasingly common between China, Indonesia, Vietnam, and the Philippines. The risk of conflict in the South China Sea grows precipitously as the compound pressures on fisheries from overexploitation, pollution, and climate change intermingle with increasingly nationalized rhetoric from regional actors and the United States.

The United States has joined international pushback on China's nine-dash line claims, which are based on a mid-20th century mapping of their sovereignty in the region.[369] Tensions have flared between the two countries, in part due to U.S. government rhetoric about China's purported responsibility for the COVID-19 pandemic. At the same time, China has furthered its maritime activities in the South China Sea by conducting military exercises, ramming foreign vessels and repurposing reefs and atolls into fully constructed military facilities.[370]

Chinese aggressive fishing activities have also moved beyond Asia waters and into the coasts of Africa, threatening economic and food security as well as sovereignty claims. Media reports have implicated illegal Chinese fishing vessels in waters off the African nations of Cameroon[371], Gabon[372], the Gambia[373], Ghana[374], Liberia[375], Madagascar[376], Morocco[377], Mozambique[378], Namibia[379], Republic of Congo[380], Senegal[381], Sierra Leone[382], South Africa[383], and Tanzania.[384] Other countries, such as South Korea, Russia, Spain, and Thailand, also maintain a significant fishing presence off Africa.[385]

AQUACULTURE AND DISEASE

A serious constraint to aquaculture is the cyclical emergence of disease, which spreads within and between populations of fish and other marine animals. Small areas packed with large numbers of fish provide an environment conducive for the effective spread of pathogens while the cramped conditions make individuals more susceptible to infection.[386] Water pollution, limited water flow, and inadequate knowledge of aquatic pathogens all contribute to major production losses roughly every three to five years. Few drugs exist for treating fish disease.[387]

IUU FISHING

The term *illegal, unreported, and unregulated (IUU) fishing* refers to an expansive set of fishing activities that undermines the sustainable management of fish stocks. *Illegal* fishing refers to fishing activities conducted in violation of applicable laws and regulations, including both regional and international laws. *Unreported* fishing refers to fishing activities that are not reported or intentionally misreported to proper authorities. *Unregulated* fishing refers to fishing activities in areas where there are no applicable conservation or management measures, such as outside a country's exclusive economic zone (EEZ) or not under the jurisdiction of a regional fisheries management organization (RFMO). Fishing activities in which vessels fly a flag of a state not party to a particular RFMO are also considered unregulated fishing.[388]

ECOLOGICAL REPERCUSSIONS

IUU fishing poses a critical risk to the stability of several critical ecosystems on which societies are highly dependent. Coral reefs, already under pressure from warming oceans and toxification, suffer from destructive fishing methods such as dynamite and cyanide fishing. The sustainable management of fish stocks is greatly undermined when IUU catches are not included within scientific assessments. IUU fishing increases bycatch, the incidental catch of non-targeted species, which disrupts marine food networks and, upon decomposition, contributes to ocean dead zones. Developing nations with weak maritime governance are especially affected, where over half of fish resources are removed illegally.

ECONOMIC DAMAGE

The economic damage accrued from IUU fishing is immense. Globally, IUU fishing deprives nations of an estimated 8 to 14 million tons of fish annually, according to a recent report.[389] At estimates ranging from $11 to $36 billion, the corresponding net economic loss is larger than the gross domestic product (GDP) of every nation except the United States and China.[390] Since less than 10 percent of IUU fishing occurs on the high seas outside of any country's EEZ, coastal nations suffer disproportionately.[391] Some countries incur economic damage that is a significant fraction of their GDP (see Figure 19).

Figure 19. National Economies Most Affected by IUU Fishing

(as fraction of GDP)

Country (Africa)	Annual Loss (USD/yr x 10^6)	GDP (USD/yr x 10^6)
1. Guinea-Bissau	189 – 303	1,390
2. Mauritania	654 – 1,047	7,430
3. Guinea	380 – 609	14,200
4. Somalia	121 – 194	4,920
5. The Gambia	38 – 62	1,810

Country (Asia)	Annual Loss (USD/yr x 10^6)	GDP (USD/yr x 10^6)
1. Cambodia	288 – 460	26,320
2. Burma	269 – 431	70,890
3. Malaysia	940 – 1,514	336,330
4. Yemen	46 – 76	20,950
5. Maldives	9 – 15	4,710

Country (Americas)	Annual Loss (USD/yr x 10^6)	GDP (USD/yr x 10^6)
1. Suriname	8 – 14	2,540
2. Peru	262 – 427	195,760
3. Saint Kitts & Nevis	1.1 – 1.8	870
4. Venezuela	36 – 59	48,610
5. Chile	159 – 260	245,510

Country (Oceania)	Annual Loss (USD/yr x 10^6)	GDP (USD/yr x 10^6)
1. Kiribati	0.07 – 0.12	190
2. Tuvalu	0.02 – 0.03	50
3. Samoa	0.13 – 0.22	830
4. Tonga	0.059 – 0.099	500
5. Fiji	0.38 – 0.62	3,930

Sources: Suamila (2020), International Monetary Fund (2020)

MARITIME PIRACY

Connections between IUU fishing and maritime piracy are well-established. Somali pirates were a threat off the Horn of Africa from the early 2000s to about 2013, purportedly pushed into these activities by the collapse of the Somali government and incipient illegal fishing by international vessels. A 2012 study of 2,600 piracy incidents worldwide concluded that states with depressed values of fisheries production and state weakness were more likely to experience piracy.[392] This linkage is bolstered by NGO-conducted interviews with Somali pirates themselves, who overwhelmingly pointed to foreign illegal fishing activities as a primary point of grievance.[393] Recent upswings in piracy in West Africa's Gulf of Guinea are also likely connected to both IUU fishing and intensified industrial fishing activities, according to a 2019 report.[394]

FISHERIES AND FORCED LABOR

Forced labor in the fishing industry, on fishing vessels and in fish processing centers, is believed to be substantial although the empirical data necessary to evaluate its scale remains sparse. Victims can be ensnared into forced labor by apparently real employment opportunities, however once enlisted find themselves trapped by physical internment, debt, wage retention, and threats of violence toward themselves or family members. Reports of child workers on fishing boats and in shrimp hatcheries and processing plants are common.[395] [396] [397]

Fishers are increasingly vulnerable to human trafficking because depleted fish stocks erode the already low-profit livelihoods necessary to provide for themselves and their families. Distant water fishing in remote areas away from monitoring increases the vulnerability of crews to exploitation. The most well-documented instances of forced labor in the fishing industry have been in Southeast Asia, according to the UN.[398]

Forced laborers can face horrifying working and living conditions at sea. Working hours can hover around 18 hours a day with no overtime pay, according to some reports, often on injurious or deadly tasks.[399] [400] Sleeping quarters are often crowded with "cardboard mattresses stacked less than a meter above one another," according to a UN report.[401] Victims have become malnourished and ill from excessive exposure to sun and ocean water.

CASE STUDY: CHINESE FISHING TRAWLERS OFF THE GALAPAGOS

In July of 2020, Ecuador reported the existence of a fleet of roughly 260 Chinese fishing vessels just beyond the 188-mile Exclusive Economic Zone (EEZ) of the Galapagos, setting off another skirmish in an ongoing series of geopolitical clashes with China over its fishing activities.[402] Fishing disputes in the South China Sea have grown increasingly hostile and African nations increasingly fear threats to their food security and sovereignty. Conflicts are exacerbated by murky territorial claims, EEZs and fishing rights and China's increasingly aggressive maritime presence.

The presence of Chinese ships off Latin America is not new. In 2017 the Ecuadorian navy caused intense outrage in Beijing when it seized a Chinese cargo vessel carrying 300 tons of fish, including endangered shark meat, and jailed 20 crew members.[403] Reports of Chinese trawlers off South America have become increasingly common.

United States and China Coast Guards interdict vessel for illegally fishing on the high seas.

Coast Guard Cutter Morgenthau / U.S. Coast Guard / Flickr

China's fishing presence off Ecuador in July 2020 seems to be on an unprecedented scale for Latin America, however. Furthermore, just a few weeks later, Ecuadorian military surveillance saw the fishing fleet swell to 340 ships that can mostly carry up to 1,000 tons of catch each. Fishing typically takes place in international waters off the coasts of Peru and the Galapagos, but officials say there is a huge threat posed to migratory species who may move beyond the 200-mile zone boundary and be overfished by the Chinese fleet.[404]

China seems similarly emboldened in their actions near the Galapagos EEZ, sending one of their largest fishing fleets in years. Initial statements by the Ecuadorian government focused on diplomacy and protecting migratory species through international agreements, or establishing marine corridors via the EEZs of neighboring countries along the Pacific.[405]

The Chinese Foreign Ministry announced a fishing ban from September to November and condemned illegal fishing, but their approach was met with scrutiny by conservation groups arguing that the ban simply coincides with the natural end of the season and fails to offset the depletion from the previous months. The United States and China have offered contradictory statements on the status of the fleet and its practices in the area, leading to further escalated tensions and accusations of misinformation. Ecuador has completed military exercises with the U.S. while reporting that nearly half of the ships have disabled their tracking, yet they also are implementing austerity measures and working to restructure their $6.5 billion oil-backed debt to China, which drove them to leave OPEC in January of 2020.[406]

The September ban was focused on waters near the Galapagos EEZ, which drove the Chinese fleet south to just beyond the Peruvian and Chilean coasts. This has led Peru and Chile to join Ecuador and Colombia in a mutual cooperation and information sharing pact to combat all instances of illegal fishing in the future.[407]

V. OUTLOOK

As discussed in Sections III and IV, the state of global ecological disruption is dire. Still, it would be worse, perhaps catastrophically so, if not for several decades of ecological and environmental protection policies and actions. Some of the more recent U.S. efforts are described below. The future of ecological security is also briefly explored, as well as some intriguing insights from horizon scans from the past five years on what issues may emerge in ecological security.

RECENT RELEVANT U.S. POLICIES AND LAWS

WATER

In 2014, President Obama signed into law the **Paul Simon Water for the World Act**, which had extensive bipartisan support. This legislation directs the State Department to develop a government-wide water strategy every five years to further U.S. foreign policy, development, and security objectives internationally. The Trump administration issued the 2017 **U.S. Global Water Strategy** that focused on four strategic objectives: "(a) Promote sustainable access to safe drinking water and sanitation services, and the adoption of key hygiene behaviors; (b) Encourage the sound management and protection of freshwater resources; (c) Reduce conflict by promoting cooperation on shared waters; and (d) Strengthen water sector governance, financing, and institutions."[408] International water issues are also supported by the **U.S. Global Water Partnership**, established in 2012, which organizes and mobilizes resources from a network of private-public partnerships.

Water issues remain fragmented across many government agencies, however, and most focus on sanitation and hygiene. There is little sustained U.S. focus on water as a component of global security.[409]

FOOD

The U.S. government's signature effort in increasing global food security is the **Feed the Future Initiative** launched in 2010 by the Obama administration, built on George W. Bush-era efforts to increase aid for food security after the price shocks of 2007-08. Developed by the Department of State and implemented primarily by the United States Agency for International Development (USAID), the main objectives of the $3.5 billion program are to advance global agricultural development, increased food production and food security, and improved nutrition, particularly for vulnerable populations. Independent studies indicate that Feed the Future has been largely effective in its mission, with notable improvements in nutrition-associated outcomes such as stunting and underweight children.[410]

President Obama signed the **Global Food Security Act** in 2016, which codified most of the objectives of Feed the Future into law. The three stated objectives of the **U.S. Global Food Security Strategy** are: "(a) Inclusive and sustainable agricultural-led economic growth; (b) Strengthened resilience among people and systems; and (c) A well-nourished population, especially women and children."[411] It is not clear from the strategy itself whether the U.S. seeks geostrategic outcomes from its food security programs, such as minimizing the risks of food-related conflict or political instability.

OCEANS

The **National Ocean Policy** was established in 2010 by the Obama White House, in partial response to the Deepwater Horizon disaster. Built on more than a decade of efforts under prior administrations, the policy directed the government to consider the ecological, economic, and social dimensions in their entirety when making decisions regarding ocean management, with explicit protections for marine biodiversity and support for ocean sustainability. President Trump repealed the eight-year-old National Ocean Policy, replacing it with an Executive Order that gave more responsibility of ocean stewardship to states for offshore oil and gas extraction. According to a Harvard Law review, the order also prioritized "economic growth and national security, rather than preserving the ecological health of the ocean."[412]

The Obama administration expanded many marine protected areas created by President George W. Bush, and added new ones. In 2014, President Obama expanded sixfold the **Pacific Remote Islands Marine National Monument**, which now covers 490,000 square miles. In 2016, Obama quadrupled the size of the Bush-era **Papahānaumokuākea Marine National Monument** to 583,000 square miles. Also in 2016, the Obama Administration added the first national monument in the Atlantic, the **Northeast Canyons and Seamounts Marine National Monument**, and was instrumental in the creation of the world's largest marine protected area later that year in Antarctica's Ross Sea under the Commission for the Conservation of Antarctic Marine Living Resources. In 2020, the Trump administration proclaimed it was easing restrictions on commercial fishing within the Northeast Canyons marine monument, and considered similar rollbacks in other marine protected areas.

ENVIRONMENTAL CRIME

Recent efforts to combat **wildlife trafficking** have evolved after the U.S. government began to identify it as a security threat. In 2013, the Obama administration issued an Executive Order that established a Presidential Task Force on Wildlife Trafficking, which issued a **National Strategy for Combating Wildlife Trafficking**. The **Eliminate, Neutralize, and Disrupt (END) Wildlife Trafficking Act of 2016** codified the Task Force in law, and directed $10 million in training aimed at countering corruption, illicit revenues, and the spread of zoonotic disease. In 2017, the Trump administration issued an Executive Order calling for disrupting transnational criminal groups, including those engaged in wildlife trafficking. In response to the COVID-19 pandemic, Senators Booker and Cornyn introduced a bill that would prohibit the purchase and sale of all wild species for food or medicine, and close all markets that served that purpose.

The United States has several laws and policies that address **illegal logging**. Imports of timber can be banned or regulated if the species is listed under the Endangered Species Act. Under **The Lacey Act**, U.S. companies that illegally import timber are subject to civil and criminal penalties. The **Tropical Forest Conservation Act** allows some countries to restructure debt towards the conservation of tropical forests. The U.S.-developed **Congo Basin Forest Partnership** has sanctioned foreign countries because of illegal logging. The U.S. also addresses some aspects of illegal logging through bilateral agreements, such as with Peru.[413]

In 2014, the U.S. Senate ratified the **Port State Measures Agreement** (PSMA), an international treaty designed to prevent and eliminate **IUU fishing** and seafood fraud. The treaty requires that fishing vessels obtain permission for docking at ports and share details of its fishing operations, and permission can be denied if unregulated fishing has occurred. Other aspects of the treaty include inspections of equipment, catches, and ship's records. However, of the 25 riskiest port states, only four had ratified the PSMA, according to a 2020 NGO report.[414] In 2015, President Obama also signed into law the bipartisan bill **The Illegal, Unreported, and Unregulated Fishing Enforcement Act**. In 2020, President Trump issued an Executive Order that, among other things, requires further implementation of regulatory actions under the PSMA while directing Federal agencies to improve the effectiveness of fisheries law enforcement.

