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THE U.S. FISH AND WILDLIFE SERVICE'S PROPOSED 2023 BUDGET

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

ONE HUNDRED SEVENTEENTH CONGRESS

SECOND SESSION

MAY 18, 2022

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SECOND SESSION

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C O N T E N T S

Page

MAY 18, 2022

OPENING STATEMENTS

Carper, Hon. Thomas R., U.S. Senator from the State of Delaware 1
Capito, Hon. Shelley, U.S. Senator from the State of West Virginia 3

WITNESSES

Williams, Hon. Martha, Director, U.S. Fish and Wildlife Service, Department of the Interior 5
Prepared statement 7
Responses to additional questions from:
Senator Carper 14
Senator Capito 16

ADDITIONAL MATERIAL

Articles
Alaska at center of Trump administration's drive to drill public lands during pandemic 38
Data contradict common perceptions about a controversial provision of the US Endangered Species Act 53
Climate Change 2022, Impacts, Adaptation and Vulnerability 59
King Cove-Cold Bay: Assessment of Non-Road Alternatives 94
The Predicted Influence of Climate Change on Lessor Prairie-Chicken Reproductive Parameters 212
This study just unsermined a huge myth about the Endangered Species Act, Chelsea Harvey, Washington Post 224
Letter to President Biden from the Several undersigned leading philanthropic institutions 227
World Economic Forum; The Global Risks Report 2022 17th Edition 231

THE U.S. FISH AND WILDLIFE SERVICE'S PROPOSED 2023 BUDGET

WEDNESDAY, MAY 18, 2022

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The committee, met, pursuant to notice, at 10:01 a.m. in room 406, Dirksen Senate Office Building, Hon. Thomas R. Carper (chairman of the committee) presiding.

Present: Senators Carper, Capito, Cardin, Whitehouse, Kelly, Padilla, Inhofe, Cramer, Lummis, Sullivan, Ernst.

OPENING STATEMENT OF HON. THOMAS R. CARPER, U.S. SENATOR FROM THE STATE OF DELAWARE

Senator CARPER. Good morning, everyone. I am pleased to call this hearing to order.

Today, we again welcome Martha Williams, Director of the U.S. Fish and Wildlife Service, before our committee to discuss President Biden's Fiscal Year 2023 budget proposal for that agency.

We know that budgets are a reflection of priorities. The President's most recent budget request includes nearly $2 billion for the Fish and Wildlife Service, a much-needed funding increase that would go a long way to further the Service's mission of conserving, protecting, and enhancing our Nation's wildlife and habitats.

This 25 percent increase in funding over 2022 enacted levels in President Biden's first budget proposal is in fairly stark contrast to the almost 15 percent proposed cuts in President Trump's first budget. Providing the agency with more secure and robust funding is, in my judgment, certainly justified.

After years of underfunding the Fish and Wildlife Service, the agency's mission has never been more important. Why, people might ask? Let's just look at the science. In February, the United Nations Intergovernmental Panel on Climate Change released a report that I found alarming. It finds that, among other perils, climate change continues to cause severe biodiversity loss and habitat degradation. We are told that this trend is only going to worsen as climate change intensifies and its impact puts greater stress on habitats and on the species that call them home.

That is not all. Earlier this year, the World Economic Forum states that biodiversity loss is among the top three risks to humanity due to irreversible consequences for our environment and our economy as well.

Earlier this week, I had the privilege of touring South Bethany Beach with a number of our local leaders. It is one of several Dela-

ware beaches severely eroded by storms over the past 2 weeks. People travel from all over the world to visit our five-star beaches and to view species like piping plovers and red knots. The Fish and Wildlife Service plays a critical role in preserving these versatile habitats.

To that end, the President's latest budget proposes nearly $600 million for the National Wildlife Refuge System. That is about a $79 million increase compared to Fiscal Year 2022 levels, after several years of relatively flat funding.

This system consists of, this is interesting to me and I hope to others as well, 568 refuges. There is at least one in every State and territory. Together, they provide habitat for more than 280 threatened and endangered species. Delaware is fortunate to boast two national wildlife refuges. One is called Bombay Hook, and the other is called Prime Hook, right along the Delaware Bay, which are internationally recognized as premier birding locations. We are grateful that the President's budget prioritizes stewardship of these public lands and others.

In addition to including robust funding for the National Wildlife Refuge System, President Biden's budget prioritizes species conservation. His budget proposes $356 million for its ecological services program to conserve imperiled species, an increase of approximately 25 percent over Fiscal Year 2022 enacted levels.

The Fish and Wildlife Service would utilize this funding in close partnership with private landowners, States, Tribes, nonprofit organizations, and other Federal agencies. The Service would also use this funding to improve its efficiency in reviewing and permitting infrastructure projects, an outcome I know we all support.

While this request represents a healthy increase over Fiscal Year 2022 enacted levels for recovering threatened and endangered species, we must also acknowledge the decades of chronically underfunding the Endangered Species Act.

The Fish and Wildlife Service has a backlog of approximately $49 billion in recovery activities for threatened and endangered species. This is likely not a problem that the Congress can fix through the annual appropriations process. My hope is that our committee can continue to seek out solutions to address this backlog over time.

The President's budget also reflects the urgency of addressing climate change and transitioning to a cleaner energy future while also protecting wildlife. It calls for nearly $28 million for activities associated with energy development, including $8 million to support the expeditious review and permitting of clean energy projects. This investment is critical to ensuring that our clean energy projects move forward in a way that minimizes the impacts on wildlife.

When it comes to meeting the President's all-of-government climate goals, I am also pleased to see that this budget includes more than $16 million to assist in transitioning the Fish and Wildlife Services vehicle fleet to zero emissions, not overnight, but by 2035.

Last, I also want to express my strong support for the budget's inclusion of the Fish and Wildlife Service's science applications program. The request of more than $57 million for this non-regulatory program would support the continued development of plans with partners to conserve landscapes and species across our Nation.

We look forward this morning to hearing more from Director Williams on how the President's 2023 budget would support the work she is overseeing, with the help of her team, at the Fish and Wildlife Service.

Before we hear from you, Ms. Williams, we would like to hear from our Ranking Member, Senator Capito, for any comments that she would like to make. Senator Capito?

OPENING STATEMENT OF HON. SHELLEY MOORE CAPITO, U.S. SENATOR FROM THE STATE OF WEST VIRGINIA

Senator CAPITO. Yes, thank you, Mr. Chairman, and thank you, Director Williams, for being here with us today and your recent visit to West Virginia and future visit, we hope. I appreciate your coming before the committee today.

This hearing is particularly important as the committee continues to oversee the implementation of the IIJA.

Last year, I was proud to work with Chairman Carper and my colleagues on the committee in developing and reporting surface transportation and drinking and wastewater legislation unanimously, which were then included as part of the IIJA. If implemented as Congress intended, the IIJA will facilitate the construction of much-needed energy, industrial, and transportation projects across the Country.

The Service must play a key role in ensuring those projects are built in a timely manner. One of the well-known and longstanding roadblocks to efficient permitting is the Section 7 consultation process under the Endangered Species Act. That process requires Federal agencies to consult with the Service on projects that may affect listed or designated critical habitat. The process is a perennial source of delay for projects in my home State of West Virginia. I am sure you might have had some experience in Montana as well.

The Service has attributed the Section 7 review and consultation backlog solely to funding and staffing shortages, but I am not convinced that this is the reason for those delays, based on my conversations that I have had with our West Virginia agencies. For example, for the past 11 years, the West Virginia Department of Highways has fully funded a position at that field office and is still experiencing delays and a lack of technical assistance from the field office.

Additionally, the West Virginia Department of Environmental Protection is being told that they need to fund four positions in order to have their projects reviewed, with no guarantee of how much time those consultants would actually spend on West Virginia projects.

Meanwhile, in addition to the positions the Service is requiring our State agencies to fund, the Administration budget asks for more than 1,000 additional, that is on top of what States would pay for, full-time employees compared to last year.

In order to evaluate that request, I think we need to review the staff the Service currently has, the number of biologists on that staff that conduct consultations, and how those staff are distributed across the regional offices, and whether the leaders at the Service have directed them to clear the existing backlog as an Administra-

tion priority. I look forward to discussing those issues with you today.

I also welcome your thoughts on another longstanding issue with the Section 7 consultation process, and that is the never-ending litigation process. For example, the Mountain Valley Pipeline now has had two rounds of biological opinions stayed or remanded by the Fourth Circuit. If we are going to build natural gas and hydrogen pipeline infrastructure to lower energy prices for our citizens, particularly those in the northeast, and support our allies as they delink their fuel supplies from Russia and China, we must have a consultation process that works and biological opinions that stand up in court. Working with you, Director Williams, I hope we can identify efficiency improvements to that process and ways to make those documents stronger from attacks.

As the former director of a State agency yourself, you also know firsthand how much expertise State fish and wildlife departments have on the species within their borders. I wonder if some of the issues with the quality of biological opinions can be resolved by a more concerted partnership with our States through improved data sharing, increased cooperation, or even delegation of review and consultation authority to the State experts on the ground.

Instead of focusing on improvements, so far, I feel like the Administration has taken actions which will introduce more delays. I raised this issue last week with CEQ Chair Brenda Mallory at last week's hearing. The Biden Administration's changes to the regulations of NEPA, the Migratory Bird Treaty Act, and the Endangered Species Act will make it harder to permit and build infrastructure, including those authorized in the IIJA.

An issue that particularly impacts West Virginia is the Service's decision to up-list the Northern Long-Eared Bat from threatened to endangered. In the listing redesignation, the Service admits that bat populations are declining due to effects separate and apart from development of infrastructure like roads and transmission, namely an invasive communicable disease known as white nose syndrome, you are obviously very familiar with this, that is spread among the bats, primarily when they hibernate in caves.

That means that broad restrictions to development across large swaths of the Country intended to protect the bats as a result of their endangered listing will not meaningfully help mitigate or prevent the disease in the animals, while the endangered label on the bat will not help its future unless the Service provides States and projects sponsors alternative pathways to mitigating white nose syndrome. This decision will have far-reaching implications on our ability as a State to move forward with critical projects that will afford West Virginians economic opportunities. I suggest we work together on a better path that actually protects species as well as American livelihoods.

I thank you, Mr. Chair, for the opportunity.

Senator CARPER. Great to sit here next to you.

We want to again welcome our witness today. How long have you been in this post? How many months has it been?

Ms. WILLIAMS. I haven't been counting, Chairman Carper, but I have been in the post since the beginning of this Administration, but I was confirmed thanks to this committee and your work. I was

confirmed, I believe, in February, so formally in the post since February.

Senator CARPER. Well, we are glad you are here today. I look forward to this hearing very much.

Just by way of introduction, as a reminder, prior to her leadership role at the Fish and Wildlife Service, Ms. Williams served as the Director of, as we heard already from Ranking Member Capito, the Montana Department of Fish, Wildlife, and Parks.

Again, we are happy to see you. Please proceed with your statement. We look forward to asking some questions and hearing your responses. Thanks so much.

STATEMENT OF HON. MARTHA WILLIAMS, DIRECTOR, U.S. FISH AND WILDLIFE SERVICE, DEPARTMENT OF THE INTERIOR

Ms. WILLIAMS. Thank you, Chairman Carper.

Good morning, Chairman Carper, Ranking Member Capito, and members of the committee. I am Martha Williams, Director of the U.S. Fish and Wildlife Service. Thank you for the opportunity to testify on the Service's Fiscal Year 2023 budget request.

The Service collaborates with partners across the Country and around the globe to fulfill our mission of working with others to conserve, protect, and enhance fish, wildlife, plants and their habitats for the continuing benefit of the American people. The Service's mission emphasizes the importance of partnership. Collaboration is key to successful conservation, and it is the lens through which I view my work as the Service's Director.

The Service collaborates with partners on conservation in many ways. For example, we work with States using a science-based process to maintain healthy populations of migratory waterfowl over North American flyways. We collaborate proactively with States, tribes, private landowners, conservation groups, and industry to serve at-risk species before they require Federal protection.

We work with interested landowners to restore and conserve wildlife habitat on their private lands, and we provide support to our international partners to conserve some of the world's most iconic wildlife. An example of collaboration that I am excited about is the National Fish Passage Program, which got a boost through the Bipartisan Infrastructure Law. We work with local communities on a voluntary basis on hundreds of projects to remove fish passage barriers and restore natural functions to rivers and streams.

The positive effects of this work are immediate and increase with time. They benefit fish populations, ecosystems, local communities, and the economy. These are just some examples of how the Fish and Wildlife Service employees work every day in every State and territory with our partners to do great things for the American people.

The Administration is proposing a budget of $2 billion to fund the Service's resource management and conservation programs, an increase of $326 million. The budget proposal makes important investments to restore and enhance our work force and our capacity to be proactive and work with partners. I will touch on some of those investments here.

The Service oversees a network of over 560 national wildlife refuges. These important public lands are managed for the benefit of fish, wildlife, plants, and their habitats, and they provide recreational and educational opportunities to the public, economic benefits to the surrounding communities, and I believe as we all learned during the pandemic, they provide such an important physical and mental health benefit to all of us.

This year's budget request of almost $598 million is the largest request ever for the refuge system. The Ecological Services Program is a leader in conserving our Nation's imperiled species and their habitats, ensuring that sustainable populations of fish, wildlife, and plants continue to thrive for future generations.

The budget request proposes about $356 million to implement the Endangered Species Act and the other laws that the Ecological Services Program implements. The budget supports the Administration's efforts to responsibly site, permit, and deploy priority infrastructure projects. With an increase of almost $41 million for planning and consultation, the Service can restore field office capacity and be better positioned to facilitate development through timely and effective environmental reviews.

The request provides robust support for migratory birds and our fisheries programs, which are so important to the economy as well as to overall fish and wildlife populations. Funding for the Law Enforcement Program would support efforts to investigate wildlife crimes, interdict illegal wildlife shipments, facilitate the legal wildlife trade, and deter the introduction of invasive species.

The request also supports adaptive science work, landscape-level conservation, invasive species control, international conservation, and preventing the spread of zoonotic disease.

Finally, the request also includes a legislative proposal known as the Resource Protection Act. This legislation would ensure the compensation for damages to Service resources then to make sure those are used to repair those resources. We look forward to working with any members interested in this legislation.

Thank you for the opportunity to testify. If enacted, this budget will make a significant difference in our ability to conserve our natural resources in collaboration with others for the benefit of all Americans.

I would be pleased to answer any questions that you may have.

Thank you, Mr. Chair.

[The prepared statement of Ms. Williams follows:]

Testimony of Martha Williams,
Director, U.S. Fish and Wildlife Service, Department of the Interior,
before the Senate Committee on Environment and Public Works
regarding the U.S. Fish and Wildlife Service's Fiscal Year 2023 Budget Request

May 18, 2022

Introduction

Good morning, Chairman Carper, Ranking Member Capito, and Members of the Committee. I am Martha Williams, Director of the U.S. Fish and Wildlife Service (Service) within the Department of the Interior (Department). Thank you for the opportunity to testify before you today on the Service's Fiscal Year (FY) 2023 budget request. I appreciate the Committee's continued support of the Service's work.

For more than 150 years, the Service has collaborated with partners across the country and around the globe to fulfill our mission of "working with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people." To conserve our Nation's natural resources, including threatened and endangered species, migratory birds, certain marine mammals, and certain native and interjurisdictional fish, the Service administers and enforces an array of environmental laws and treaties. The Endangered Species Act (ESA), Migratory Bird Treaty Act (MBTA), Lacey Act, and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are just a few of the important statutes and treaties that guide our work.

The Service has a wide range of programs, offices, and activities that help fulfill these and other statutory responsibilities. We oversee a network of more than 560 national wildlife refuges, located in all 50 States, the Commonwealth of Puerto Rico, and the U.S. Territories. These important public lands and waters are managed for the benefit of fish, wildlife, and plants and their habitats, and they provide premier recreational and educational opportunities to the public. We also work with partners across the country to advance shared conservation priorities for some of our nation's most treasured landscapes. Beyond our nation's borders, many of our programs have international responsibilities, partnering with other countries to conserve international species of interest to the American people.

The nation's investment in the Service over the generations has returned incalculable dividends in terms of economic return, public health, cultural sustenance, and integrity of the world's environment. While we acknowledge the successes of the past, we must also recognize the essential nature of continuing this investment, with a focus on the critical challenges facing wildlife conservation today and in the future.

The Administration is proposing a budget of $2.0 billion for FY 2023 to fund the Service's principal resource management and conservation programs and to support the Administration's priorities. The discretionary request of $2.0 billion is an increase of $326.4 million over the FY 2022 enacted level. The Service also receives $1.8 billion in permanent appropriations, most of

which the Service apportions to the states and territories to support their fish and wildlife conservation and outdoor recreation programs.

Administration Priorities Reflected in the FY 2023 Budget Request

The Service's budget proposal advances Administration priorities, including implementing the *America the Beautiful* initiative, addressing the effects of climate change on Service trust resources, deploying clean energy, and promoting equity and diversity. The budget request also makes important investments that will help enhance our conservation capacity and our ability to conserve our cherished wildlife and natural resources.