INTERNATIONAL CONSERVATION STRENGTHENS NATIONAL SECURITY

The benefits derived from the conservation of species and habitats go beyond the natural environment. International conservation is essential to the security and survival of the human population as it can protect human health, assure food and water security, and reduce levels of environmental crime. Populations that receive their physiological and safety needs are less prone to conflict and political instability as the needs and interests between different groups are being met. Conservation is essential to maintaining ecosystem function and sustaining livelihoods which are reliant on strong biodiversity and Earth's finite natural resources.

As of 2019, approximately 15 percent of the world's terrestrial surface falls within protected areas, somewhat short of the 17 percent target under the Convention on Biological Diversity Strategic Plan for Biodiversity

2011-2020. Protected areas dampen extinction risk by at least twofold and probably much more, according to a scientific article.[415] The buffering effect that these protected areas have on extinction risk was found worldwide, but higher for regions with larger remaining extents of wilderness.

Primary forests, those forests that have experienced little to no human interference, deserve special mention because of their crucial role in both sustaining biodiversity and offsetting the effects of climate change. While forests generally encompass much of Earth's ecosystem, species, and genetic diversity while also storing vast quantities of carbon, this is especially true for primary forests. In many regions, especially in temperate and tropical zones, little primary forest remains while forest fragmentation also contributes to the loss of ecological function.

Secondary forests that arise from reforestation or recovery after disturbance provide comparatively inferior ecological and climate protection. The process of returning to primary forest condition is generally slow. For example, forest regeneration in the Congo Basin can take up to fifty years and over 150 years for some temperate forests.[416] [417] Hence, while rapid afforestation programs such as "trillion tree" initiatives should be applauded, they should be considered lesser and more expensive efforts than protecting primary forests in the first place. There is also growing evidence that grasslands are more reliable carbon sinks than forests.[418] Furthermore, most scientists judge that climate policies will be at best modestly effective if they don't directly address reducing greenhouse gas emissions significantly by the middle of the century. It is possible that attempts to rapidly regrow forests will have unintended damaging effects, such as on hydrological cycles and existing ecosystems and species.

FUTURE TRAJECTORIES

The concept of "saving the planet" through environmental policy and protection is misleading. Earth's systems operate on timescales of millions of years, and the planet will continue to exist long after people are gone. What *is* at stake is the trajectory of organized human civilization. In time, it is possible—optimists might even say probable—that innovation, resolve, or survival instincts will kick in and we find a way to steer the climate out of dangerous territory, rebalance biogeochemicals such as nitrogen and phosphorus in our soils and waters, and detoxify the air and oceans. What is certain, however, is that our role in expediting the extinctions of species, an irreversible deletion of genetic information from the biosphere, has shaped the evolutionary trajectory of the Earth.

The 2019 IPBES report found that the primary drivers of extinction and other losses of biodiversity are, in descending order: (a) Changes in land and sea use; (b) Direct exploitation of organisms; (c) Climate change; (d) Pollution; and (e) Invasive alien species. Three of these drivers, (a, c, and d) are also important factors in water and food stress, four (a, b, c, and e) are important in forest integrity, and all five are also drivers of fisheries declines. All five drivers also contribute to emerging infectious diseases and other aspects of global health. Important sub-drivers include the growth and changing demographics of the global human population, which requires more resources to feed, house, and employ people. Problems are worsened by institutions at all scales that narrowly view prosperity through a purely economic lens with little regard to associated damages to ecological support systems and the security of human systems that depend on them. Globalization has accelerated or enabled many of these factors. Most of these drivers are human-caused and could, at least theoretically, be slowed or stopped by concerted international and national actions.

Climate change, on the other hand, is not only an increasingly consequential factor in ecological disruption, but also possesses an unfortunate lag time between climate action and observable change. This means that the multifaceted effects of climate change on extreme weather events, hydrological cycles, land, ice, the ocean, and the myriad components of the biosphere will continue for some time,[xvii] even after efforts to draw down atmospheric greenhouse gas emissions kick in.

The effects of climate change will fall on people and societies already undermined by the other drivers of ecological disruption, unless aggressive offsetting efforts are enacted. In other words, stopping and reversing the trends undermining ecological stability are a crucially important component of decreasing the vulnerability of people to locked-in climate change already in the pipeline. Of course, ecological disruption poses a significant threat to humanity in its own right, irrespective of effective action on climate change. Without transformative actions on both climate change and ecological disruption, the future portends a dangerous period ahead of ecological, political, and socioeconomic collapse, punctuated with conflict, political instability, loss of social cohesion, infectious disease, migration, and many dimensions of human suffering.

Plastic lining the beach in Sulawesi, Indonesia. Joleah Lamb / ARC CoE for Coral Reef Studies / Flickr

xvii The exact degree of this lag is a matter of scientific debate, but estimates range from years to several decades. The debate is somewhat academic since the likelihood of global greenhouse gas emissions being taken to zero in a short period of time is very low.

Box 2. Possible Emerging Factors in Ecological Security

Since 2009, the Department of Conservation Biology at Cambridge University has hosted an annual gathering of researchers, practioners, journalist, and other experts to participate in a horizon scan of issues that could have substantial ecological consequences. In other fields, horizon scanning has helped identify emerging issues well before the public or policymakers become aware of them. Issues with potentially substantial security implications are designated in **red**.

2016	Artificial Superintelligence in Conservation Changing Costs of Energy Storage and Consumption Models Ecological Civilization Policies in China	**Electric Pulse Trawling** Osmotic Power **Managed Bees as Vectors** **Unregulated Fisheries in the Central Arctic Ocean** **Increasing Construction of Artificial Oceanic Islands**	Increasing Aquatic Levels of Testosterone Effects of Engineered Nanoparticles on Terrestrial Ecosystems **Satellite Access to Shipborne Automatic Identification Systems** **Passive Acoustic Monitoring to Prevent Illegal Activity**	Synthetic Body Parts of Endangered Animals **Artificial Glaciers to Regulate Irrigation** Invasive Species as Reservoirs of Genetic Diversity
2017	**Manipulating Coral Symbionts to Avoid Mass Bleaching** The Use of Robots to Target Invasive Marine Species **Electronic Noses to Combat Illegal Wildlife Trade and Improve Biosecurity**	Bumblebee Invasions in New Regions Extensive Use of Bacteria and Fungi to Manage Agricultural Pests **Sand Becoming a Scarce Resource** Effects of Border Fences on Wild Animals	**Effects of Changing Waste Management on Animal Movements and Populations** Increasing Wind Speeds at the Sea Surface Development of Floating Wind Farms Creating Fuel from Bionic Leaves	Lithium-Air Batteries Reverse Photosynthesis for Biofuel Production Mineralizing Anthropogenic Carbon Dioxide Blockchain Technology
2018	**Thiamine Deficiency as a Possible Driver of Wildlife Population Declines** **Geographic Expansion of Chronic Wasting Disease** **Breaks in the Dormancy of Pathogenic Bacteria and Viruses in Thawing Permafrost** **Belt and Road Initiative in China**	RNA-Based, Gene-Silencing Pesticides Genetic Control of Mammal Populations **Use of Lasers in Commercial Deepwater Fishing** **Use of Metal-Organic Frameworks for Harvesting Atmospheric Water**	**Aquaporins Engineered to Increase Plant Salt Tolerance** Effect of Culturomics on Conservation Science, Policy, and Action **Changes in the Global Iron Cycle** **Underestimation of Soil Carbon Emissions**	Rapid Climatic Changes on the Qinghai-Tibet Plateau **International Collaborations to Encourage Marine Protected Area Expansion in the High Seas** Potential Effects on Wildlife of Increases in Electromagnetic Radiation
2019	Change in the Capacity of Antarctic Benthos to Store Carbon as Climate Changes **Extensive Release of Mercury by Thawing Permafrost** Ecological Effects of Options for Reducing Plastic Pollution **Effects of Shinorine Sunscreens on Corals and Other Marine Species**	**A New Irrigation Canal in Northwest China Supplied by Water from Qinghai-Tibet Plateau** Modification of Weather in the Tibetan Plateau by Cloud Seeding Salt-Tolerant Strains of Rice Effects of Noncompliance with the Montral Protocol on Global Environmental Governance	Effect on Insects of Transgenic Oilseed Crops that Produce Omega-3 Fatty Acids Harnessing Plant Microbiomes for Agricultural Production and Ecosystem Restoration **Expansion of Plantations and Infrastructure into Indo-Malay Islands**	**Development of Fisheries in the Mesopelagic Zone** Industrial Microbial Feed Production Innovative Insurance Products to Share Costs and Benefits of Protecting Natural Assets U.S. Government Decision Not to Regulate Gene-Edited Plants
2020	Land-Use Change in Response to Derivation of Nanocellulose from Wood Policy Incentives for Derivation of Energy from Wood Manipulating Floral Species Composition to Improve Bee Health	**Asian Long-Horned Tick Reaches the Americas** **Global Declines of Kelp Forest** Atmospheric Circulation and the Shrinking Antarctic Ozone Hole May Affect Extent of Polar Ice Effects of Small Hydropower Systems on Riverine Ecosystems	Rise of Blockchain Companies with Hidden Owners **Genetically Modified Fungus Kills Malaria-Carrying Mosquitos** Use of Artificial Wombs and Ectogenesis in Mammalian Conservation International Growth of Traditional Asian Medicine	Large Recirculating Aquaculture Systems New UN Legal Principles to Reduce the Environmental Impact of Armed Conflict New Regulations Jeopardize Net Neutrality

Source(s): W. J. Sutherland et al A Horizon Scan of Emerging Global Biological Conservation Issues for 2020 (and analogs from 2019, 2018, 2017, and 2016). Trends in Ecology & Evolution (January 2020)

VI. POLICY RECOMMENDATIONS

Over the next decade, the United States government will need to respond to surfacing threats associated with global ecological disruption. The COVID-19 pandemic that has caused global social disruption and economic anguish in 2020 is best understood as just one event in an increasing pattern of emerging infectious diseases arising from the degradation of natural systems. Accelerating rates of species and population extinction, overexploitation of resources, momentous conversions of habitat, intensifying climate change, and widespread toxification portend a breakdown in the ecological processes that support populations and American security interests globally. These trends raise the specter of a difficult period ahead of conflict, political instability, migration, economic hardship, food insecurity, and human suffering if substantial mitigating efforts are not undertaken.

The Executive Branch will be challenged to respond to this disruption. The national security apparatus is designed to protect Americans against malign actors. Actorless security threats, like infectious disease outbreaks and climate change, present problems that national security agencies are not institutionally, educationally, or doctrinally prepared to address. Actions to broaden and deepen the aperture of these agencies to incorporate consideration of and responses to ecological security challenges and to enhance interagency collaboration of the national security agencies with other elements of the U.S. government will be required. Rethinking which Federal agencies get a seat at the national security table on particular issues is also badly needed, which could help offset the tendency of the United States to view national security through a narrow defense or military lens. Congress, meanwhile, will be challenged to reframe ecological threats beyond low-priority environmental concerns and to resource them at levels more appropriate for the serious security implications for people and nations, including the United States, that these ecological threats and environmental concerns pose.

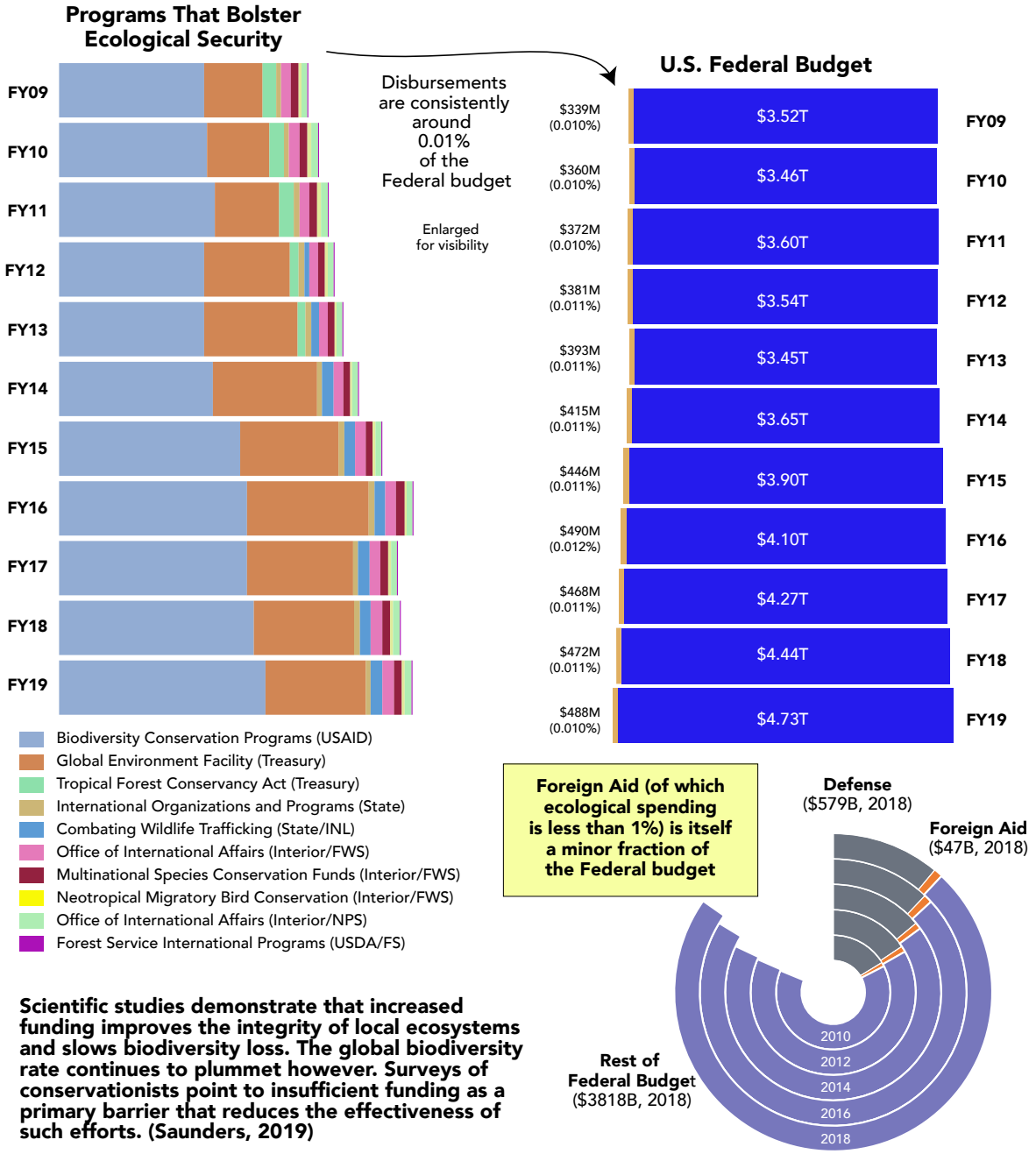
Scientists warn that Earth is entering a sixth mass extinction. If true, our ecological predicament is dire. U.S. government institutions, including the security enterprise, need to respond with appropriate and timely measures.