- ***America the Beautiful* Initiative**: The *America the Beautiful* initiative is a call to action to support locally led conservation and restoration efforts across public, private, state, and Tribal lands and waters to collectively conserve, connect and restore 30 percent of U.S. land and water by 2030. The guiding principles—which include a commitment to collaboration, support for voluntary and locally led conservation, and honoring of Tribal sovereignty and private property rights—are essential to building and maintaining broad support, enthusiasm, and trust. Upholding these principles, the FY 2023 budget request includes increases to support local partnership programs, improve targeted conservation efforts, restore damaged lands, and promote locally led efforts of all kinds wherever communities wish to safeguard the lands and waters they know and love.

- **Conservation Capacity**: Conservation is at the heart of the Service's mission. The President's budget will restore capacity across the Service's programs, building our conservation workforce and enhancing our ability to care for our trust resources. The budget provides needed capacity for Service programs, which are seeing cost inflation and increases in workload. The budget accelerates conservation efforts by supporting the *America the Beautiful* initiative, investments in partner programs, climate science, and habitat adaptation and resilience. Additional funding will be used to support at-risk and endangered species, address the loss of migratory birds, combat invasive species, and improve habitat connectivity.

- **Climate Change**: The Service is addressing climate change through all of its programs. The request includes an increase of $21.5 million above FY 2022 for the Science Applications program, including $6.2 million for cooperative landscape level work to guide expanded use of clean energy sources and improve resilience to changing temperatures, water levels, and weather patterns resulting from a changing climate. The budget will also support expanded scientific research into the balance of conservation and development and inform conservation decisions in cooperation with the U.S. Geological Survey and other Federal agencies, state and local government partners, and non-government organizations.

- **Deploying Clean Energy**: The budget proposes $22.6 million for activities associated with energy development, including a program increase of $8 million for the Ecological Services Planning and Consultation program to support reviews and permitting of clean energy projects. Within the Migratory Bird Management program, the budget includes

program increases totaling $3.5 million to support clean energy projects and other permitting improvements to ensure renewable resources can be deployed while protecting migratory birds, notably iconic bald and golden eagles. The Service recognizes the need to support the development of clean energy sources to create new industries to support American workers while reducing emissions that contribute to climate change.

- **Promoting Equity and Diversity**: Additionally, the budget request for the Service includes $7.2 million to promote diversity, equity, inclusion, and accessibility, including continued funding for a Department of the Interior-wide budget initiative first funded in 2022 to address high-priority needs in support of Executive Order 13985, Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, and Executive Order 13988, Preventing and Combating Discrimination on the Basis of Gender Identity or Sexual Orientation. The budget request will enable the Service to promote equity and diversity within the agency as well as with our work with communities across the country.

FY 2023 Budget Request for U.S. Fish and Wildlife Service Programs

National Wildlife Refuge System

The National Wildlife Refuge System (Refuge System) is a model for conservation around the world. The FY 2023 budget for the Refuge System is $597.9 million. Funding for operations—including wildlife and habitat management, visitor services, Refuge law enforcement, and planning—is $426.6 million. These funds will support the Service's core mission to increase adaptive management, climate resilience, and the use of climate-related science. The request for Refuge Maintenance is $171.3 million. The Refuge System is a focal point for the Civilian Climate Corps, a program to put people to work improving America's lands, waters, and infrastructure. The FY 2023 budget for the Service includes $10 million—including $8 million in the request for refuges and $2 million for the Service's National Conservation Training Center to develop the next generation of conservation workers and create a new pathway to good-paying jobs.

The FY 2023 budget for the Partners for Fish and Wildlife Program is $67.4 million, and the Coastal Program request is $16 million in recognition of the importance of cooperative conservation of private lands to habitat adaptation and resilience as well as a healthy economy. These programs work collaboratively with partners to restore, enhance, and protect habitat for priority Federal trust species.

Ecological Services

The Service's Ecological Services program is a leader in conserving our nation's imperiled species and their habitats, ensuring that sustainable populations of fish, wildlife, and plants continue to thrive for future generations. One of its primary responsibilities is administering the ESA, one of our Nation's most important wildlife conservation laws. The ESA has had notable success since its passage nearly 50 years ago, including the recent recovery of the interior least tern, Hawaiian hawk, and snail darter, which was proposed for delisting under the ESA this past fall. Preventing extinction and achieving recovery of listed species continues to be one of the Service's highest priorities. To further this priority, the budget request proposes a total of $356.2

million to implement the ESA and other laws under the Ecological Services program, including the Marine Mammal Protection Act and Coastal Barrier Resources Act.

The budget supports the Administration's efforts to responsibly site, permit, and deploy priority infrastructure projects, including energy solutions, by providing $152.8 million for planning and consultation services. With an increase of $40.7 million for planning and consultation, the Service can restore field office capacity and be better positioned to facilitate environmentally sound development through timely and effective environmental reviews, including support for the investments made through the historic Bipartisan Infrastructure Law. The request also advances proactive, cooperative conservation with investments in programs aimed at preventing the need to list species under the ESA. The request provides $54.3 million to support conservation of at-risk species and their habitats, $125.1 million for species recovery, and $23.9 million to accelerate completion of 5-year species status reviews.

Migratory Birds

The budget includes $70.2 million for the Migratory Bird program. The budget includes increases for population monitoring and conservation to address the staggering loss of most groups of migratory birds, including at-risk species. The budget also includes funding to modernize the permitting process and supporting systems to enable the use of the latest scientific information and energy production technologies when evaluating development proposals. The Joint Ventures program will support grants to improve the resilience of important habitats—and nearby communities—across the Nation's four migratory bird flyways. The program's Urban Bird Treaties grants support partnerships to conserve birds in urban environments by creating parks and restoring nearby wetlands—all while engaging local communities.

Fish and Aquatic Conservation

The budget requests $260.4 million to support 71 National Fish Hatcheries, 1 Historic National Fish Hatchery, and 51 Fish and Wildlife Conservation Offices to carry out aquatic habitat conservation and restoration, and the prevention and control of aquatic invasive species. The budget also includes $83.5 million for operation of the National Fish Hatchery System and $49.8 million for fisheries maintenance. The Hatchery System is an international leader in the propagation of imperiled aquatic species, and the budget expands capabilities to ensure the health of aquatic species. Advancing aquatic conservation requires modernizing and maintaining hatchery infrastructure, which is not eligible for funding under the Great American Outdoors Act. The budget also includes $127.1 million for Aquatic Habitat and Species Conservation. This request expands and strengthens aquatic invasive species prevention and early detection and rapid response, fully funds the National Fish Habitat Action Plan at the authorized level, and provides for aquatic species assessments and cooperative management to enhance habitat adaptation and resilience.

Investment to prevent and control invasive species must also be met with the statutory tools necessary to protect natural resources, human and animal health, infrastructure, and the economy. The Service historically interpreted the Lacey Act to include a prohibition on the transportation of injurious species between states within the continental United States. However, in 2017 the U.S. Court of Appeals for the D.C. Circuit held that the law does not prohibit transport of injurious wildlife between states within the continental United States. As a result, the

prohibition on transport of injurious wildlife within the United States is limited to the jurisdictions listed in the statute. The budget request supports efforts in Congress to amend Title 18 of the Lacey Act to return the longstanding authority of the Service to prohibit interstate transport of injurious species. Recent examples of injurious species contaminating commercial products, such as injurious zebra mussels contaminating a widely traded aquarium plant commodity called "moss balls," demonstrate the need to restore this authority. It is estimated that failing to prevent mussel infestation in the Pacific Northwest would exceed more than $500 million annually in increased costs including those for power generation, drinking water systems, irrigation structures, and recreation.

The budget also requests funding for the Service to pilot an aquatic invasive species rapid response fund, which will complement the Service's broader National early detection and rapid response (EDRR) framework, a coordinated strategy to protect the Nation's lands and waters and the communities they support.

International Affairs

The Service provides technical and financial assistance to conserve priority species and habitats around the world and combat wildlife trafficking. The Service also implements CITES, which will have the 19th meeting of the Conference of the Parties this year. This year's budget includes $31.8 million for International Affairs. This request would support expanded conservation capacity in Latin America, the most biologically diverse region of the world. It would support efforts to reduce the spread of zoonotic disease including improving wildlife health and ecosystem resilience, strengthening capacity to regulate wildlife imports, and supporting capacity building with CITES Parties. The budget request will also support ongoing efforts to modernize permitting systems and to develop methodologies to better evaluate and improve the effectiveness of international conservation efforts, and increase transparency, accountability, and oversight in technical and financial assistance programs.

Office of Law Enforcement

Law Enforcement programs are funded at $99.3 million in the budget request. This program enforces the Nation's wildlife laws, ensures sustainable and legal wildlife trade, and investigates wildlife crimes. The Service continues to work with the State Department, other Federal agencies, and foreign governments to address the threat to conservation and global security posed by wildlife trafficking. The budget supports law enforcement efforts to investigate wildlife crimes, interdict illegal shipments entering and moving through U.S. ports of entry, deter the introduction of invasive species, facilitate the legal wildlife trade, and build local enforcement capacities in other nations. The budget request would also support the hiring of a class of twenty-four special agents to replace agents who are reaching the mandatory retirement age in the next year, as well as support for special agent attachés stationed at U.S. embassies around the world, and inspection enhancements at U.S. ports of entry.

Science Applications

The FY 2023 request for Science is $57.5 million. The program supports adaptive science work with collaborative groups to design and implement conservation and habitat management strategies that improve climate adaptation and resilience on the ground. Collaboration will focus on addressing climate stressors, with goals that include increasing coastal resilience, mitigating

desertification, controlling invasive species, and reducing the prevalence and magnitude of wildfires. The budget invests $19 million in a revitalized Cooperative Landscape Conservation Program to support the development of landscape conservation objectives that promote biodiversity, climate adaptation and resiliency, and habitat conservation to achieve the Administration's conservation objectives. By weaving together proven landscape conservation designs and leveraging locally based conservation blueprints, the program will invest in technical capacity, such as geospatial mapping and social science expertise, to proactively engage with States, Tribes, industry, conservation groups, and other stakeholders to identify and pursue high-priority conservation opportunities.

Wildlife and Sport Fish Restoration

The Wildlife and Sport Fish Restoration (WSFR) Program provides federal aid and grants to states to benefit fish and wildlife. The WSFR Program administers several types of grants for projects that improve and manage aquatic habitats, protect, and conserve coastal wetlands, hunter education, and provide important access and infrastructure for boaters. The programs are funded by Federal excise taxes on firearms, ammunition, archery gear, fishing equipment, electric motors, and a portion of the Federal gasoline tax.

The WSFR Program also administers the State Wildlife Grant program, which supports a strategic national conservation framework through individual State Wildlife Action Plans. These plans, developed in coordination with government agencies, conservation organizations and the public, are integral to national efforts to effectively address threats to priority habitats and species of greatest conservation need. The Tribal Wildlife Grant Program supports Tribes in the development and implementation of wildlife and habitat conservation programs, and it directly benefits many Tribes whose members depend on wildlife for subsistence, cultural uses, and livelihoods. The budget includes $82.4 million for State and Tribal Wildlife Grants, an increase of $9.8 million from 2022 enacted to support state and Tribal efforts to protect wildlife habitat.

Administration Legislative Proposal

The budget request also includes a legislative proposal to seek compensation from responsible parties who injure or destroy Service resources. We welcome the opportunity to work with the Committee and any potential sponsors for this provision, which would provide the Service with similar authority to the National Park Service and National Oceanic and Atmospheric Administration. Today, when Service resources are injured or destroyed, the costs of repair and restoration falls upon the appropriated budget for the affected field station or office, often at the expense of other Service programs. Between 2015 and 2017, the National Wildlife Refuge System documented over 76,000 incidents of trespass, arson, and vandalism, with a total cost estimate of $1.1 million of unrecovered damages.

This provision would enable the government to require persons responsible for harm to pay for any intentional injury they cause. The Service has criminal penalties (fines) for those injuries occurring on Service property. In most cases, the injuries far exceed any fines recovered by the U.S. Government. With this authority, the recovery of damages for injury to Service resources would be used to reimburse assessment costs; prevent or minimize the risk of loss; monitor

ongoing effects, and/or use those funds to restore, replace, or acquire resources equivalent to those injured or destroyed.

Additionally, this language would clarify that the Service may retain restitution payments ordered in cases prosecuted by the U.S. Department of Justice. There have been circumstances in the past in which the Service has sent court-ordered restitution payments to Treasury because there is no explicit authority allowing the Service to retain them, thus preventing those payments from funding actual restitution of the damaged resources.

Conclusion

Thank you for the opportunity to testify today and for your interest in the Service's FY 2023 budget request. If enacted, this budget will make a significant difference in our ability to conserve our natural resources and manage our lands and waters for all Americans.

I would be pleased to answer any questions that you may have.

Questions for the Record
Senate Committee on Environment and Public Works
Oversight Hearing on "The U.S. Fish and Wildlife Service's Proposed 2023 Budget"
May 18, 2022

Questions from Chairman Carper

Question 1: As you know, our Committee played a central role in the development of the Infrastructure Investment and Jobs Act, which included the first ever wildlife crossings pilot program at the Department of Transportation and provided funding for the Fish and Wildlife Service to continue implementing existing laws, such as the Delaware River Basin Conservation Act. I was glad to see that the Fish and Wildlife Service's 2023 budget request intends to leverage the investments Congress made through that Act. Would you share with the Committee more about how the 2023 budget request leverages these investments?

a. Is the Fish and Wildlife Service facing any challenges in implementing the Infrastructure Investment and Jobs Act?

Response: The U.S. Fish and Wildlife Service (Service) appreciates the support Congress provided through the Bipartisan Infrastructure Law (BIL). Through this historic law, the Service is working on restoration activities in the Klamath Basin, Lake Tahoe, and Delaware River Basin; sagebrush ecosystem conservation; and fish passage. The Service's FY 2023 budget request includes additional funding above the BIL funding for all of these programs. Delaware River is requested at $10 million, Klamath at $11.6 million, fish passage at $18.6 million and Lake Tahoe invasive species at $4.1 million. Together with the $455 million received in BIL for these programs, the Service will have substantially enhanced ability to restore important ecosystems. The Service is proceeding with its BIL investments and will have announced project lists for most of our funds by this summer. We are concerned, however, about the Service's ability to complete timely Section 7 consultations and other environmental clearances on BIL projects from other agencies. We are actively working to address this by engaging with BIL action agencies to expand our consultation capacity. In addition, in the FY 2023 President's Budget, the Service requested an increase of $40,715,000 over the FY22 Enacted funding level to bolster the planning and consultation workforce and maximize the productivity and effectiveness of the program. These funds will be invested in additional staff, updated technology and planning tools, and methods to increase efficiency nationwide.

Question 2: The Fish and Wildlife Service Science Applications Program brings experts together, both from within and outside of the Service, to identify and act upon shared priorities that are based on sound science. This collaborative effort spans across Fish and Wildlife Service programs and promotes landscape scale conservation for the benefit of people and species. Would you elaborate on the importance of the Science Applications Program and what the Service might be able to accomplish with the funding requested for this program in the 2023 budget?

Response: The Science Applications program is uniquely positioned to proactively address complex, multi-jurisdictional conservation challenges across large landscapes using a

collaborative approach to develop shared conservation priorities, actions, and outcomes. Science Applications led development and coordination of the Climate Change Action Program, the Service's comprehensive approach to climate adaptation. The program provides leadership to the Department of the Interior in landscape conservation and climate change, and are sought out for expertise in Nature Based Solutions to climate change. The FY 2023 budget request will enhance our approach to climate change and increase Service capacity to effectively coordinate internally and support local, state, private, and Tribal conservation and restoration efforts that will advance collaborative landscape conservation. The budget request supports the voluntary integration of State Wildlife Action Plans at regional levels as described in the Association of Fish and Wildlife Agencies framework to enhance landscape-scale and cross-boundary conservation. The Science Applications program facilitates a collaborative three sovereign approach, working with Tribal and state governments by providing capacity to engage in prioritizing needs and conserving wildlife, corridors, and landscapes and ensuring that indigenous and traditional ecological knowledge is incorporated into conservation actions in a way that has not been done before. In addition, the budget request is critical for establishing an Office of Pollinator Conservation that for the first time will dedicate integrated capacity solely to the conservation of pollinator species, while benefiting other species such as grassland birds, reptiles, and their habitats.

Questions for the Record
Senate Committee on Environment and Public Works
Oversight Hearing on "The U.S. Fish and Wildlife Service's Proposed 2023 Budget"
May 18, 2022

Questions from Ranking Member Capito

Question 1: Please provide both state-by-state and field office-by-field office breakdowns of time frames for the completion of formal and informal section 7 consultations under the Endangered Species Act of 1973 for the past 5 years.

Response: Please see the combined response below.

Question 2: Please provide both state-by-state and field office-by-field office breakdowns of projects currently waiting for section 7 consultations under the Endangered Species Act of 1973.

Response: Nationally, every regional office and Ecological Services field office of the Service is working to adapt to growing consultation workloads and a declining workforce. Since 2003, our environmental review staff has decreased by 22 percent, while the number of listed species has risen by 30 percent.

The Bipartisan Infrastructure Law (BIL) will substantially increase the Service's environmental review workload, primarily through additional ESA section 7 consultations. Because the BIL did not include funding to address this increased workload, we are actively working to address this by engaging with BIL action agencies to expand our consultation capacity. Given our already existing staffing limitations, the Service is pursuing transfer funding from other Federal agencies so that we may review their BIL projects in a timely manner. In addition, in the FY 2023 President's Budget, the Service requested an increase of $40,715,000 over the FY22 Enacted funding level to bolster the planning and consultation workforce and maximize the productivity and effectiveness of the program. These funds will be invested in additional staff, updated technology and planning tools, and methods to increase efficiency nationwide.