The following set of recommendations are based on **three fundamental precepts**.

First, the U.S. Congress needs to **appropriately resource efforts that directly address ecological disruption**. We recommend a **tenfold increase over the next ten years** in resource allocation to programs that promote international conservation, combat environmental crime, enhance water and food security, strengthen pandemic preparation, and build local capacity. These programs are not typically resourced from funds appropriated for national security, but their positive impacts on U.S. national security interests, and their high return on investment, argue strongly for dramatic increases. As urged in a 2017 letter to Congress by the U.S. Global Leadership Council and signed by 121 retired generals and admirals, resources for

international affairs need to "keep pace with the growing global threats and opportunities we face," citing wildlife trafficking, water and food security, and pandemic prevention as critical issues facing the nation.[419] [420] The level of resource allocation towards ecological security is currently extremely low (see Box 3).

Box 3. Ecological Security is Massively Underfunded in the Federal Budget



Scientific studies demonstrate that increased funding improves the integrity of local ecosystems and slows biodiversity loss. The global biodiversity rate continues to plummet however. Surveys of conservationists point to insufficient funding as a primary barrier that reduces the effectiveness of such efforts. (Saunders, 2019)

Sources; USAID Explorer, govinfo.gov, Foreignassistance.gov

Second, comprehending and responding effectively to the problem requires an **infusion of science and scientific expertise**, much of it coming from fields atypically engaged in national security. The defense, diplomatic, and intelligence communities currently have insufficient capacities and missions to track current trajectories in many[xviii] Earth systems, especially the biosphere. Augmenting security and policy discussions with scientific expertise from disciplines such as disease ecology, climate change biology, forestry, fisheries, invasion science, mycology, and soil science would bridge many knowledge gaps. Many of the world's experts in these fields are already employed by the government but generally siloed from contact with many others in the security community.

Lastly, the U.S. government needs **a national security doctrinal reboot**. A nation with a significant defense budget will still be vulnerable to threats for which it does not adequately prepare and prevent. The existing U.S. national security architecture must adapt to the threats presented by a changing planet and its embedded socio-ecological systems. Such actorless national security threats need greater attention from the National Security Council, the State Department, the intelligence community, and the Department of Defense. The security community needs to enhance strategic foresight capabilities not drawn from clandestine sources, and deepen engagement with non-Title 50 Federal agencies, such as NOAA, NASA, and USDA, entities that are often not invited to national security deliberations.

Based on these three precepts, we recommend the following **8 pillars of action** to address the security implications of ecological disruption:

1. PROMOTE INTERNATIONAL MECHANISMS THAT AIM TO REVERSE AND REDUCE THE DRIVERS OF ECOLOGICAL DISRUPTION

1.1. Ratify the UN Convention on Biological Diversity. The United States is one of the few nations that does not belong to the Convention on Biological Diversity (CBD). This absence represents an abdication of American leadership on an issue of critical importance to the wellbeing of people and nations. Although the United States was instrumental in the CBD's formulation and President Clinton signed it in June 1993, ratification stalled after it was submitted to the Senate for advice and consent in November 1993. The next President should urge for ratification and the Administration should deploy national security officials to bolster the case.

Beyond asserting American leadership, the U.S. stands to gain tangible benefits from officially joining the CBD. Upon ratification, the U.S. would be accorded full powers at meetings of the Conferences of Parties and political standing to drive international alignment and push domestic policies to a global scale, rather than sending its diplomats to observe and operate at the margins. Under the CBD, the U.S. would gain new opportunities to control invasive species, combat environmental crime, enhance climate change adaptation, and develop new avenues for scientific research. **(ACTION: Senate)**

xviii Excluding outstanding expertise in the Department of Defense on meteorological and marine systems.

1.2. Ratify the UN Convention on the Law of the Sea. The 1982 UN Convention on the Law of the Sea (UNCLOS) was submitted to the Senate for accession and ratification in October 1994. However, this has not advanced, despite calls of support from Presidents Bill Clinton, George W. Bush, and Barack Obama, as well as numerous senior U.S. military leaders and the U.S. Chamber of Commerce. Ratification gives the U.S. a direct voice on critical matters of global maritime policy, which includes the management, conservation, and exploitation of living marine resources such as fish. Becoming a party to UNCLOS would provide the U.S. the opportunity to exert leadership on the problem of overfishing and activate the critical legal tools that allow the U.S. Coast Guard to better enforce maritime regulations. **(ACTION: Senate)**

1.3. Infuse Ecological and Natural Security into Climate Change Efforts. Beyond rejoining the Paris Agreement, the United States will need to lead a major international effort to ratchet up the ambitions of member countries' greenhouse gas emission targets as well as pursue opportunities to reduce vulnerability to the effects of climate change. It is clear that the direct anthropogenic degradation of nature and its ecosystem services threatens climate stability and amplifies nearly all negative impacts of climate change on water, food, invasive species, and infectious diseases, for example. An international effort that addresses climate change but ignores the interconnected but distinct problem of global ecological disruption is not only hamstrung by its incompleteness, but probably destined to fail. An initial step would be to advocate for an Intergovernmental Panel on Climate Change (IPCC) Special Report on climate change and the biosphere, in the spirit of prior IPCC Special Reports on oceans, the cryosphere, and land. **(ACTION: White House, Executive Branch agencies)**

1.4. Integrate Sustainable Agriculture and Food Supply into Policy and Science. There is widespread acceptance that the global food system cannot support the planet's growing population despite a history of global investment efforts in novel protein sources and crop modifications. Yet, improvements have been incremental rather than transformative. Food supplies remain largely extractive in nature rather than based on renewable or circular natural resources. Moreover, the shortcomings of supply chains and food production facilities undermine productivity. Risks are heightened drastically when these systems and facilities involve livestock, where they act as a conduit for zoonotic diseases that endanger both humans and animals. Land degradation and ecosystem damage are not generally factored into analyses of food productivity. Programs supporting climate-smart agriculture may unintentionally worsen biodiversity loss, water stress, and ecological instability if they focus too narrowly on greenhouse gas emissions or resilience. The global food supply chain appears remarkably vulnerable to some forms of compound stress.

A robust research agenda is needed to illuminate the transformative actions necessary to move the global food system away from ecological tipping points and towards a safe, secure operating space for humanity. As argued in a 2016 study on the future of sustainable agriculture, research is needed that would include "discovery, testing, and implementation of mechanisms across scales that allow for adaptive management and governance of social-ecological systems essential for long-term human provisioning."[421] These efforts would be boosted by empowered science policy dialogues at national and international scales that meaningfully bring together the sometimes-divergent business, environment, and civic communities towards a common purpose. **(ACTION: White House, Executive Branch agencies, Congress)**

1.5. Promote Actions that Reduce Overexploitation. Increased funding and attention for international efforts that halt deforestation, defaunation, overfishing, soil degradation, groundwater over-extraction, desertification, and biodiversity loss are necessary for the enhanced security of nations. To be effective, these measures require participation at many scales, especially from the communities most affected by such policies. They must also adopt a systems approach, rather than targeting a handful of species, ecosystems, or countries.

Public participation is critical and made easier once the high ecological stakes are researched, clarified, and communicated. Advances in open-source satellite monitoring and machine learning can provide powerful and transparent tools for citizens worldwide to assess the health of key ecological resources. Specific steps can include pressuring multinational corporations across all sectors to eliminate illegal or unsustainable products from all stages of their supply chains. The United States should push for greater international adoption of demand-side legislation that requires transparency throughout the supply chains, thereby protecting the competitiveness of U.S. businesses. **(ACTION: White House, Executive Branch agencies, Congress)**

2. PROMOTE METHODS THAT PROTECT AND EXPAND CRITICAL SYSTEMS AND SERVICES

2.1. Counter Harmful State Actions Towards Critical Resources. The United States should use its instruments of national power to counter foreign states that, in the pursuit of critical resources such as fish or timber, engage in violations of sovereignty, precipitate conflict, fail to comply with international laws and norms, and exploit weaknesses in governance. In doing so, the U.S. should strengthen partnerships with like-minded countries, leverage law enforcement and anti-corruption tools, and build allies within the private sector, academia, non-governmental organizations, and other sectors. **(ACTION: White House, Executive Branch agencies)**

2.2. Expand Protected Areas. Well-managed protected areas are known to reduce rates of habitat loss and help maintain levels of species and populations.[422] Indeed, the current ecological predicament would be far worse without the growth of protected areas over the last century, which now covers close to 15 percent of the Earth's land and 10 percent of its territorial waters. Despite the expansion of protected areas, calamitous ecological declines continue. Many scientists point out that the current total protected area is far below what is necessary[xix] to avoid continued degradation. Robust science is needed to help international policymakers land on an appropriate increase for global security.

The expansion of marine protected areas (MPAs) has been a critical tool to offset the degradation of the ocean and associated declines in ecological benefits the ocean provides. The economic impacts alone argue in support of substantially expanding MPAs further. For example, establishing a no-take MPA provides benefits between 1.4 and 2.7 times higher than associated costs, according to a 2020 scientific study.[423] These benefits are maximized when targeting areas with high biodiversity with little to no prior human disturbance. Expanding MPAs could have benefits in combating IUU fishing in addition to restoring ocean health. **(ACTION: White House, Executive Branch agencies)**

xix Models of habitat loss, such as Andren's 1994 work, show a transition from contiguous habitat to patchiness at about 40 percent loss of habitat. Similar results have been shown in percolation theory of forest fires and other ecological systems. Many prominent ecologists now argue that at least 50 percent of the planet needs to be reserved for total protected area.

2.3. Better Manage and Protect Protected Areas. Simply expanding the acreage of protected areas worldwide is insufficient to improve ecological security. Many nations, including the United States, are backsliding on their commitment to support their protected areas. Resources available for protected area management, including law enforcement, border control, and resource security, often pale in comparison to the disruptive pressures on these areas. Some studies suggest that only 20 to 50 percent of global protected areas are effectively managed, leading to substantial ecological deterioration.[424] Management of protected areas without the inclusion of local communities is unlikely to be successful.

The U.S. security community has a vested interest in stabilizing protected areas because of their sometimes-enabling role in conflict and heightened opportunities for peacebuilding.[425] Combatant commands could enhance information-sharing, such as satellite imagery or ecological forecasts, to assist partner countries. The intelligence community could be tasked with collecting and sharing information on actors, such as illegal loggers, illegal fishers, and poachers, who threaten the integrity of critical protected areas. U.S. security forces could better protect conservation organizations operating in conflict zones. All such efforts should be balanced to prevent or minimize protected areas from becoming militarized zones. **(ACTION: White House, Executive Branch agencies)**

2.4. Protect Critical Ecosystem Services that Span Geographies. In addition to protected areas, the United States should prioritize the protection of critical ecosystem services that are not geographically specific, such as pollination, climate regulation, and water purification. Towards this end, the U.S. should pursue the establishment of a Threat Assessment Framework for ecosystem services at regional, national, and global levels.[426] Similar to the International Union of Conservation of Nature (IUCN) Red List of Threatened Species, this framework could warn of ecosystem services at risk from collapse, unsustainable use, or other stresses. These assessments should move beyond narrowly-defined monetary valuations of ecosystem services towards broader potential socio-ecological implications. Meanwhile, the U.S. should return to a robust evidence-based strategy on domestic pollinator protection while pursuing similar efforts in international engagements. Commensurate efforts should be considered towards soil services, seed dispersal, water detoxification, and biological pest control. **(ACTION: White House, Executive Branch agencies)**

3. BUILD AND STRENGTHEN INTERNATIONAL ALLIANCES

3.1. Assert Global Leadership on Climate and Ecological Security. The United States must elevate efforts to combat climate change and ecological disruption, arguably the two most critical emerging threats in the 21st century, as an organizing principle for international engagement. These efforts must not be relegated to technical discussions within environmental agreements but instead infused into our security alliances, such as NATO and the UN Security Council, and our bilateral engagements. **(ACTION: White House, Executive Branch agencies)**

3.2. Bring Together Ecological Security Communities. Many groups worldwide are focused on crucially important ecological security goals, such as reducing conflicts over water or fish, countering environmental crime, reversing dangerous biodiversity loss, or rebalancing socio-ecological systems. They invariably operate

in silos detached from one another. These communities should be regularly convened under the common purpose of understanding, articulating, and ameliorating the grave risks to humanity from intensifying ecological disruption. **(ACTION: White House, Executive Branch agencies)**

3.3. Increase International Communications on Ecological Risks. Research and awareness of ecological risks are under-resourced and understudied. This creates murky low-information environments that enable illicit trade and activities, such as IUU fishing and wildlife and timber trafficking. Standardizing and harmonizing global monitoring efforts will facilitate and improve tracking and interdiction of these practices, which are often reliant on international actors and global supply chains. **(ACTION: White House, Executive Branch agencies)**

3.4. Develop, Share, and Collaborate on Ecological Defense Frameworks. Security assistance targeting forms of ecological stress should be co-led by the Departments of State and Defense, with support from other Federal agencies. Such an effort would be aimed at creating enhanced capabilities within partner nations to better address their own needs. Enhanced information-sharing and breakthroughs in analytic capabilities could strengthen international efforts to combat environmental crime and other threats to resource security as well as monitor and coordinate actions on developing and unforeseen ecological disruptions. Such collaborations allow for greater continuity beyond national ups-and-downs, and systemic breakdowns become less likely if macroscale approaches are adopted. **(ACTION: White House, Department of State, Department of Defense)**

4. TREAT ENVIRONMENTAL CRIMES AS SERIOUS CRIMES

4.1. Prioritize Anti-Corruption Efforts. Corruption permeates many social ills beyond environmental crime and requires approaches outside the environmental sector. The U.S. should continue to push for international transparency and accountability standards, and ensure that corruption in the natural resource trade is well recorded. Since corruption is linked to the root causes of political instability, as well as a wide array of criminal and unethical activities, instruments that focus on anti-corruption are likely to have wide-ranging positive outcomes. **(ACTION: White House, Executive Branch agencies)**