In order to ensure equity in allocations, the Service distributes funding for environmental reviews to each of the eight regions based on the number of listed, proposed, and candidate species in each region. The regions use similar approaches to allocate funds to field offices, such as the West Virginia Field Office.

Similar to the workload in other FWS offices, Section 7 consultation submissions and technical assistance requests to the West Virginia Field Office have grown dramatically in the last year due in part to a growing number of infrastructure projects. Since the fall of 2021, new project submissions and requests have increased approximately 200 percent. More than 90 percent of these projects are infrastructure-related, submitted in anticipation of the $6 billion invested in West Virginia through the BIL. We expect this important infrastructure workload to continue to rise with implementation of the BIL.

It is also important to note the amount of time Service staff spend reviewing and advising on a project can vary greatly depending on: 1) the completeness of information we receive from

project proponents and other agencies (i.e., whether we receive adequate information to review the project), 2) the complexity of the proposed project, and 3) the proposed project's location (i.e., proximity to ESA-listed species).

The West Virginia Field Office employs five fish and wildlife biologists. Of these five individuals, one works exclusively on Department of Highways projects, and another works on Forest Service projects and other ESA-related reviews. The other three fish and wildlife biologists work on the remaining ESA section 7 consultations. The Service is adding capacity to the West Virginia Field Office, both through backfilling two positions (bringing the total number of fish and wildlife biologists to seven) and advertising for a detailee to support immediate needs. Additionally, the Service's West Virginia Field Office is in discussions with partners to establish funding agreements that would support additional biologists to support the increased workload.

The Service is aware of, and doing its best to address, the consultation backlog and will continue our work to protect our nation's biodiversity while supporting the needs of the public.

Senator CARPER. Thank you, Ms. Williams. Thanks very much for joining us. Thanks for your leadership.

I am pleased that the 2023 budget request includes an increase of a little more than 20 percent over the Fiscal Year 2022 enacted level for the implementation of the Endangered Species Act. When the Endangered Species Act is adequately funded, it works.

Unfortunately, the Fish and Wildlife Service has not received sufficient funding not just for years, but for decades, leaving stakeholders frustrated and many of our Nation's most imperiled species vulnerable to extinction. Over 1,500 species are currently listed, and the Fish and Wildlife Service estimates the cost of necessary recovery actions at $49 billion. That is billion, with a B.

Question: would you expand for us, please, this morning, on the challenges associated with chronic underfunding of the Endangered Species Act? How is the Fish and Wildlife Service working to creatively address this backlog? Moreover, would you elaborate on why the 2023 proposed increase is so important for species recovery?

Ms. WILLIAMS. Thank you, Chairman Carper, for your question and for your underlying support for recovering imperiled and endangered species.

I couldn't agree more with you that the Endangered Species Act has been a success and can work better when the Fish and Wildlife Service has the adequate capacity and resources to implement it to the best of its ability. What I would argue is, with the chronic underfunding, the Fish and Wildlife Service has been on its back foot, and we have been on the defense with the Endangered Species Act.

With this proposed budget, we will be able to be more proactive, more on our front foot, and to be able to emphasize preventing the need to list species, being able to get the backlog of listing proposals, and as you State, adequately invest in the recovery of the species that did need listing.

I look forward to, hopefully, this increase, the $17 million increase in recovery specifically to kickstart those recovery efforts, those specific actions that are already in recovery plans that, with adequate resources, we can catalyze efforts to undertake those recovery efforts and make the Endangered Species Act's next 50 years even more successful.

Senator CARPER. Thank you.

The Fish and Wildlife Service is responsible, as you know, for working with other Federal agencies to make sure that Federal actions do not jeopardize imperiled species. The 2023 budget request before us today includes $152.8 million for agencies' planning and for consultation activities to allow the Service to undertake this responsibility and advance important infrastructure projects.

Would you elaborate for us today on why the 2023 budget request for planning and consultation activities is important to prevent bottlenecks in the environmental review process? This is a really important question. This is an issue that comes up again and again, as you know, so I want us to dwell on this for a little bit.

If the Service receives this funding, will it help you more expeditiously issue permits for infrastructure projects?

Ms. WILLIAMS. Thank you again for that question, Chairman Carper.

I agree with you that this is a very important question. It is a topic that I am paying close attention to, as is all of the Service. We are very aware of and appreciate the incredible benefits of infrastructure projects, specifically those under the Bipartisan Infrastructure Law.

At the same time, we recognize that we do not want to be the bottleneck, and we want to be able to conserve threatened and endangered species and also allow projects to move forward expeditiously. I would say that the additional $40 million proposed in this budget for planning and consultation, we will use and be very careful that the capacity goes to those field offices and to those areas that need the capacity the most, so that we can break through the backlog and address any bottlenecks.

I would answer that, really, I am thinking of, the Service is thinking of this increased funding as allowing us to be more proactive, to be creative, and to be responsive. Thank you.

Senator CARPER. Thank you. I am sure we will come back to this issue during the course of this hearing.

But the idea to say we are going to, like in the last Administration, call for deep cuts in funding for this agency that you lead, and at the same time, we expect you to provide better, more expeditious service with respect to permitting, it doesn't work. It doesn't work.

So with that in mind, let me yield to our Ranking Member, Senator Capito. Senator Capito?

Senator CAPITO. Thank you. Again, thank you for being before the committee.

I want to go back to some of the discussion that I had in my opening statement about the concerns, and the Chairman just talked about this, on the Section 7 consultations and cooperation. It has been brought to our attention that we have $640 million worth of projects that have been waiting for review from the Service. One of these is the Corridor H project, which is a massive four-lane that comes into the State and really opens up the State for economic development. Some of these projects have been in the queue since 2014 and 2019.

In response to this, Fish and Wildlife had submitted to our DEP a one-page proposal that calls for, I think, kind of incredible demands, basically saying that for more than a half million dollars, the State of West Virginia could provide Fish and Wildlife with four FTEs whose GS pay scales only really cover half of what Fish and Wildlife is asking for, because this payment would escalate over 5 years to $800,000 a year with increase of salaries of 8 percent and an assumption of 23 to 38 percent overhead.

I have to ask you, as somebody who has worked at a State Agency, how does this, does it make sense to have a proposal like this? Why would a State spend $800,000 a year on something that the Federal Government is supposed to be providing? Would it be better to have the State be able to have the oversight with liability protections to be able to be a part of this process?

I was really surprised when I saw this proposal from Fish and Wildlife to the State. What do you have to say about the proposal, first of all?

Ms. WILLIAMS. Thank you, Mr. Chair and Ranking Member. I just became aware of this document last night. I am certainly looking into it.

I think that, while I can't speak to the specifics of the document more, I can understand the underlying concerns that it would present. One, I think if we work through it, I think it can be an opportunity. I agree with you in that I think there is always the opportunity for us to work as closely as we can with our State partners.

That said, our focus typically is on threatened and endangered species. Often coming from a State fish and wildlife agency, we never had adequate resources for non-game species, to be honest, or to be fair about it. Nonetheless, I think that there is an opportunity for us to work more closely and share in responsibility with the States.

Senator CAPITO. I would be interested, as you have a chance to look at this in more detail, I was really shocked when my staff brought it to my attention. I would love if you would come to West Virginia. Being a former State agency head yourself, to address this massive backlog, I think that would be a way for us to help us figure out how to get through these delays. Would you be interested in doing that?

Ms. WILLIAMS. Absolutely, Ranking Member Capito. I am pleased to say that we have added two biologists to our West Virginia field office. I know that you and your staff have worked with us so well in trying to increase capacity and effectiveness and efficiency there. So I look forward to working on that issue with you, as well.

Senator CAPITO. I think, you know, as we pass the IIJA, we obviously, the longer the delay, the less the money, the supply chain is going up; inflation is going up. Everything is going to cost more.

We had a situation where Virginia has the candy darter, West Virginia has the candy darter on the endangered species list. They had a project in Virginia, they had a conservation plan. It was approved in Virginia. We had another project in West Virginia that involved the candy darter. They mirrored the same exact provisions from the Virginia conservation plan, and the West Virginia plan was rejected by the West Virginia office.

What kind of inconsistencies are you finding across the Country, and it is very frustrating, especially being from neighboring States and like habitats?

Ms. WILLIAMS. Ranking Member Capito, I can understand that frustration. In fact, I was on a call, it may have been yesterday or the day before, talking about a general habitat plan and the need to coordinate habitat conservation plans so that we are more consistent. I know there is interest in the Service, and I will pursue this further where we are more consistent when we are talking about similar species, similar types of projects, and similar landscapes.

Senator CAPITO. If we are talking about delays and bureaucracies and shortages of resources that you have sited, it seems to me that if you are dealing with the same species in relatively the same type of habitat, that mirroring this just makes total sense. It certainly would save a lot of the Fish and Wildlife regional or State offices a lot of time and energy so they could devote it to future projects.

Thank you very much. I look forward to seeing you in West Virginia.

Ms. WILLIAMS. Thank you.

Senator CARPER. Thank you. You know, it is just a hop, skip, and a jump over there. You have been there many times, I am sure. It is easy to get there.

Senator Cardin, please?

Senator CARDIN. Thank you, Mr. Chairman. Madam Director, welcome. Thank you for what you are doing. We appreciate it very much.

I want to start by talking about the Chesapeake Bay; you are not going to be surprised to learn about that. We are very interested in how Fish and Wildlife will be enhancing resiliency in the Chesapeake Bay watershed. We are excited about the beneficial use of dredged materials. We saw some at Blackwater, but now Midbay on dealing with the challenges in the Bay. We have at Blackwater, really exciting things happening at Blackwater, trying to preserve its wetlands.

I want to first start off with the new program, the Chesapeake WILD Program that was in this current fiscal year, funds were appropriated. I am interested in how you are using this to deal with wildlife conservation as anticipated in the legislation, which provided for fish and wildlife, habitat, climate change, community partnership, public access, water quality. I recognize that in the budget cycle, it has been difficult to know what we were doing, because the omnibus was so late. But we want to make sure that there is constant funding for this program, so I am interested in your view as to the resources you will need in Fiscal Year 2023.

Ms. WILLIAMS. Thank you, Senator Cardin. I feel at home when I hear you pronounce water, so I know I am with a fellow Marylander.

[Laughter.]

Senator CARDIN. I feel more comfortable about that, also.

Ms. WILLIAMS. I first want to thank you, though, for your leadership with the Chesapeake WILD Program. I think it is an example of one of those programs that while we received $4 million in our first appropriation and that may seem small compared to some programs, it is incredibly mighty, and it is an example of how we can leverage and build off of that initial $4 million investment.

We are working with the National Fish and Wildlife Foundation to deliver those funds on the ground, and I know that we received our first proposals in March and expect to announce the first set of awards late in the summer. Should Congress provide additional funding for this program in Fiscal Year 2023, we certainly can support that and think that it really makes a difference to the people in the Chesapeake Bay, to wildlife, and habitat health. Thank you for your interest in that.

Senator CARDIN. We appreciate your help and partnership. We might need to get some more specific information from you. I know Senator Van Hollen is also very interested in this. We might need to have a better understanding as to the resources that could be utilized in Fiscal Year 2023, so I would ask your cooperation in that regard.

Ms. WILLIAMS. I am happy to do that, Senator Cardin.

Senator CARDIN. Just recently, I filed legislation with Senator Portman, bipartisan legislation, for neotropical bird reauthorizations at a higher level and at a better mix from the point of view of a match to deal with better utilization of this program. Since 2002, I think it is, there have been over 600 projects funded by the Neotropical Bird Program in 36 countries. It is vital and critical to migratory birds, including the very famous Baltimore Oriole.

Give us your view as to the importance for us paying attention to the reauthorization and the funds that are available.

Ms. WILLIAMS. Again, Senator Cardin, I can't thank you enough for your leadership on the Neotropical Bird Program.

Yes, it is incredibly important right now, as the Chairman opened this hearing in talking about the biodiversity crisis that we do face and that it has very much impacted birds. We know that we have lost three billion birds. So this program is of utmost importance, and I think it demonstrates to all of us as Americans how much we all love birds, that it is not a partisan issue, and that it is something that I think the American public really cares about.

So, thank you for your leadership in this.

Senator CARDIN. I am going to just mention one other issue, and that is an issue that we have not been able to deal with, and that is to allow you to recover for those who damage a wildlife refuge. Unlike the National Parks Service or NOAA, you don't have the authority to assess the fines and use the fines from those who violate our refuges.

We have had legislation on this in the past. I would hope that the Administration, I think it is in your budget, I would hope that you would be actively engaged and see whether we can't get that to the finish line.

Thank you, Mr. Chairman.

Senator CARPER. Not at all. Thank you for your leadership on these issues.

Before I turn to Senator Inhofe, three billion birds over what period of time?

Ms. WILLIAMS. I realized I didn't finish that sentence, Chairman Carper, on purpose. I believe in the past decade.

Senator CARPER. Just respond for the record. Thank you.

Senator Inhofe, welcome.

Senator INHOFE. Thank you.

Director Williams, it is no surprise to you that I am going to bring up yours and my favorite subject, and that is the lesser prairie chicken.

As you know, the updated population data is a key factor when determining if a species should be listed under the Endangered Species Act. On March the 15th of 2022, the Western Association of Fish and Wildlife Agencies announced plans to release updated lesser prairie chicken population data in the coming months. Director Williams, do you plan to include the Western Association of Fish and Wildlife Agencies' most current lesser prairie chicken population data in your listing decision?

Ms. WILLIAMS. Thank you, Senator Inhofe, for your continued interest on this issue. I hope I get to visit with you about it more. I never get tired of those visits and talking about all of the incred-

ible voluntary efforts that are underway to conserve lesser prairie chicken.

Senator INHOFE. I might add, successful efforts.

Ms. WILLIAMS. Yes, many of them very successful. In fact, you know, as we are looking at lesser prairie chicken and, I believe as it was in the proposed rule that one of the reasons why there are two distinct population segments and why one is threatened and one is endangered is those recovery efforts and the restoration efforts that have been underway.

To answer your question, Senator Inhofe, I believe that indeed, we did take into account those numbers. The proposed rule, I think, shows our responses. Yes, we have taken robust public comment and will take those numbers into account.

Senator INHOFE. I appreciate that. Let me talk fast here to get my time to effectively end where I want it, and that is the conservation practices have helped to nearly double the total lesser prairie chicken population size since 2013. That is pretty remarkable. That is, I am sure, something would be now on your plate of concern.

In your response letter to my inquiries regarding your proposal to list the lesser prairie chicken under the Endangered Species Act, you made it clear it was not necessary to perform a Policy for Evaluation of Conservation Effort Assessment.

So, Director Williams, can you provide an update on your work with the Western Association of Fish and Wildlife Agencies to address conservation concerns with the Candidate Conservation Agreement with Assurances, considering you do not plan to perform this assessment?

Ms. WILLIAMS. Mr. Chair and Senator Inhofe, when I first started in this position, because I had been a member of the Western Association of Fish and Wildlife Agencies, I was very careful not to have direct contact with WAFWA, if you will. I would need to look into the answer to your question more, and then I will be very careful to be at arms' length with WAFWA per se. But I do know that our staff and especially Amy Lueders, our Regional Director, has been very involved in the CCAA with the Western Association of Fish and Wildlife Agencies.

Senator INHOFE. I always enjoy the idea that we are doing something where the current information should be helpful to us. When we look and we see that we have had that kind of a success over that period of time, not all of them have that. So, I look forward to keeping that on the table, but not waiting for another meeting to come along, because you know of my interest in this issue.

Ms. WILLIAMS. Thank you, Senator Inhofe, and thank you also to all of those who worked so hard in your State to conserve lesser prairie chickens.

Senator INHOFE. Successfully.

Ms. WILLIAMS. Successfully.

Senator INHOFE. Yes. Thank you so much. Thank you.

Senator CARPER. Thanks, Senator Inhofe.

Senator Whitehouse, then followed by Senator Cramer. If she is able to return, Senator Ernst would be next.

Senator Whitehouse?

Senator WHITEHOUSE. Welcome, Director Williams. Thank you for being here, back in front of the committee. It is good to see you.

I wanted to talk to you for a moment about zettajoules. A joule is the unit of measure of heat energy. A zettajoule is that measure with 21 zeros behind it. It is a really, really, really big number with 21 zeros behind it. It is so big, that to give it a more concrete example, the entire energy use and consumption of the human species on the entire planet adds up to one-half of a zettajoule.

So our fossil fuel energy is less than one-half of a zettajoule, and it is less than one-half of all of our energy production and consumption. For the price of that less than half zettajoule of human energy production, we have created an environment in which we are dumping 14 zettajoules, so 30 times as much, heat into our oceans. It is the equivalent of setting off multiple Hiroshima-sized atomic bombs in our ocean every single second. It is warming at a colossal, geologic level. We are not paying anywhere near enough attention to what this means for our oceans.

But with that kind of upheaval happening in the oceans, it makes it increasingly important that the Fish and Wildlife Service pay adequate attention to what is going on to saltwater fish and ocean wildlife, as opposed to just freshwater fish and terrestrial wildlife.