4.2. Target Transnational Criminal Markets over Localized Criminal Groups. Transnational organized environmental crime typically spans several national jurisdictions, adapts readily to obstacles and opportunities, and operates largely out of sight. As crime has globalized, often faster than legitimate commerce, transnational criminal markets have eclipsed criminal groups in importance. Building national and international capacity to track and respond to transnational crime markets is necessary. Global approaches, such as through the UN Convention against Transnational Organized Crime, are important but hampered by the highly fragmented legal frameworks and laws worldwide. **(ACTION: White House, Executive Branch agencies)**

4.3. Move Beyond Seizures and Promote Effective Prosecutions and Deterrent Penalties. Environmental crime is market-driven making a law enforcement-only approach inadequate. Seizures are necessary components of a robust anti-trafficking strategy. Yet, they address just one link in the illegal wildlife supply chain and fail to target systemic corruption or organized crime structures successfully. Meanwhile, demand in these markets is growing. Future approaches need to further target corrupt activities such as bribery, patronage, falsified permits, and the like, and seek to dissuade the demand side of the illicit trade. **(ACTION: White House, Executive Branch agencies)**

5. REDUCE PANDEMIC RISK AT POINT OF ORIGIN

5.1. Enhance Monitoring and Understanding of Pathogen Space. Efforts to detect and characterize novel viruses in wildlife, such as the USAID PREDICT program and many independent academic laboratories, should continue to be vigorously supported. However, simply cataloging viruses without additional insights into their interactions with human cells is unlikely to prevent the next outbreak. More studies, including insights from disease ecology and epidemiological modeling, are needed to establish the risk of transmission to humans. **(ACTION: White House, Executive Branch agencies, Congress)**

5.2. Increase Assistance for One Health Efforts. Scientists recognize that the health of humans, animals, and the environment are intertwined. Responding to emerging zoonotic pathogens requires a coordinated approach that spans sectors and disciplines. Despite this recognition, implementation on the ground often suffers. The U.S. should use its myriad international programs to help strengthen foreign government capacities in One Health approaches. An expanded understanding of how pathogens pass through the wildlife-livestock interface to humans would help better elucidate pandemic risk. Heightened attention to the role of animals, particularly wildlife species, in contributing to antimicrobial resistance could be critical in addressing one of major challenges in infectious disease. **(ACTION: White House, Executive Branch agencies, Congress)**

5.3. Address Pandemic Risk in the Wildlife Trade. In addition to aggressively combating illegal wildlife trade, the United States needs to enhance monitoring and surveillance of wildlife imports to the country in the legal wildlife trade. Towards this end, Congress should consider wildlife health legislation, with appropriate resources, to close pathways for the spread of zoonotic pathogens. Targeted bans on trade in particular species, such as bats, rodents, and primates, or from high-risk markets or supply chains are probably justifiable. A blanket ban on legal wildlife trade needs to be balanced by unintended consequences on human and animal welfare, including driving more trade underground into black markets. **(ACTION: White House, Executive Branch agencies, Congress)**

6. AMPLIFY ECOLOGICAL AND NATURAL SECURITY ISSUES IN THE U.S. GOVERNMENT

6.1. Create a Deputy Assistant to the President and an Office of Environmental Security Within the National Security Council. The President needs dedicated staff in the White House who tackle the national security dimensions of planetary change and coordinate effective interagency policies and actions to bolster U.S. national security interests. A Deputy Assistant to the President for Environmental Security, with a primary focus on the security ramifications of climate change and ecological disruption, is necessary to mold national security for the challenges of the coming decades while effectively convening and coordinating the actions of the necessary agencies across the Executive Branch. The Deputy Assistant to the President would oversee an Office of Environmental Security whose work would be rooted in national security. **(ACTION: White House, National Security Council)**

6.2. Infuse Ecological and Natural Security into White House Strategic Planning. The risk landscape the United States faces over the next several decades is likely to be dissimilar to those of the past, punctuated by shocks and disruptions from climate change, health crises, information attacks, and the like. In the quest for security, the U.S. needs to factor in the effects of ecological disruption. Its absence will almost certainly greatly undermine the ability of our nation to weather these challenges. Issues of ecological disruption should figure prominently alongside climate change and other serious threats in the next Administration's National Security Strategy. The National Security Council should appoint a senior officer to coordinate U.S. government actions with respect to ecological security. **(ACTION: White House, National Security Council)**

6.3. Increase Capacity of Ecological and Natural Security Issues Within the Intelligence Community. The U.S. intelligence community (IC) has the capacity to analyze a handful of environmental security issues, such as negative outcomes that can arise from water stress or climate change. However, the ability to analyze the negative effects of ecological disruption, such as harmful ecological regime shifts and declines in ecosystem services, are largely absent, however. More analytical positions towards ecological security are needed in the intelligence agencies, such as the Central Intelligence Agency, the Defense Intelligence Agency, the National Security Agency, and the State Department's Bureau of Intelligence and Research. The Office of the Director of National Intelligence should create a Deputy National Intelligence Officer for Ecological Security[xx] issues, housed at the National Intelligence Council.

Simply adding more analytical positions will be insufficient, however. The low prioritization of environmental and ecological security issues in the intelligence community is a persistent, long-standing barrier to deeper engagement on these issues, despite frequent calls for assistance from some of the senior-most levels of government. Offices or individual analysts often justify working on issues such as wildlife trafficking or IUU fishing by tying these activities to "more serious" and traditional threats to national security, such as political instability or terrorism, and minimizing the threat to the very ecological systems responsible for human existence and global security in the first place. The IC's self-disabling posture, beyond adjudicating which threats and criminal activities are more serious than others, also ignores the fact that foreign nations often see ecological security issues as threats to their national security.

xx Ideally, this Deputy National Intelligence Officer would support a badly needed National Intelligence Officer for Environmental Security that would oversee analysis and intelligence support on climate change, ecological disruption, and other environmental and ecological issues.

The Office of the Director of National Intelligence should therefore elevate the relative importance of ecological security issues, along with climate change, within the intelligence community prioritization framework. Further, ODNI should explore new avenues for harnessing open-source intelligence into analysis since most relevant information falls outside of clandestine sources. To this end, ODNI should seek new and enhanced partnerships with Non-Title 50 Federal agencies, such as NASA, NOAA, HHS, USDA, USGS, and the US Fish and Wildlife Service to bolster their respective missions. **(ACTION: White House, Office of the Director of National Intelligence)**

6.4. Elevate International Water Security Issues (including their climate dimensions) at the Department of State. Many nations rightfully view water as a core element of their national security. Judging from worrying trends in water governance and climate change, already tense international transboundary water disputes are likely to intensify. The role of the United States has never been more important in bolstering peace and security through cooperation of shared water resources. However, when nations turn to Washington for diplomatic or technical assistance, persistent institutional shortcomings impede meaningful U.S. engagement on these issues.

No position exists in the White House whose primary or even secondary role is engagement on international water security issues. Meanwhile, the deep expertise at the State Department rarely surfaces above multiple layers of bureaucracy, consulted and dispatched only when the inevitable emergencies flare. This reflects a persistent institutionalized view that water is merely an environmental issue rather than one that transects geopolitical, security, and humanitarian domains. Coordination with other relevant agencies, such as the Army Corps of Engineers, the Department of Interior, and USAID, is often ad hoc and personality-driven, rather than institutionally bringing the considerable resources and expertise of these agencies to bear towards a strategic whole-of-government purpose.

Elevating international water security within the U.S. government would help advance several objectives of the 2017 Global Water Strategy, such as reducing conflict over shared waters and strengthening water governance. To this end, the State Department should dedicate a Senior Director for International Water Security in the Office of the Secretary whose sole focus is engagement on international water security issues. This action would build on and institutionalize prior successful periods of U.S. engagement on the issue, such as when the State Department's Under Secretary for Democracy and Global Affairs took on international water as a top priority in the early 2000s. The Senior Director would be vested with the imprimatur of the U.S. government, able to construct dialogs that bring together foreign diplomatic and security counterparts rather than being restricted to poor-yield technical-only tracks. The Senior Director could use and elevate the existing State Department-led Inter-agency Water Working Group as a vehicle to tap the resources of other pertinent agencies. **(ACTION: White House, State Department, Executive Branch agencies)**

6.5. Add More Ecological and Natural Security Issues to Military-Military and Intelligence-Intelligence Engagements. The findings from the Ecological Security Matrix (see Chapter VII, page 97) suggest that many socio-ecological stresses are unlikely to have substantial adverse effects on militaries. Still, military bases, operations, missions, and readiness make up a cornerstone of national security that is vulnerable to global change. The worldwide reach of the U.S. military, and its strategic partnerships around the world, position the Pentagon as an effective conduit for preventing the emergence and escalation of ecological stresses, both in the service of national and global security. Promoting enhanced water and food security is well within the defense community's interest in preventing political instability, and promoting marine fisheries integrity and policies is consistent with its mission to deter international disputes at sea.

The U.S. intelligence community has much to offer and gain through deeper engagement with foreign intelligence agencies, in both classified and unclassified settings, on ecological security issues. Many partner nations have comparatively greater attention to issues of environmental crime, natural resource security, and biodiversity loss. Unclassified bilateral or multilateral discussions could substantially enhance shared understanding and information-sharing of ecological threats, as well as provide the U.S. an underutilized tool for foreign engagement on important issues. **(ACTION: White House, Department of Defense, Office of the Director of National Intelligence)**

6.6. Augment Ecological and Natural Security in U.S. Defense and Intelligence Academic Curricula. Future national security leaders need to understand emerging 21st Century threats from a changing planet. This goal could be greatly assisted by including ecological security and climate change in the formal curricula of the country's defense and academic institutions. Such Professional Military Education institutions funded by the Department of Defense include the National Defense University in Washington D.C., the U.S. Army War College in Carlisle, Pennsylvania, the Naval War College in Newport, Rhode Island, and Air University in Montgomery, Alabama. National Intelligence University in Bethesda, Maryland serves a similar function for the U.S. intelligence community. **(ACTION: Department of Defense, Office of the Director of National Intelligence)**

7. INITIATE AN ECOLOGICAL SECURITY RESEARCH AGENDA

7.1. Deepen Understanding of Linkages Between Ecological Disruption and Security. The National Security Council should convene an Ecological Security Working Group that brings together relevant agencies from the security, policy, and science agencies to scope the problem and identify knowledge and policy gaps that need to be addressed. Deeper engagement with NGOs, academia, and industry will be a necessary component of this line of effort. This group should strongly consider commissioning a report from the National Academies of Sciences, Engineering, and Medicine (NASEM) examining ecological disruption and social stress (similar to the 2013 NASEM report *Climate and Social Stress: Implications for Security Analysis*[427] that provided the foundation for climate security analysis in the U.S. government and elsewhere). Horizon scanning exercises that seek to anticipate emerging issues in ecological security (see Box 2, Page 73) should be routinely undertaken. **(ACTION: White House, National Security Council, Executive Branch agencies)**

7.2. Develop Early Warning Indicators for Impactful Ecological Regime Shifts. A long-standing scientific problem with enormous societal relevance is what signals, if any, are detectable as an ecosystem under stress moves nonlinearly towards abrupt change. The U.S. security community should engage the academic and Federal science communities on the topic, thereby creating a demand signal for enhanced focus on the topic. Such information could allow policymakers to anticipate or avoid harmful regime shifts or theoretically move ecosystems out of danger. Identifying proxies that capture ecological stresses at early stages will be critical for improving and incentivizing quick response times. **(ACTION: White House, Executive Branch agencies)**

7.3. Bring Ecological Forecasting to Maturity. Building sustainability and resilience to future shocks requires a knowledge of how ecosystems are going to change with time as well as how policy decisions affect their trajectories. Such knowledge requires ecological forecasting (akin to weather forecasting but encompassing more systems and more complexity). NOAA has engaged in experimental forecasting efforts on harmful algal blooms, hypoxia, sea level rise, ocean acidification, and wave energies. The U.S. should build on these successes and expand into greater ecosystem coverage and widen its scope to the international arena. As a national asset, the United States could use ecological forecasting in its diplomatic and security engagement abroad. **(ACTION: White House, Executive Branch agencies)**

7.4. Foster More Research on Insect Declines. Despite media reports announcing an ongoing "insect apocalypse," comprehensive studies on the global state of declines in insects and other arthropods have been lacking.[428] This shortcoming severely limits our ability to properly assess their societal and security implications. The potential for severe and perhaps catastrophic impacts on people and societies worldwide argues strongly for the scientific community to close this knowledge gap, and the United States government should propel and assist with this research effort. **(ACTION: White House, Executive Branch agencies, Congress)**

8. ENGAGE THE PUBLIC ON ECOLOGICAL AND NATURAL SECURITY ISSUES

8.1. Deploy Effective Advocates. While understanding of the nexus between ecological disruption and security is still growing, there are already advocates and thought-leaders that can effectively advance the conversation with the public. Many of these proponents are national security leaders, both within and outside government, who both understand ecological problems and can articulate the security repercussions in nonpartisan ways. These types of engagement will be a critical step in bolstering public support for enhanced resources and attention towards ecological security. **(ACTION: NGOs, White House, Executive Branch agencies)**

8.2. Convene Ecological and Natural Security Conferences. Deepening our understanding of ecological security requires bringing scientists, policy, and security experts together. Unfortunately, these communities do not naturally mix. Sessions dedicated to ecological security could be developed within existing conferences, such as the annual meeting of the American Association of the Advancement of Science. Alternatively, some scientific associations, such as the American Geophysical Union, draw a large interdisciplinary audience that could push the enterprise forward. Both approaches would benefit from deep engagement with experts from climate security and other intertwined environmental security communities. **(ACTION: NGOs, academic institutions, White House, Executive Branch agencies)**

8.3. Expand the Aperture of *Natural Security*. The *Natural Security* campaign has been an important effort in articulating the security dimensions of many forms of ecological disruption. The scope is arguably too narrow, however, particularly in light of mounting evidence that destabilization of the biosphere poses as big a threat to humans as does climate change.

The campaign focuses on profits generated by wildlife trafficking, illicit timber, IUU fishing, and other forms of transnational organized environmental crime, and how these profits finance extremist groups, enhance corruption, and undermine the rule of law. Likewise, articulating the real threats to regional peace and political stability arising from water and food stress is necessary and well-founded. The campaign's efforts to illuminate the adverse effects of illegal trade in natural resource commodities on markets and the U.S. economy is supported by credible estimates of financial losses from these activities, and the incipient damage to U.S. national security through these shortfalls is largely[xxi] well-grounded. More than a marketing framework to draw attention to comparatively neglected problems, the *Natural Security* campaign has helped establish an important foundation on which to understand the security implications of ecological stress, while enabling meaningful dialogues between audiences far wider than those typically interested in environmental issues.

Despite the damage from environmental crime and the risks that natural disasters and water and food insecurity pose for governments and communities worldwide, there is even more at stake for national and global security. The pace and scale of accelerating global ecological disruption (see Section III) argues that the campaign's scope is probably too narrow. Indeed, scientific studies underscore that the loss of biodiversity and ecosystem services poses a danger to people equal to, or perhaps more than, that of climate change, an issue whose security dimensions have been largely[xxii] acknowledged.[429] The continued rapid extinctions of species and populations are clearly dangerous. But they also captivate the public, which is probably desperate to understand their deeper significance beyond conservation implications.

The COVID-19 pandemic has exposed the glaring mismatch between U.S. national security doctrine and a suite of transnational threats coming ahead. There are signs, however, that national security experts are taking notice. The time is ripe for moving even further beyond conservation language and rooting *natural security* as a vital interest in human, national, and global security. **(ACTION: NGOs)**

xxi There is a counter-argument that these illicit activities impact corporate economic security more than U.S. national security, an argument bolstered by the marked presence of multinational corporations in the resource trade. The degree to which economic security is part of U.S. national security is somewhat administration-dependent, and this report strives to be agnostic on this point.

xxii During the 2019-2020 campaign season, climate change was cited by many Presidential hopefuls as the number one security risk facing the world. In addition, the topic of climate change was raised in both Presidential debates in 2020, a first (and second).

VII. INSIGHTS FROM THE COMMUNITY

Population growth, demographic shifts, globalization, urbanization and other socioeconomic forces have reconfigured the Earth's natural systems. For more than three decades, scholars and practitioners have studied and debated how these planetary changes affect human, national, and global security. The emerging recognition of the security implications of climate change by national leaders over the past several years has been welcome and long-overdue, as has been a greater acceptance of how water and food insecurity affect societies and nations.

Far behind, however, is a commensurate appreciation of the role of a destabilizing biosphere in security. Part of the problem lies in inadequate articulation of the consequences for humanity of wholesale changes to the natural world. In other words, while most people probably understand that many ecological changes, such as the accelerating extinctions of species, are bad for human civilization, we lack the ability to point to specific pathways of harm.

Another challenge is the dearth of foundational analysis that links socio-ecological stresses to security outcomes. Ecological economists have long used the ecosystem services concept to calculate the monetary equivalent of losses of ecological benefits to people. Constructing a security equivalent of ecosystem services, and ecosystem *disservices* for that matter, would greatly advance understanding on the matter.

The first section of this chapter presents testimonials on various aspects of ecological and natural security from the global community. The second section offers a novel framework (and Ecological Security Matrix) for analyzing and articulating some of the pathways from ecological stress to security outcomes.

TESTIMONIALS

DR. E. WILLIAM COLGLAZIER

"Global pandemics and climate change represent potentially catastrophic national security threats to the United States. This report makes abundantly clear that global ecological disruption must be added to that list."

- Dr. E. William Colglazier, Editor-in-Chief of Science & Diplomacy and Senior Scholar in the Center for Science Diplomacy at the American Association for the Advancement of Science. Former Science and Technology Adviser to the Secretary of State, Executive Officer of the National Academy of Sciences and the National Research Council.

THE HONORABLE JOHN CONGER

"Since the emergence of COVID and the new focus that has been placed on non-nation-state security threats, few reports have made me think so deeply about the complex web of policy issues upon which our own national interests depend. Climate change is a piece of this story, but the authors illustrate the broader ecological narrative in a way that is both compelling and illuminating."

- The Honorable John Conger, Director of the Center for Climate and Security, Chair of the Climate and Security Advisory Group (CSAG), Senior US Advisor to the International Military Council on Climate and Security (IMCCS). Former Principal Deputy Under Secretary of Defense (Comptroller) at the U.S. Department of Defense.

FRANCESCO FEMIA

"As this report highlights, we are facing potentially catastrophic security threats not just from climate change, but from a broad range of ecological disruptions that are unprecedented in human history. However, as also evidenced by the analysis in the report, we have unprecedented foresign about these threats. We can see many of them coming with a degree of awareness and certainty that we could not have imagined in the past. This combination of unprecedented threat and unprecedented foresight underlines a responsibility to prepare for and prevent these disruptions, to the best of our ability. But there's not a lot of time left. The U.S. security community, including America's top national security leadership in the White House, should take these issues up now, and with great seriousness."

- Francesco Femia, Co-Founder and Research Director, The Council on Strategic Risks and the Center for Climate and Security; Co-Founder and Senior Advisor, The International Military Council on Climate and Security; Former CEO of the Center for Climate and Security and the Council on Strategic Risks (2010-2019).

DR. THOMAS FINGAR

The multiple and interactive threats to the biosphere, humanity, and national security summarized in this excellent and timely study are real, intensifying, and accelerating. Each of the many threats to the ecosystem summarized by the authors should be cause for alarm and a prod to action. Their most worrisome message is that earlier, albeit less comprehensive, warnings were largely ignored or dismissed. The threats they describe demand at least the attention and magnitude of effort now devoted to "conventional" threats to national security.

- Dr. Thomas Fingar, Shorenstein APARC Fellow at Stanford's Freeman Spogli Institute for International Studies. Former Deputy Director of National Intelligence for Analysis, Chairman of the National Intelligence Council, and Assistant Secretary of State for Intelligence and Research. Oversaw production of and provided Congressional testimony on the 2008 National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030.

BRIGADIER GENERAL GERALD GALLOWAY, US ARMY (RET)

"Ecological disruption clearly is underway worldwide and is a threat to both national and natural security. Water is the fabric that holds ecology together and by its presence or absence impacts lives across the globe on a day-to-day basis. It is also an element that is taken for granted, perhaps even ignored, until a crisis arrives that brings its critical position to our attention. Leaders and water experts in international and national organizations find that it is largely neglected and mismanaged. Study after study has reported that water challenges have and will continue to be catalysts for conflict at the local and regional level and a major source among nations of tension that could spill into conflict. The report by Schoonover, Cavallo, and Caltabiano provides a long needed and concise description of the relationships among natural systems, and their ties to security. They make a strong case that continuing neglect of the ecological issues that face the world today creates a risk that cannot be tolerated and places a sword of Damocles over the lives of nations and individuals. The report effectively describes the linkages that exist among natural systems and identifies actions that must be taken to ensure that these natural systems, including water, will be equitably available for future generations. In the face of stark and growing realization of the threats of climate change, it is clear that the time for action is now. The report creates an effective roadmap to guide national and international action and needs to be immediately addressed by US government and national leaders."

- Brigadier General Gerald E Galloway, US Army (Ret), PE, PHD, Member of the Center for Climate and Security Advisory Board, Glenn L Martin Institute Professor of Engineering, Department of Civil and Environmental Engineering and an Affiliate Professor at the School of Public Policy of the University of Maryland, former Dean of the United States Military Academy and former Dean of the Faculty, Industrial College of the Armed Forces, National Defense University; National Academy of Engineering.

THE HONORABLE SHERRI GOODMAN

"Security in the 21st century is being fundamentally reshaped by global ecological disruption, from zoonotic disease, to climate change, to declining ocean health. This report offers a new national narrative in which planetary health is a core element. This report will enable decision makers in both Congress and the Executive branch to take practical steps to address ecological disruption, including pandemic risks, environmental crime, biosphere degradation, forests and fisheries, as key components of national security strategy, plans and programs. The Biden Administration has a unique opportunity to elevate ecological security, along with climate security, to the highest levels of attention in diplomacy, development, defense, disaster planning, and scientific research."

- Sherri Goodman, Senior Strategist and Member of the Center for Climate and Security Advisory Board, Chair of the Board at the Council on Strategic Risks, Secretary General of the International Military Council on Climate and Security, and Senior Fellow at the Woodrow Wilson International Center's Polar Institute and Environmental Change and Security Program. Formerfirst Deputy Undersecretary of Defense (Environmental Security)

LUKAS HAYNES

"When politically objective scientists warn us that a 'sixth mass extinction event is under way, policymakers risk ignoring the metaphorical 'forest' and focusing too much on the near-term health of 'the trees'. This report should be a clarion call to policy research funders and policymakers in every branch of government: the security, development, justice and foreign policy mechanisms of the USG are ill-equipped to deal with unfolding collapse of natural systems that ensure health and prosperity. Now is the time to reinvent them and mobilize government and NGO allies to meet the challenge of the century."

- Lukas Haynes, Member of the Center for Climate and Security Advisory Board, and Executive Director of the David Rockefeller Fund.

REAR ADMIRAL LEN HERING, US NAVY (RET.)

"This is the most comprehensive and well thought out and presented piece I have read in more than 10 years. The detail to which this study outlines and explains the impacts we are to face-- should we continue to ignore climate science-- is extraordinary. Methodically linking the forecast ecological disruptions to the components of national security is enlightening, and clearly shows how desperate the consequences will be if we do not act. Without exception, I know of no other piece that captures the totality of the situation we face. I truly believe this piece should be a must read at the Services War Colleges and institutions of higher learning offering courses in foreign and national policy. "

- Rear Admiral L.R. Hering, US Navy (Ret), Member of the Center for Climate and Security Advisory Board, and Executive Director, I Love A Clean San Diego

THE HONORABLE ALICE HILL

"This report focuses on the issue that will dominate national security experts for decades to come: the cascading risks that flow from environmental degradation worsened by climate change. The collision of accelerating climate extremes with the unsustainable exploitation of the earth's resources-- through practices like overfishing, deforestation, and wildlife trafficking--will fuel transnational crime, undermine human security, and erode global stability. The Security Threat That Binds Us provides a much-needed policy roadmap for the U.S.government to address these growing threats."

- The Honorable Alice C. Hill, Member of the Center for Climate and Security Advisory Board, Member of the Council on Strategic Risks' Board of Directors, and Senior Fellow for Climate Change Policy at the Council on Foreign Relations. Former Senior Counselor to the Secretary of the Department of Homeland Security (DHS) and ex officio member of the Third National Climate Assessment.

GENERAL JAMES JONES, US MARINE CORPS (RET)

"Our world faces many threats in the 2st century. No longer can we think of threats to our security as being purely military in nature. That type of thinking ended with the 20th century. The United States has been blessed with an abundance of natural wealth and resources not seen anywhere else on the planet. For America to remain at the pinnacle of global influence, it must lead by example and by its willingness to lead in all domains possible. It must also share its knowledge and abundance with other countries that are not so fortunate. From all matters pertaining to energy, climate, food, water, fisheries, and forests, we must dedicate ourselves to helping other countries join in the 21st century revolution towards democracy, prosperity and freedom."

- General James Jones, US Marine Corps (Ret), Executive Chairman Emeritus of the Atlantic Council, Founder, Jones Group International, Former National Security Advisor to the President of the United States, Former Supreme Allied Commander Europe and COmbatant Commander USEUCOM, and 32nd Commandant of the Marine Corps.

GENERAL RONALD KEYS, US AIR FORCE (RET)

"This report is a clarion call to arms for ecological security. The authors have laid out the multifaceted risks to natural, financial, social, and political capital that ecological destruction, disruption, and collapse pose, and it is clear and compelling how ecological and natural security is critical for all of us. The time for more studies is over. The time for choices, action, and responsibility is here."

- General Ronald Keys, US Air Force (Ret), Member of the Center for Climate and Security Advisory Board, Chairman of the CNA Military Advisory Board, and former Commander of Air Combat Command

DR. MARCUS KING

"Ecological disruptions are responsible for significant changes across numerous Earth systems, yet they remain under-studied and under-discussed. This report addresses the changing security landscape by clarifying the nexus between altering ecosystems and national security risks. Laying the foundation for an exploration of such disruptions, this report outlines tangible steps that policymakers can take to minimize 'actorless' security threats, such as resource insecurity and pandemics that result in part from ecological degradation."

- Marcus King, Senior Fellow and member of the Advisory Board at the Center for Climate and Security, John O Rankin Associate Professor, and Director of the Master of Arts in International Affairs Program (MAIA) at George Washington University's Elliott School of International Affairs, formerly a foreign affairs specialist in environmental security in the Office of the Secretary of Defense

DR. CHRISTOPHER KOJM

"The Council on Strategic Risks' ecological security report documents the security ramifications of environmental disruption. In short, we are facing a national security issue of the first order. Scientific expertise must guide the response of our defense, diplomatic and intelligence communities to this profound threat. A new national security doctrine--and urgent action by the President and Congress--are needed now to save our planet."

- Dr. Christopher Kojm, Director of George Washington University Elliott School's Leadership, Ethics and Practice Initiative and Professor of Practice in International Affairs. Former Chair of the National Intelligence Council, Deputy Assistant Secretary of State for Intelligence and Research, and Deputy Director of the 9/11 Commission.

ADMIRAL SAM LOCKLEAR III, US NAVY (RET)

"The Security Threat That Binds Us sheds considerable light on the serious security implications presented by the growing threat of significant global ecological disruptions. These real and dangerous threats have been largely neglected in both national and international security doctrine, planning and preparation, and must be addressed with urgency. This report provides valuable insights into the growing threat and provides US and other global leaders and decision makers valuable recommendations on how to better recognize, organize and prepare for the challenges that are coming...soon."

- Admiral Samuel J. Locklear III, US Navy (Ret), Member of the Center for Climate and Security Advisory Board. Previously served as a commander for the U.S. Pacific Command, U.S. Naval Forces Europe and Africa, and NATO's Allied Joint Force Command.

THE HONORABLE MARIA OTERO

"This report makes the powerful case that ongoing ecological destruction and disruption need to be considered alongside climate change as critical threats deserving of heightened national security and foreign policy attention. Water insecurity worldwide is already a serious and sometimes acute threat to human and national security. More than mere environmental concerns, such stresses to water, food, wildlife, forests, and fisheries contribute to conflict and political instability, fuel corruption and crime, and undermine human health and security. The authors effectively argue that biosphere degradation poses wide-ranging security risks, such as heightened pandemic potential, and provide a thoughtful plan for the United States to lead on addressing ecological security."

-The Honorable Maria Otero, Former Under Secretary of Civilian Security, Democracy, and Human Rights of the U.S. Department of State, and the President's Special Coordinator for Tibetan Issues, and former President of ACCION International.

ERIN SIKORSKY

"If there's one thing the US national security community learns from the COVID-19 pandemic, it should be that its traditional definition of what constitutes a security threat is too narrow. This ground-breaking report on ecological security is a key step toward broadening that definition--it provides concrete examples of the risks posed by ecological disruptions and biosphere changes and clear-eyed solutions that national security practitioners can advance."

- Erin Sikorsky, Deputy Director of the Center for Climate and Security, Director of the International Military Council on Climate and Security, and former Deputy Director, Strategic Futures Group, National Intelligence Council.