So, I would like to ask you what you are doing to make sure that, in light of that kind of change happening in our marine environments, your organization will continue to expand its focus on saltwater fish and coastal and marine environments.

Ms. WILLIAMS. Mr. Chair and Senator Whitehouse, thank you for that question. I have to say, I share your concern about the unprecedented challenges facing our oceans and our coasts. There are a number of different ways that the Fish and Wildlife Service, even through our 2023 budget request, has asked to increase and pay more attention to these issues. We did request a $2.3 million increase for the coastal program. We also asked for a $2 million increase in the Coastal Barrier Resources Act.

On top of that, I would like to say that we, I believe, are working very well and closely with our sister agency at NOAA and understand these shared responsibilities that we have on these unprecedented challenges.

I would love to add, too, Senator Whitehouse, that while we only flew in and out of your State, I was able to go to Connecticut with the Secretary and see the benefit of restoration investment in saltwater and salt marshes and to see the intricate balance that we need to address.

Those are just some examples, Senator, of where the Fish and Wildlife Service can help, but I am always happy to work with you and talk about what else we can do to support and address this unprecedented challenge that is before us.

Senator WHITEHOUSE. Good. Well, thank you.

I think the daily temperature would probably be in the hundreds of degrees in our terrestrial States if it weren't for the ocean providing this enormous amount of cooling work that it has done to take some of the sharp edge off of the climate challenge. I think something like 90 percent of the excess heat that fossil fuels have

generated for our planet have been actually absorbed by the oceans, so we don't experience them in the atmosphere.

But the damage that causes to the oceans is profound. It ought to send us a signal about the kind of damage we are doing to our planet by continuing to recklessly burn fossil fuels and creating these massive, massive upheavals in the basic operating systems upon which human life depends.

Thank you.

Senator CARPER. Our next colleague is Senator Cramer. He is going to be followed by Senator Padilla on WebEx. We have been joined by Senator Lummis. Welcome.

Senator Cramer, you are on.

Senator CRAMER. Thank you, Mr. Chairman. Thank you, Ms. Williams, for being here.

Would it be safe to say that NEPA compliance is a really high priority for this Administration, particularly for local communities, stakeholders, others, to provide input on Federal decisions?

Ms. WILLIAMS. Mr. Chair, Senator Cramer, that is a fair question, and I would think yes.

Senator CRAMER. I think so, too. Similarly, considering that the first Administration priority that you referenced in your opening statement is America the Beautiful or 30X30, would you say that is also a high priority?

Ms. WILLIAMS. Mr. Chair, Senator Cramer, yes. The America the Beautiful and the fundamental components of it and this collaborative, community, voluntary approach is very important.

Senator CRAMER. So, does the Administration plan on following the NEPA process for 30X30 for implementing it, carrying it out?

Ms. WILLIAMS. Mr. Chair, Senator Cramer, I am sure, on specific projects that trigger NEPA, indeed, we will follow the law.

Senator CRAMER. Now, this is one big Executive Order, 30X30. Why wouldn't that trigger NEPA when we are talking about tripling the protected acres in the United States? Wouldn't that be a pretty obvious trigger for a NEPA process or some sort of comprehensive review, programmatic review?

Ms. WILLIAMS. Senator Cramer, that is certainly not within my purview at the Fish and Wildlife Service. I think NEPA really goes to Council on Environmental Quality, and I defer to their wise counsel.

Senator CRAMER. I just sent a letter to them, so I will look forward to that. Thank you. It is signed by some other people in the room.

As you know, since I came to Congress in 2013, I have heard from literally hundreds of North Dakota landowners that are encumbered with Fish and Wildlife Service Waterfowl Protection Area easements. Their experience has been disastrous through Democratic administrations and Republican administrations alike, almost equally, I would say. They have had their private property rights trampled on, the Service not living up to its contractual agreements, using confrontational enforcement methods like showing up armed, with body armor on.

During both our private meeting and your nomination hearing, we discussed the enforcement of WPA easements. You stated that you would work with landowners to "get this issue right."

Since your nomination process, I have continued to work on the issue, as well. I introduced legislation to prohibit the Service from entering into a conservation easement of greater than 50 years. We want to give owners of existing easements the opportunity to renegotiate, renew, or even buy out their easement.

My question to you then, is, since you have been confirmed, what have you been doing to work on remedying my problem, since I have translated it to your problem?

Ms. WILLIAMS. Senator Cramer, I have been working diligently on this issue, as have many of our staff. We have put, I have somewhere here, I think over, just many hours addressing this issue.

What we have done since I have talked to you, and I know that others in the Administration also have gone to visit you, we have done a number of things. One, we are finalizing a Service Easement Policy and Handbook to address any of the past issues you may have identified with how we enforce our easements. For example, now we have only our refuge staff, not Office of Law Enforcement, go to meet with landowners. We are working through this handbook to make very clear how we want to administer these easements, which I think we do with many landowners, very successfully with many, although I understand your concerns.

In addition to that, I think we have made progress in these pre-1976 mapping efforts. I know that over 250 objections we have addressed, and we have changed many of those maps. We have been pursuing, as you had worked on, this appeal policy that goes through three steps: the refuge, the regional director, and then to me.

But I am certainly very committed to this issue and working with you on it and want to address your concerns.

Senator CRAMER. Have you talked to any landowners affected by an appeal that has gotten to the director level, either previously or recently? I am just seriously interested.

Ms. WILLIAMS. Senator Cramer, meaning, have I met with them one-on-one?

Senator CRAMER. Yes, or made a phone call or taken up an appeal personally, because it does get to your level.

Ms. WILLIAMS. Yes, Senator Cramer. Once it goes through the refuge manager, the regional director, which many of them are addressed at those levels, the ones that do come to me, I have not picked up the phone, nor have I been asked for meetings. But I would be happy to work with you, and happy to work with landowners.

Senator CRAMER. We might want to dig into that a little more specifically, maybe privately, at some point, just because I don't know of a single appeal that has ever been upheld on behalf of the landowner. So the process may be better, but I don't know of any. That is not to say there hasn't been one, but I don't know of any.

Ms. WILLIAMS. Senator Cramer, I can assure you that we have changed, through the appeal process, the easements and the delineation, some of them have changed, and we have definitely responded.

Senator CRAMER. Thank you. Thank you, Mr. Chairman.

Senator CARPER. Thank you. I think we are going to be joined by Senator Padilla by WebEx. Senator Padilla, are you out there?

Senator PADILLA. Thank you, Mr. Chairman. Yes, I am here.

Senator CARPER. Welcome.

Senator PADILLA. Director Williams, I was glad to see that the Fiscal Year 2023 budget includes increased funding for so many critical conservation programs, like the Cooperative Endangered Species Conservation Fund for Ecological Services, that supports efforts to prevent Endangered Species Act listing of species. I think it is critical that all of our Federal agencies are well-equipped to protect threatened and endangered species.

While the Fish and Wildlife Service is the primary agency charged with conserving fish, wildlife, plants, and their habitats, I also respect that you work collaboratively with other agencies who have their own important roles in recovering threatened and endangered species. In fact, the Endangered Species Act requires other land management agencies to carry out programs to conserve listed species.

That is why I am also pushing for increased funding at the Forest Service and the Bureau of Land Management for programs related to threatened and endangered species conservation programs.

All of that to say the following: in my home State of California, we have a significant amount of Federal land that is managed by the Forest Service and BLM that is home to numerous listed species.

My question, Director Williams, is this: can you talk for a minute about how Fish and Wildlife Collaborates with other agencies like BLM and Forest Service to better conserve and restore listed species and their habitat?

Ms. WILLIAMS. Thank you for that question, Senator Padilla. Indeed, that is a priority for me and for this Administration, for the Interior Department, and for the Fish and Wildlife Service. I would say that it is an area of focus where I have worked closely with the bureau chiefs, whether it is the Park Service at BLM, with other agencies, USDA, I work with them very closely, and I think that it is incredibly important.

In fact, I think one of the hallmarks of this Administration is that we have worked through some challenging issues, and we have hit them head-on.

I also agree with you in that I think this has been an opportunity for the Endangered Species Act, were we to have the capacity and adequate resources, we can be more proactive in our administration of Section 7(a)(1) and 7(a)(2) of the Endangered Species Act and be more proactive in how we work with other agencies in consultation and on their efforts on their land.

It is of utmost importance. We are doing it, and also, I think it is an area where we can do more.

Senator PADILLA. Great. As a followup to today, not to answer right now, but I would love to also hear what else Congress can do to support you and other agencies in these efforts.

But in my time remaining I did want to raise one other specific issue, and that is I am pleased to see Service's attention to the Lake Tahoe Region in the Fiscal Year 2023 budget, particularly the work you are doing to present the introduction and expansion of aquatic invasive species and to conserve native species like the Lahontan cutthroat trout.