DR. GREG TREVERTON

"I had the great good fortune to work with Rod Schoonover when I was Chair of the National Intelligence Council. I was the beneficiary then of his keen mind and careful science, and now the nation will benefit from those qualities of his and his collaborators. We have known for a long time -- but too often not behaved as though we knew -- that the two existential threats humans face are pandemics in the short run and the climate crisis in the long. It is well past time for us to expand our concept of "national security" accordingly, when more Americans die each day from Covid-19 than were killed in the World Trade Center attack. This report is an important benchmark in that redefinition, and it also reminds us that the threat of ecological disruption centers on the climate crisis but runs well beyond it. With the appointment of John Kerry as the Biden administration's special envoy for climate, the report has the unique success of having one of its main recommendations accepted before it was even printed! It will be natural to expand Kerry's writ -- even if "special envoy for ecological disruption" is not a title that falls off the tongue -- and to assure that the National Security Council is staffed to support him."

- Dr. Greg Treverton, Senior Adviser (non-resident) with the Transnational Threats Project at the Center for Strategic and International Studies (CSIS), and Professor of the practice of international relations at the University of Southern California. Former Chairman of the National Intelligence Council, and Director of the RAND Corporation's Center for Global Risk and Security

ANALYTICAL LINKAGES BETWEEN ECOLOGICAL DISRUPTION AND SECURITY

Formally analyzing the linkages between ecological disruption and security is complicated by a number of factors. First, a given natural system may be disrupted in myriad inseparable ways, from water and food stress, to biodiversity loss, degradation of ecological processes, or population explosions of harmful organisms. Second, security experts don't view national security as monolithic and most could point to several dimensions of national security within a given region or skirmish, from active conflict to humanitarian crises, from heightened international tensions to corruption, or from political instability to threats to national power. Third, the overlap between even a subset of the ecological and security domains is rarely, if ever, quantified through measurable data. Lastly, there are very few individuals who are thoroughly conversant in both the ecological and security domains.

With those issues stated upfront, the following sections offer as an analytic starting point the development of an ***ecological security matrix*** to elucidate the linkages between ecological stresses and possible national security outcomes. To work around the paucity (or nonexistence) of data available an expert elicitation method was adopted to investigate the degree of crossover between ecological stress and potential security outcome.

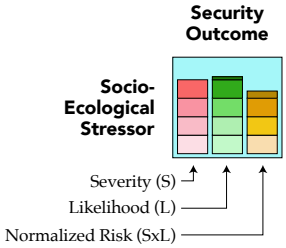
METHODOLOGY

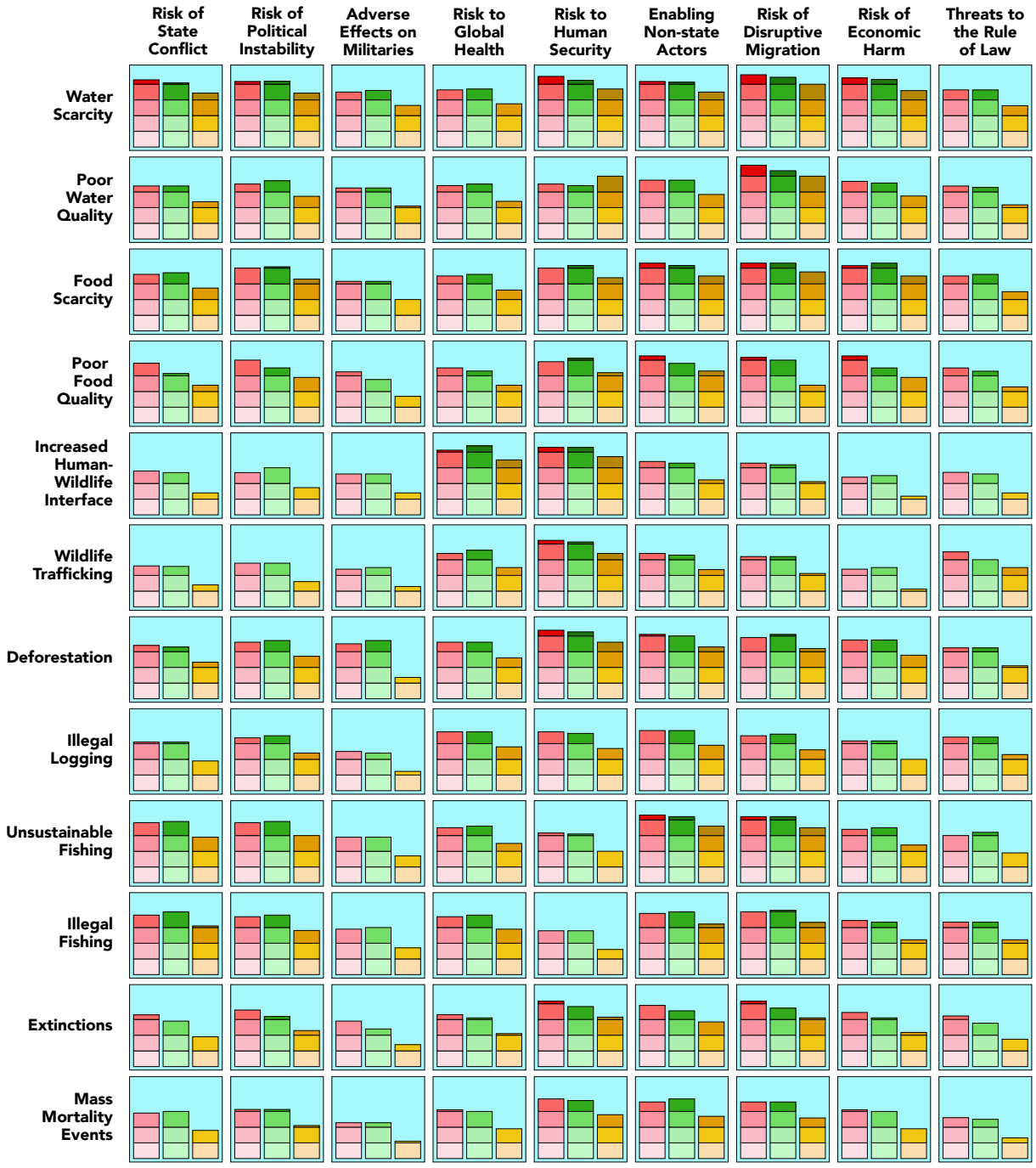
Links to an online survey platform (SurveyMonkey) were sent electronically to science, security, and policy experts drawn from academia, government, and non-governmental organizations. Each respondent was asked to self-assess their expertise on each pre-selected socio-ecological stress factor and on each security outcome. Each question prompted the respondent to assess the severity of impact as well as the likelihood of that occurrence over a ten-year timeframe. For example, respondents were asked to rank (from 0 to 5) the severity of the impact of water scarcity on state conflict, political stability, impacts on the military, and so on. The next question was similar except that respondents were asked to rank the likelihood of a particular outcome over the same ten-year timeframe. In short, this survey assesses "perceptions of risk" among the experts surveyed, as opposed to actual risk.

The survey was conducted over a 20-day period, and there were 61 usable responses. The weighted average, weighted variation, and weighted standard deviation were calculated for each of the 135 matrix cells for both the severity and likelihood question sets. (See Box 4 below. Also see Appendix II for more on the matrix results and methodology).

Box 4. Initial Iteration of an Ecological Security Matrix

To examine the linkages between ecological disruption and different dimensions of human and national security, an expert elicitation analysis was conducted. Electronic surveys were sent to experts who were asked to self-assess their expertise on 15 socio-ecological stressors and 9 security outcomes (three questions on the potential security outcomes of declines in ecosystem services are not shown below because they substantially overlap several other questions and some participants deemed them to be too general). There were 61 usable surveys. Participants were asked to assess the potential severity and likelihood of a socio-ecological stressor on each security outcome over a 10-20 year timeframe. Weighted means (on scales of 0 to 5) are displayed below.





INTERPRETING THE ECOLOGICAL SECURITY MATRIX

GENERAL TRENDS (OVER A 10-20 YEAR TIMEFRAME)

Respondents assessed, on average, substantial security outcomes for most socio-ecological stresses.
Socio-ecological stresses were largely assessed to have comparatively lower effects on militaries.
Threats to the rule of law were ranked low across the board, although that likely reflects inadequate definition in the survey.
The most impactful socio-ecological stresses were found largely in the categories associated with human security (global health, migration, and the explicitly-identified human security).
Issues with the largest standard deviations may be indicative of an emerging threat that has not been fully identified.

RISK OF INTERSTATE CONFLICT

On average, respondents assessed that water scarcity was the ecological stress most impactful and most likely to heighten the risk of conflict between states. This factor had the highest agreement (lowest standard deviation) on both the severity and likelihood scales. The survey suggests that experts may be beginning to doubt that the cooperation-over-conflict paradigm over water disputes will persist into the future. Respondents also perceived illegal fishing and overfishing as important factors in state conflict. This result may reflect ongoing tensions and sometimes violent actions between seafaring nations over fisheries. Harm to material ecosystem services also scored high in this category, which is probably unsurprising since the category implicitly contains provisioning of water, food, fish, and other resources.

Deforestation was assessed as a moderate risk for state conflict, but the degree of disagreement was one of the highest. Wildlife trafficking and an increased human-wildlife interface were assessed as the lowest risks for state conflict over ten years.

RISK OF POLITICAL INSTABILITY

Ecological stresses were assessed to be more relevant for increased risk of political instability than for interstate conflict. Respondents converged on water scarcity, food scarcity, harm to material and regulating ecosystem services, unsustainable fishing, and deforestation as important contributors to the risk of political instability. Wildlife trafficking and increased human-wildlife interface were both ranked low, with moderate agreement, as factors for increased risk of political instability. Mass mortality events were also ranked as having low impact, but disagreement was among the highest in the category.

RISK TO MILITARIES

Although ecological stresses were assessed to have a modest degree of impact on increased risk to militaries, they were nonetheless ranked less consequential and with good agreement between respondents. Water

scarcity was the stress factor that was ranked highest, but still lower than every other risk category. Interestingly, many arguments made about the national security implications of climate change are centered on adverse effects on military bases, operations, missions, and readiness. This may reflect a knowledge gap between climate change and ecological disruption among the respondents.

RISK TO GLOBAL HEALTH

Respondents assessed that ecological stress factors were moderately important factors for overall increased risks to global health. The category overall ranked lower than several other risk categories, which was perhaps surprising since the survey was conducted six months into a global pandemic. Increased human-wildlife interface was assessed to be the most impactful factor for heightened risk to global health (although it had only moderate agreement between respondents). Harm to nonmaterial ecosystem services and mass mortality events were, unsurprisingly, evaluated as low risks for global health.

RISK TO HUMAN SECURITY

Most ecological stress factors were assessed to have above average or higher importance for risks to human security. Poor water quality, water scarcity, increased human-wildlife interface, deforestation, harm to regulating ecosystem services, and food scarcity were deemed especially impactful. Illegal fishing was assessed as being the lowest risk to human security.

RISK OF ENABLING NON-STATE POWER CENTERS

Respondents converged on unsustainable fishing, harm to material ecosystem services, food scarcity, harm to regulating ecosystem services, and water scarcity as the most important risks of enabling non-state power centers like terrorist and insurgent groups. Harm to nonmaterial ecosystem services, like tourism and cultural services, was deemed lowest risk but with highest disagreement. One interpretation of this last result is that the ecosystem services category is perhaps too broad and the survey question couldn't discriminate between the different risk factors.

RISK OF DISRUPTIVE MIGRATION

This risk category was considered most affected by ecological stresses, comparatively. Water scarcity, poor water quality, harm to regulating and material ecosystem services, food scarcity, and unsustainable fishing were all deemed important risk factors for driving migration. Lowest, but only for this category, were wildlife trafficking and increased human-wildlife interface. The most disagreement was on the role of harm to nonmaterial ecosystem services.

RISK OF ECONOMIC HARM

Respondents viewed water scarcity, food scarcity, deforestation, and poor food quality as the ecological factors most important for risk of economic harm. Curiously, the stresses with known adverse effects on economic livelihoods and treasures, namely illegal fishing, illegal logging, and to a somewhat lesser extent wildlife trafficking, scored comparatively lower. There was considerable disagreement between respondents on these topics, however.

RISK OF THREATS TO THE RULE OF LAW

For increased risk of threats to the rule of law, including corruption, survey respondents assessed that water scarcity, wildlife trafficking, food scarcity, and harm to material and regulating ecosystem services were moderately important. Lowest scores were given to mass mortality events and increased human-wildlife interface.

APPENDIX I: ECOLOGICAL SECURITY MATRIX METHODOLOGY AND RESULTS

OVERVIEW

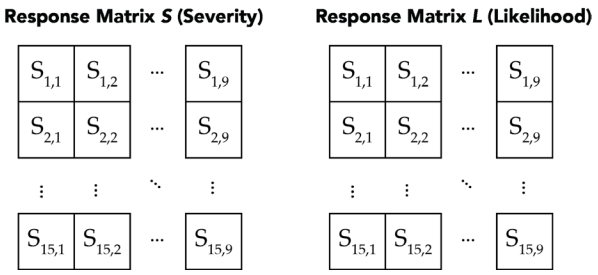
An expert elicitation method was adopted to investigate the degree of crossover between socio-ecological stress and potential security outcome. Links to an online survey platform (SurveyMonkey) were sent electronically to a list of 220 experts drawn from academia, government, and non-governmental organizations. At the beginning of the survey, each respondent was asked to self-assess their expertise on each relevant ecological stress factor and on each security outcome. The survey questions employed Likert scales and each question prompted the respondent to assess the severity of impact of a particular ecological factor on a potential security outcome as well as the likelihood of that occurrence.

The survey analyzed the effects of fifteen types of socio-ecological stresses on nine different types of security outcomes:

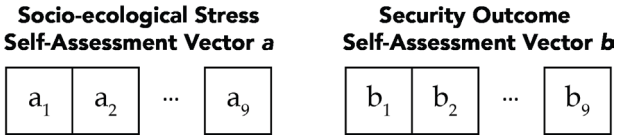
Socio-ecological Stresses (15)		Security Outcomes (9)	
Water scarcity	Poor water quality	Poor water quality	Risk of political instability
Food scarcity	Poor food quality	Adverse effects on militaries	Risk to global health
Increased human-wildlife interface	Wildlife trafficking	Risk to human security	Enabling non-state power centers
Deforestation	Illegal logging	Risk of disruptive migration	Risk of economic harm
Unsustainable fishing	Illegal fishing	Threats to the rule of law	
Extinctions	Mass mortality events		
Declines in regulating ecosystem services (ES)	Declines in material ecosystem services (ES)		
Declines in nonmaterial ecosystem services (ES)			

DATA ANALYSIS

The severity response matrix S and the likelihood response matrix L contained 135 cells each. Since respondents were permitted to skip questions on which their expertise was not high, some response matrix cells were empty.



Each respondent was required to self-assess their expertise for each socio-ecological factor m and security outcome factor n. Therefore, for each respondent there were two self-assessment vectors:



The **weighted mean**, **weighted variance**, and **weighted standard deviation** were calculated for each cell, using a modified version of Cooke's method on the full set of respondent severity and likelihood matrices.[430] The **compound-weighting factor** $w_{m,n}$ [i] for each combination of socio-ecological factor m and security outcome factor n was found by:

$$w_{m,n}[i] = \frac{w_m[i]w_n[i]}{\sum_i^N w_{m,n}[i]} = \frac{1}{\sum_i^N w_{m,n}[i]} \frac{a_m[i]}{\sum_i^N a_m[i]} \frac{b_n[i]}{\sum_i^N b_n[i]}$$

The **weighted mean** $\mathbf{P_{m,n}}$ for each element of the severity response matrix and the **weighted mean** $\mathbf{Q_{m,n}}$ for each element of the likelihood response matrix were then calculated:

$$P_{m,n} = \sum_i^N w_{m,n}[i] \times S_{m,n}[i]$$

$$Q_{m,n} = \sum_i^N w_{m,n}[i] \times L_{m,n}[i]$$

$$where \sum_i^{Nonzero\ responses} w_{m,n}[i] = 1$$

The **weighted variance** $\alpha^2_{m,n}$ for each element of the severity response matrix and the **weighted variance** $\beta^2_{m,n}$ for each element of the likelihood response matrix were calculated:

$$\alpha^2_{m,n} = \frac{V}{V^2 - W^2} \sum_i^N w_{m,n}[i](S_{m,n}[i] - P_{m,n})^2$$

$$\beta^2_{m,n} = \frac{V}{V^2 - W^2} \sum_i^N w_{m,n}[i](L_{m,n}[i] - Q_{m,n})^2$$

$$where\ V = \sum_i^N w_{m,n}[i] = 1 \quad \text{and} \quad W = \sum_i^N w^2_{m,n}[i]$$

Calculating the **weighted standard deviations** $\alpha^2_{m,n}$ and $\beta^2_{m,n}$ were straightforward:

$$\alpha_{m,n} = \left(\alpha^2_{m,n}\right)^{1/2} \text{ and } \beta_{m,n} = \left(\beta^2_{m,n}\right)^{1/2}$$

NUMERICAL RESULTS

The next section presents numerical results for the **weighted mean** and **weighted standard deviation**[xxiii] for the Severity and Likelihood response matrices, giving four tables total. Responses were scored from 1-5 as follows:

Severity Reponses		Likelihood Responses	
Severe	5	Very Likely	5
Threatening	4	Likely	4
Moderate	3	Neutral	3
Emerging	2	Somewhat Unlikely	2
None	1	Unlikely	1

xxiii The weighted variance was also calculated (but not displayed) from which the weighted standard deviation is obtained through square root.

Table 1: Weighted Mean for the Severity of Socio-ecological Stresses on Security Outcomes

For each entry, the higher the value (on a scale 1-5) the more severe the socio-ecological stress (row) was assessed by respondents with respect to particular security outcomes (column). Scanning across columns shows comparative importance of a given stress on a range of security outcomes while moving vertically shows comparative importance of different socio-ecological stresses on a given security outcome. All entries represent the weighted mean of respondent perceptions of risk and not necessarily the risk itself. The 15 highest values are shaded in red and the 15 lowest values are shaded in yellow (inclusive of tie values).

Weighted Mean (Severity)	State Conflict	Political Instability	Effects on Militaries	Global Health	Human Insecurity	Nonstate Powers	Disruptive Migration	Economic Harm	Rule of Law
Water Scarcity	4.2	4.1	3.6	3.7	4.4	4.1	4.6	4.4	3.6
Poor Water Quality	3.4	3.5	3.2	3.4	4.5	3.7	4.6	3.7	3.3
Wildlife Trafficking	2.6	2.8	2.4	3.4	4.2	3.4	3.2	2.4	3.5
Human-Wildlife Interface	2.7	2.8	2.6	4.1	4.3	3.4	3.3	2.4	2.7
Illegal Logging	3.1	3.3	2.5	3.7	3.7	3.8	3.5	3.2	3.4
Deforestation	3.4	3.6	2.5	3.6	4.3	4.1	3.9	3.7	3.2
Illegal Fishing	3.8	3.7	2.9	3.7	2.8	3.9	4.0	3.4	3.3
Unsustainable Fishing	3.8	3.8	2.9	3.5	3.2	4.3	4.2	3.4	3.0
Harm to Regulating ES	3.6	4.0	3.2	3.5	4.2	4.2	4.4	4.2	3.5
Harm to Material ES	3.8	4.1	3.1	3.6	4.0	4.2	4.3	4.2	3.6
Harm to Nonmaterial ES	3.0	3.3	2.4	2.9	3.2	3.1	3.3	3.0	3.1
Food Scarcity	3.6	4.0	3.2	3.5	4.0	4.3	4.3	4.1	3.5
Poor Food Quality	3.8	4.0	3.1	3.6	3.9	4.3	4.2	4.2	3.5
Extinctions	3.3	3.6	2.9	3.3	4.2	3.9	4.2	3.5	3.2
Mass Mortality Events	2.9	3.2	2.3	3.1	3.8	3.6	3.6	3.1	2.6

Table 2: Weighted Standard Deviation for the Severity of Socio-ecological Stresses on Security Outcomes

For each entry, the higher the value the more agreement respondents expressed with respect to the severity a particular socio-ecological stress (row) was assessed to have on security outcomes (column). Scanning across columns shows comparative agreement of importance of a given stress on a range of security outcomes while moving vertically shows comparative agreement of importance of different socio-ecological stresses on a given security outcome. All entries represent the weighted standard deviation of respondent perceptions of risk and not necessarily the risk itself. The 15 lowest values (highest agreement) are shaded in green and the 15 lowest values (lowest agreement) are shaded in brown (inclusive of tie values).

Weighted Standard Deviation (Severity)	State Conflict	Political Instability	Effects on Militaries	Global Health	Human Insecurity	Nonstate Powers	Disruptive Migration	Economic Harm	Rule of Law
Water Scarcity	0.9	1.0	1.0	1.0	0.8	0.9	0.8	0.8	0.9
Poor Water Quality	1.0	1.0	1.1	1.0	0.8	1.1	0.6	0.9	1.0
Wildlife Trafficking	1.1	1.1	1.1	1.3	1.0	0.8	1.0	1.1	1.1
Human-Wildlife Interface	1.1	1.0	1.1	1.2	0.8	1.0	1.2	1.0	1.0
Illegal Logging	1.3	1.2	1.1	1.1	1.0	1.0	1.2	1.0	1.2
Deforestation	1.4	1.1	1.0	1.2	1.0	1.0	1.0	1.1	1.3
Illegal Fishing	0.9	1.0	1.4	1.1	1.4	1.1	1.0	1.2	1.1
Unsustainable Fishing	1.0	1.1	1.4	1.2	1.4	0.9	1.0	1.1	1.2
Harm to Regulating ES	1.1	1.0	1.1	1.2	1.0	1.0	0.8	0.9	1.0
Harm to Material ES	1.0	1.0	1.2	1.2	1.0	1.0	0.9	0.9	1.1
Harm to Nonmaterial ES	1.3	1.1	1.3	1.3	1.4	1.3	1.3	1.3	1.0
Food Scarcity	1.2	1.2	1.1	1.2	1.2	0.9	1.1	1.1	1.3
Poor Food Quality	1.1	1.2	1.1	1.2	1.2	0.9	1.2	1.1	1.3
Extinctions	1.1	1.2	1.3	1.3	0.9	1.0	1.0	1.1	1.2

Table 3: Weighted Mean for the Likelihood of Socio-ecological Stresses on Security Outcomes

For each entry, the higher the value (on a scale 1-5) the more likely the socio-ecological stress (row) was assessed by respondents with respect to particular security outcomes (column). Scanning across columns shows comparative likelihood of a given stress on a range of security outcomes while moving vertically shows comparative likelihood of different socio-ecological stresses on a given security outcome. All entries represent the weighted mean of respondent perceptions of risk and not necessarily the risk itself. The 15 highest values are shaded in red and the 15 lowest values are shaded in yellow (inclusive of tie values).

Weighted Mean (Likelihood)	State Conflict	Political Instability	Effects on Militaries	Global Health	Human Insecurity	Nonstate Powers	Disruptive Migration	Economic Harm	Rule of Law
Water Scarcity	4.1	4.1	3.6	3.6	4.3	4.1	4.4	4.2	3.6
Poor Water Quality	3.4	3.8	3.2	3.5	4.4	3.7	4.3	3.6	3.2
Wildlife Trafficking	2.6	2.8	2.5	3.6	4.1	3.3	3.2	2.5	3.6
Human-Wildlife Interface	2.6	3.0	2.6	4.4	4.3	3.3	3.2	2.5	2.6
Illegal Logging	3.1	3.5	2.4	3.7	3.6	3.8	3.6	3.2	3.4
Deforestation	3.3	3.7	2.7	3.6	4.2	4.0	4.1	3.7	3.2
Illegal Fishing	4.0	3.8	3.0	3.8	2.8	4.0	4.1	3.3	3.3
Unsustainable Fishing	3.9	3.9	2.9	3.6	3.1	4.2	4.2	3.5	3.2
Harm to Regulating ES	3.6	3.9	3.4	3.6	4.2	4.2	4.4	4.1	3.5
Harm to Material ES	3.9	3.9	3.4	3.7	4.0	4.3	4.4	4.2	3.5
Harm to Nonmaterial ES	3.1	3.3	2.4	3.0	3.2	3.2	3.5	3.1	3.0
Food Scarcity	3.8	4.1	3.2	3.6	4.2	4.1	4.3	4.3	3.6
Poor Food Quality	3.1	3.6	2.8	3.3	4.1	3.8	4.0	3.5	3.3
Extinctions	2.9	3.2	2.4	3.1	3.8	3.6	3.7	3.1	2.7
Mass Mortality Events	3.0	3.2	2.3	3.0	3.7	3.8	3.6	3.0	2.5

Table 4: Weighted Standard Deviation for the Likelihood of Socio-ecological Stresses on Security Outcomes

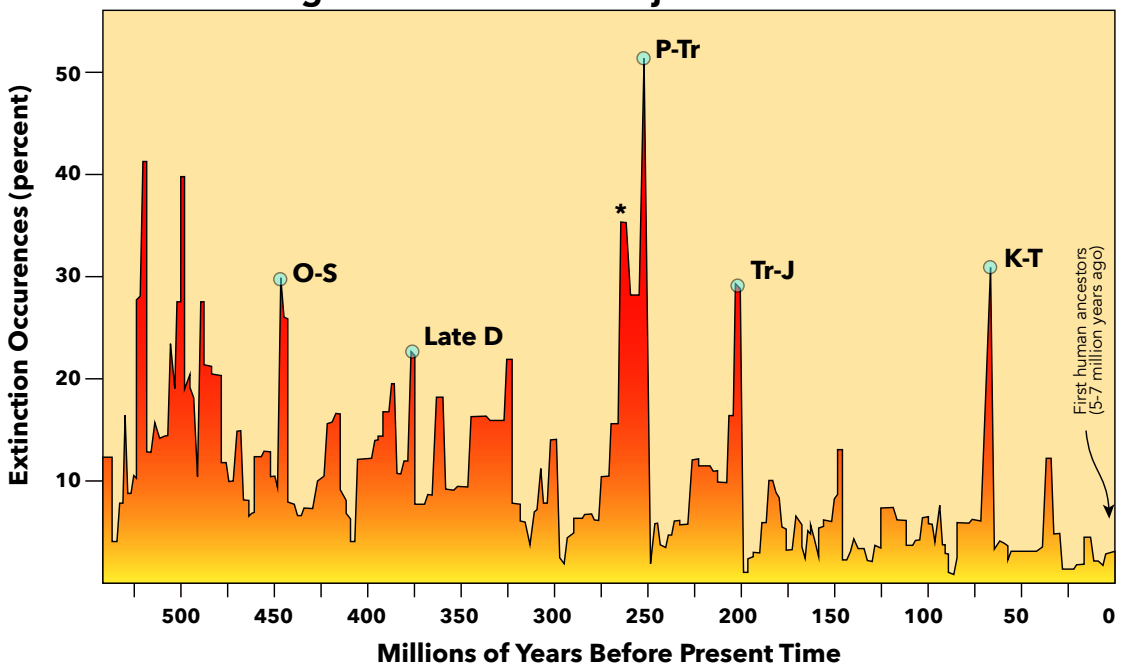
For each entry, the higher the value the more agreement respondents expressed with respect to the likelihood a particular socio-ecological stress (row) was assessed to have on security outcomes (column). Scanning across columns shows comparative agreement of likelihood of a given stress on a range of security outcomes while moving vertically shows comparative agreement of likelihood of different socio-ecological stresses on a given security outcome. All entries represent the weighted standard deviation of respondent perceptions of risk and not necessarily the risk itself. The 15 lowest values (highest agreement) are shaded in green and the 15 lowest values (lowest agreement) are shaded in brown (inclusive of tie values).

Weighted Mean (Severity)	State Conflict	Political Instability	Effects on Militaries	Global Health	Human Insecurity	Nonstate Powers	Disruptive Migration	Economic Harm	Rule of Law
Water Scarcity	0.9	1.0	1.0	1.0	0.8	0.8	0.8	1.0	0.8
Poor Water Quality	0.9	0.9	1.1	1.0	0.8	1.0	0.8	1.1	0.9
Wildlife Trafficking	1.1	1.0	1.3	1.2	1.0	1.0	1.0	1.2	1.1
Human-Wildlife Interface	1.1	1.1	1.2	1.4	0.9	1.1	1.1	1.1	1.0
Illegal Logging	1.3	1.2	1.0	1.0	1.1	1.0	1.3	1.0	1.2
Deforestation	1.3	1.0	1.0	1.2	1.1	0.9	1.0	1.1	1.3
Illegal Fishing	1.0	0.9	1.4	1.1	1.4	1.0	1.0	1.2	1.1
Unsustainable Fishing	1.1	0.9	1.4	1.2	1.4	0.9	0.9	1.0	1.3
Harm to Regulating ES	1.1	1.0	1.1	1.2	1.0	1.0	0.9	0.9	1.1
Harm to Material ES	1.0	1.1	1.2	1.2	0.9	0.9	0.9	0.9	1.1
Harm to Nonmaterial ES	1.3	1.2	1.2	1.3	1.4	1.3	1.3	1.4	1.1
Food Scarcity	1.1	1.0	1.2	1.3	0.9	1.0	0.8	0.9	1.1
Poor Food Quality	1.3	1.1	1.3	1.3	1.1	1.1	1.0	1.2	1.2

APPENDIX II: THE FIVE MAJOR MASS EXTINCTIONS

Many scientists warn that the Earth is now entering a **sixth mass extinction**, the Holocene extinction, as human-induced biodiversity loss and climate change accelerate the species extinction rate well beyond natural background rates (see Page 16).[431] [432] [433] [434] To calibrate the seriousness of such a statement, exploring what happened in the five prior mass extinctions is instructive.

Figure A1. The Five Major Mass Extinctions



Percent extinction occurrences (of genera) as reflected in the fossil record. Rapid and dramatic losses of biodiversity have occurred at least five times, and often define the end of a geologic era. Some scientists include the Capitanian extinction (*), occurring around 260 million years ago, as a major extinction event.

The fossil record has helped scientists identify five events where the populations of over 75 percent of species underwent decline in a short period of time. Scientists estimate that over the last 3.5 billion years, more than 99 percent of all species that have ever lived are now extinct. Mass extinctions are a part of the natural planetary cycle and can be a result of climate phenomena such as rising temperatures or acidifying oceans, volcanic activity, or extraterrestrial origins such as the infamous meteor strike.

Around 444 million years ago, the **Ordovician-Silurian (O-S), or end-Ordovician, Extinction** was the first characterized mass extinction. The event was marked by two waves of extinctions of small marine organisms in which 85 percent of marine species disappeared. The first wave was probably caused by the retreat of ice sheets that altered ocean currents while the second was characterized by sea level rise and global warming which caused marine anoxia (absence of oxygen). The O-S extinction saw the end of many trilobites and *Hirantia* fauna, brachiopods, and other marine species.[435]

The **Late Devonian (Late D), or end-Devonian, Extinction**, the second mass extinction, started around 380 million years ago and was characterized by 20 million years of intermittent extinctions. Many tropical marine genera including corals, sponges, and trilobites and jawed vertebrates went extinct over this period. Major vertebrate clades experienced over 50 percent of biodiversity loss which restructured vertebrate ecosystems. Survivors included tetrapods, four-limbed animals, and other small vertebrates less than a meter long which underwent diversification.[436]

The **Permian-Triassic (P-Tr), or end-Permian, Extinction**, also known as the "Great Dying", was the third and largest mass extinction event in Earth's history. During the late Permian, 96 percent of species including marine animals and 56 percent of genera went extinct.[437] The end of the Permian period was probably caused by a volcanic eruption in Siberia that blasted carbon dioxide into the atmosphere and subsequently made hypoxic bacteria release methane. This mixture of gases created a greenhouse effect which destroyed part of the ozone layer and coincided with surged temperatures, acidified oceans, deepwater anoxia, and wildfires which ultimately made the living environment uninhabitable for most species.[438]

About 201 million years ago, the **Triassic-Jurassic (Tr-J), or end-Triassic, Extinction** was likely caused by another eruption that introduced carbon dioxide into the atmosphere and caused global warming similar to the end of the Permian. This extinction saw the demise of many large land animals and amphibians, but most marine invertebrates survived. As vertebrate species went extinct, dinosaurs and archosaurs grew in diversity and number.[439]

Known for the extinction of dinosaurs by a meteorite, the **Cretaceous-Tertiary (K-T), or end-Cretaceous, Extinction** 65 million years ago was the last of the five mass extinctions. The end of the Cretaceous period was caused by the extinction of 75 percent of species including non-avian dinosaurs, bivalves, and flyer reptiles. This paved the way for the beginning of the Tertiary period during which mammals dominated and humanity evolved.[440]

APPENDIX III: ILLUSTRATIVE OPEN-SOURCE REPORTS

This section draws from recent open-source media reports on a variety of ecological security issues. Their inclusion in this report is meant to be illustrative of how these issues manifest in real-world situations and are by no means reflective of the voluminous quantities of media stories. The aggregate of events reported in these stories demonstrates the pattern of global ecological disruption that is generally unseen through individual reports alone.

ZOONOTIC DISEASE

Africa: "Human Price of Forest Destruction Paid in Plague." 4 March 2015, Scientific American

French Guiana: "Deforestation in French Guiana linked to increase in infectious tropical disease." 21 Dec 2016, PhysOrg

Global: 'Era of Pandemics' to Intensify Without Transformative Change, Report Says." 29 Oct 2020, Voice of America

Global: "By cutting down forests, humans may be giving themselves malaria." 21 Dec 2015, Washington Post

Global: "COVID was just one—there could be 850,000 other animal viruses in the zoonotic pipeline." 30 Oct 2020, PhysOrg

Global: "Habitat loss linked to global emergence of infectious diseases." 24 Jun 2019, ScienceDaily

Global: "Land use changes may increase disease outbreak risks." 5 Aug 2020, ScienceDaily

Global: "Our Exploitation of Wildlife Is Directly Causing More Viruses to Spread to Humans." 8 Apr 2020, ScienceAlert

WATER

Africa: "Bridging the Gap in the Nile Waters Dispute." 20 Mar 2019, International Crisis Group

Belarus: "Fresh water system in Minsk collapses." 25 Jun 2020, Intellinews

India: "India's ghost villages: Food and water scarcity forcing many to leave." 6 Aug 2019, Deutsche Welle

Iran: "Water crisis spurs protests in Iran." 29 Mar 2018, Reuters

Kashmir: "Acute water scarcity triggers protest in north Kashmir." 12 Nov 2020, Kashmir Walla

Kenya: "'Peace ambassadors' ease water conflicts in drought-prone Kenya." 27 Jun 2019, Reuters

Mexico: "Water conflict, feud with Chihuahua governor behind president's visit to Juarez, border expert says." 1 Oct 2020, WRBL.com

Middle East: "On Afghanistan's border with Iran, a water fight brews." 6 Feb 2020, Los Angeles Times

Nile Basin: "Nile dam talks between Egypt, Ethiopia and Sudan fail again." 5 Nov 2020, Aljazeera

Pakistan: "Coal power plants pose risk of water conflict." 8 Aug 2020, Express Tribune

South Asia: "Climate Change and Himalayan Water Conflict in South Asia." 31 Aug 2017, Science International

South Asia: "India Threatens a New Weapon Against Pakistan: Water." 21 Feb 2019, New York Times

Southeast Asia: "Water wars: Mekong River another front in US-China Rivalry." 24 Jul 2020, Reuters

Tibet: "Chinese dams in Tibet raise hackles in India." 8 Feb 2013, Washington Post

Zimbabwe: "Facing Water Shortage, Harare Community Taps Graveyard Well" 22 Oct 2020, Voice of America

FOOD

Asia: "As Asia's rice crop shrivels, food security fears resurface." 1 May 2016, Reuters

Global: "Coronavirus upends global food supply chains in latest economic shock." 23 Apr 2020, Reuters

Global: "Lack of reporting on phosphorus supply chain dangerous for global food security." 9 Sep 2019, ScienceDaily

Global: "UN official warns '2021's going to be a very bad year' - 'Famines of biblical proportions.'" 17 Nov 2020, Daily Express

Global: "What if several of the world's biggest food crops failed at the same time?" 4 Jun 2017, The Conversation

Nigeria: "Looters raid Nigeria food warehouse as unrest spreads." 24 Oct 2020, Yahoo! News

Rwanda: "Rwanda: Police shot dead 11 refugees in food riot." 27 Feb 2018, Deutsche Welle

USA: "Wisconsin Adds Ten Million To Coronavirus Food Security Efforts." 12 Nov 2020, Brownfield

Venezuela: "'We want food!' Looting and riots rock Venezuela daily."12 Jun 2016, Reuters

FORESTS

Amazon: "Fears over rising violence in Amazon as 'forest guardians' battle logging." 13 May 2019, Reuters

Australia: "Illegal logging on steep slopes putting lives at risk." 21 Nov 2019, PhysOrg

Bolivia: "Rare trees are disappearing as 'wood pirates' log Bolivian national parks." 29 Jan 2020, Mongabay

Brazil: "Brazil police arrest dozens in illegal Amazon rainforest logging ring." 2 Jun 2020, Reuters

Europe: "Brussels threatens Romania over illegal logging in primary forests." 13 February 2020, Euronews

Fiji: "Illegal logging a rampant issue: Baleinabuli." 10 Sep 2020, FBC News

India: "Illegal logging 'mafia' stripping hornbill habitat in Northeast India." 22 May 2020, Mongabay

Indonesia: "Indonesia equips forest rangers with guns in illegal logging battle." 9 Jan 2020, Straits Times

Mexico: "Mexican crime gangs branching into illegal logging, researchers warn." 22 Apr 2020, Reuters

North America: "Drug cartels stripping conifer forests for profit in Western Sierra Madre." 2 Jul 2020, BorderReport

Romania: "Illegal logging in Romania overwhelms authorities." 3 Jun 2020, Euractiv

Taiwan: "Taiwan Authorities Bust Illegal Logging Ring as Island's Forest Wars Rage On." 26 Dec 2019, The Diplomat

Thailand: "Thai authorities nab Cambodians for illegal logging." 15 May 2020, The Star

Uganda: "Uganda loses sh138b in illicit timber trade." 12 Nov 2020, NewVision

Ukraine: "Illegal Logging Is Blamed for Worsening Floods in Ukraine." 24 Jun 2020, New York Times

US/Peru: "U.S. extends ban on Peruvian company for 'illegal timber imports.'" 29 Oct 2020, Woodworking Network

USA: "Don't let illegal logging put Arkansas' foresters out of business." 10 Jun 2020, Talk Business

FISHERIES

Africa: "Why maritime crime persists in Gulf of Guinea." 2 Jun 2020, The Nation

Atlantic: "Coast Guard finding more illegal fishing charters in Atlantic." 23 Sep 2020, Virginia Pilot

Canada: "Lobster dispute between Indigenous and commercial fishers boils over, again." 18 Sep 2020, RCI

Ecuador: "Ecuador's authorities and activists call for fisheries control near Galapagos." 15 Aug 2020, LaPrensaLatina

Europe: "Cod crisis: stocks of Europe's most popular white fish collapsing." 9 Apr 2020, EuroNews

Global: "A high-seas food fight has already 'gone kinetic,' and US military officials warn it still poses a bigger threat." 23 Sep 2020, Business Insider

Global: "Climate change increases risk of fisheries conflict." 4 May 2020, ScienceDaily

Indonesia: "Indonesia seizes Vietnamese boats for illegal fishing." 4 Oct 2020, The Star

Nigeria: "$10 billion is Lost Annually to Illegal Fishing, Says Amechi." 4 Oct 2020, This Day Live

South Korea: "Illegal Chinese Fishing in S. Korea Grows Increasingly Unrestrained." 5 Oct 2020, Korea Bizwire

Sri Lanka: "Navy arrests 27 persons for illegal fishing." 13 Aug 2020, Hiru News

Uganda: "Worry as illegal fishing returns on Lake Victoria." 22 Jul 2020, Daily Monitor

Vietnam: "Vietnam: Kien Giang cracking down on illegal fishing." 19 Aug 2020, Thai News Service

West Africa: "The fight for West Africa's fish." 12 Mar 2020, Financial Times

WILDLIFE

Botswana: "350 elephants drop dead in Botswana, some walking in circles before doing face-plants." 7 Jul 2020, LiveScience

China: "Chinese 'ivory queen' charged with smuggling 706 elephant tusks." 8 Oct 2015, The Guardian

Global: "Global wildlife trade higher than was thought." 7 Oct 2019, BBC

Hong Kong: "Call for tougher wildlife crime laws in Hong Kong." 24 Oct 2020, Asia Times

Latin America: Wildlife trafficking on the rise all across Latin America, 7 Oct 2019, The Guardian

South Africa: "South African volunteers rescue endangered pangolins." 7 Nov 2020, Press Herald

Southeast Asia: "'Jaw-dropping' wildlife trafficking reported in South-east Asia."19 Feb 2020, DPA

Tanzania: "Time's up: Wildlife trafficking through Tanzania's ports." 16 Apr 2020, MarketLine

UK: "Illegal wildlife trade's 'dirty money' targeted by big banks." 19 Oct 2018, Mongabay

Vietnam: "Vietnam Wildlife Trafficking Arrests Rise, After COVID-19 Link to Animals." 1 Sep 2020, Voice of America

BIODIVERSITY LOSS

Australia: "A billion animals have been caught in Australia's fires. Some may go extinct." 9 Jan 2020, Washington Post

Australia: "The world's largest reef system is heading towards 'widespread ecological collapse.'" 4 Apr 2019, WCJB.com

Canada: "Scientists study ecological fallout of sea star die-off." 25 Apr 2016, CBC.ca

China: "Mass animal die-off in China due to disinfectants, authorities say." 19 Feb 2020, UPI

Global: "40% of world's plant species at risk of extinction."20 Sep 2020, The Guardian

Global: "Birds species extinction rates accelerate hundred times faster than before." 21 Jan 2020, The Wire

Global: "Climate change may doom 1 in 3 species of plants and animals in the next 50 years." 21 Feb 2020, CNN

Global: "Extinction crisis: 'The window of opportunity is closing.'" 30 Sep 2020, DeutscheWelle

Global: "Humans, not climate, have driven rapidly rising mammal extinction rates." 9 Sep 2020, ScienceDaily

Global: "Mammal Extinctions Are Speeding to an Unprecedented 'Second Wave', Scientists Warn." 7 Sep 2020, ScienceAlert

Global: "One-third of all plant and animal species could be extinct in 50 years, study warns." 14 Feb 2020, USA Today

Russia: "Kamchatka: Toxic algae blamed for 'massive die-off' of sealife in Russian wilderness." 23 Oct 2020, Sky News

USA: "'Unprecedented': Birds mysteriously dropping dead across southwestern U.S."15 Sep 2020, GlobalNews

POPULATION BOOMS

Africa: "Perched on a knife-edge: Lake Victoria's ailing fisheries." 31 Oct 2013, Pambazuka News

Asia: "Fall Armyworm marches on as pest that devastated African crops spreads in Asia." 9 Jan 2019, Telegraph

Australia: "Jellyfish explosion as numbers of stinging creatures surge around ALL of Australia's coastline." 8 Jan 2020, Daily Mail

Chile: "Deadly Algal Bloom Triggers Social Uprising in Southern Chile." 11 May 2016, IPS News

China: "China's Aircraft Carriers Have a Menace: Jellyfish Swarms." 4 Dec 2017, Popular Mechanics

East Africa: "Gigantic new locust swarms hit East Africa, threatening millions with hunger." 12 May 2020, National Geographic

Europe: "Toxic algae spreads in Baltic waters in biggest bloom in years." 1 Aug 2018, Reuters

Global: "Jellyfish are causing mayhem as pollution, climate change see numbers boom." 5 Jan 2019, ABC News

Israel: "Extreme heat wave in Israel spawns explosion in insect population." 18 May 2020, Haaretz

Japan: "Japan braces for further damage by crop-hungry fall armyworm." 15 Aug 2020, Kyodo News

Mexico: "The sargassum keeps on coming: 1,000 tonnes are being collected daily." 11 Jul 2019, Mexico News Daily

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THE SECURITY THREAT THAT BINDS US

THE UNRAVELING OF ECOLOGICAL AND NATURAL SECURITY AND WHAT THE UNITED STATES CAN DO ABOUT IT

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