In addition to protecting Lake Tahoe from the threat of wildfires, removing and preventing aquatic invasive species in Lake Tahoe is one of the highest ecological priorities for the area. As you know, the Federal Government owns and manages approximately 78 percent of the land within the Tahoe watershed, making Federal involvement in the region critical. We had a success in response to the zebra mussels threat in 2009 because of the successful watercraft inspection programs that were implemented.

So, the question is, how will the Service's budget request buildupon the Bipartisan Infrastructure Law's investments in invasive species management and continue to implement initiatives to fight invasive species in Lake Tahoe and protect native species?

Ms. WILLIAMS. Thank you, Senator Padilla, for your interest in the Lake Tahoe region and in the leadership that you have shown on this issue so far.

As you noted, the Bipartisan Infrastructure Law is terrific investment in this region and one that we are deploying strategies to really prevent the introduction and spread of aquatic invasive species. I have long been aware of and have followed the Lake Tahoe aquatic invasive species management plan. When I was in Montana, we closely followed the efforts that Lake Tahoe had undertaken to try to prevent invasive mussels there.

So the Bipartisan Infrastructure Law allows Fish and Wildlife Service to really work and dig in and partner with our States and Tribes in this area, especially for Fiscal Year 2023.

I appreciate your leadership, and I think this is an important area, and one I think we can all, working together, make such a difference, especially in preventing the spread of invasive species.

Senator PADILLA. Thank you very much. I am looking forward to our followup. Thank you, Mr. Chairman.

Senator CARPER. Senator Padilla, thanks for joining us today. I am going to slip out and take a phone call.

Senator Lummis, you are recognized, and I will be right back. Thank you. Thanks for joining us.

Senator LUMMIS. Thank you, Mr. Chairman. It is good to see you again, Director Williams. During your confirmation hearing, I used the entirety of my time to visit with you about the Greater Yellowstone Grizzly. I am going to start with a question about that again today because it is so critical to my State.

My first question is, will the Service follow the statutory deadlines set by the ESA to respond to Wyoming's Greater Yellowstone grizzly delisting petition within 12 months, with a status review and recommendation? These timelines are really important to us.

Ms. WILLIAMS. Senator Lummis, thank you for that question. I enjoyed visiting with you on this issue. It is one that is very near and dear to my heart, as well. I very much appreciate the efforts of your State and the leadership they have shown, especially recently with grizzly bear recovery efforts.

We did receive, the Fish and Wildlife Service did receive a petition from the State of Wyoming, as you mentioned. We also received one from the State of Montana and one from the State of Idaho. They are similar, but not entirely the same, no surprise there, and we are currently working on all three of these petitions.

I am certainly aware of the deadlines that the Endangered Species Act sets out.

Senator LUMMIS. The reason for my asking the question, of course, is that the Service has already missed an initial 90-day deadline. If you are trying to bundle our petition with Montana and Idaho, I want to encourage you to respond to Wyoming's petition alone, and on its own merit. Because doing them together will slow things down for us so incredibly and make it even more difficult for us to address the ongoing issues, as this issue is slow-walked and not dealt with in a manner that I believe would be contemplated under the Act.

Is it your intention to address them all three together, or are you willing to address the Wyoming petition as a standalone?

Ms. WILLIAMS. Senator Lummis, I don't think I can answer that perfectly for you. I know that in our regional office, they are working on this, and I have not been engaged at the moment, nor should I be in that it is a scientific review at this point, other than I know that they are working on these.

I understand your request, and it is something that I will ask, and I can go back and look at. I understand your request also because I think the issues are somewhat similar in the three States, and yet, they are distinct. I think that, as you look at the grizzly bear recovery amongst all three States in the lower 48, they are complicated and maybe different than just Wyoming's petition alone.

I hear your request and will look into it.

Senator LUMMIS. OK, thank you. Well, the issue, the geographic area, the geography around Yellowstone, does tend to keep grizzly bears within certain areas from which they do not stray. Sometimes, they don't go into the other States adjacent because of simple geography. So, please, I implore you to respond to Wyoming's petition alone and on its own merits.

OK, my next question is similar to Senator Cramer's. That is, people in Wyoming are concerned about this 30X30 plan. Of course, NEPA requires that any major Federal action undergo analysis. Do you believe that 30X30 should undergo NEPA analysis?

Ms. WILLIAMS. Senator Lummis, as I answered to Senator Cramer, and I mean to be consistent, I think that is a question more for the Council on Environmental Quality than for me.

What I can say, too, is that I view the America the Beautiful Initiative, and if you look at its underlying principles, it sets out principles, it sets out a way of undertaking actions, and any specific actions that the Fish and Wildlife Service would undertake as a result of it, I am sure, that trigger NEPA, we would do so.

An example of what the Fish and Wildlife Service already did in the America the Beautiful, I think, it views or amplifies is our Partners for Fish and Wildlife work. I don't think the America the Beautiful changes that work. It only, I think, amplifies and encourages a way of collaborative, locally led voluntary conservation.

Senator LUMMIS. Mr. Chairman, can I have a quick followup? I know I am running over.

Senator CARPER. No, no, you are fine.

Senator LUMMIS. OK. It would be so helpful for the people I represent to have a legally cited explanation for why potentially

changing the use of hundreds of millions of acres is not a major Federal action. When an initiative is announced that is hugely consequential for the west, yet it doesn't have the normal framework that is used to have interaction and public input and dialog in a State like mine that is half Federal land, it is scary.

So, how can we get something in writing? Should I ask CEQ? Am I asking the wrong person today?

Ms. WILLIAMS. Senator Lummis, what I would say, what I can answer is, I would be more than happy to work with you and the State of Wyoming so that we can hear from people. We want to be transparent. I am happy to address any concerns and opportunities that there are around that, so I would be willing to work with you on this and in Wyoming specifically.

Senator LUMMIS. Thanks, Director Williams. It is a thing that people fear in Wyoming. You hate to see, when you have this grandiose, aspirational program, America the Beautiful, and the American people are afraid of it, then there is a disconnect that we need to resolve. Thank you.

Thank you very much, Mr. Chairman. I yield back.

Senator CARPER. Thank you so much.

I have several more questions I would like to ask. We may be joined by Senator Sullivan and a couple of others, but we are at least halfway home right now.

My next question would be to deal with Fish and Wildlife Service's collaborative nature. During your visit to Delaware last year, thank you for coming, a recollection came back, actually, before you had been confirmed, as I recall.

During your nomination hearing, we talked a good deal about the Fish and Wildlife Service's collaborative conservation efforts. Specifically, we discussed how the Fish and Wildlife Service is working with partners to prevent species like the salt marsh sparrow from requiring protections under the Endangered Species Act. This is not the only way the Service works collaboratively with partners, as part of a team.

As I like to say, teamwork makes the dream work. I know the Fish and Wildlife Service, under your leadership, really has embraced this mantra.

Would you just elaborate for us on how the Fish and Wildlife Service is working collaboratively with a diverse suite of partners, and how the 2023 budget request supports this important work?

Ms. WILLIAMS. Thank you for that question, Senator Carper. I think our shared interest in teamwork makes our dream work. It is exactly why I feel like I am in this position right now, thanks to your interest and leadership.

So, yes, indeed, the Fish and Wildlife Service, we view our work across the board through this lens of partnership and collaborative work because it is the only way for us to achieve real conservation success. The examples are myriad and are littered throughout the Service and our programs, as it should be.

An example, I think, that I had mentioned earlier, is our Fish Passage Program and the investment in that program. Those are, all of those projects, every single one of them, are a product of numerous partnerships, leveraging money, and using the Fish and

Wildlife Service engineering technical expertise and planning to support a community and projects.

I can think of our Partners for Fish and Wildlife program, which is all about collaborative work. I can think about visiting with you to Prime Hook and our coastal program, and our migratory bird program, our international program, our law enforcement program. Really, every program that we have is infused with this desire to be collaborative and to leverage the resources available to deliver conservation on the ground.

Senator CARPER. We have been joined by a couple of our colleagues. They came in just at the same time. Who would be next? Senator Sullivan and Senator Kelly, thank you for joining us. If you can stay, we would be grateful. If you can't, we understand. Senator Sullivan, are you ready? You are always ready.

Senator SULLIVAN. I will defer to my colleague from Arizona if he wants to go. I know he is always a very busy man.

Senator KELLY. Well, thank you, and thank you, Mr. Chairman.

Senator CARPER. Sure.

Senator KELLY. Ms. Williams, thank you for being here today.

I have a question about the Mexican gray wolf listing. Last week, the Service finalized revisions to the management regulations for the Mexican gray wolf in Arizona and in New Mexico. As you probably know, the revised management plan has left some ranchers and some landowners concerned that this could lead protected wolf populations to grow significantly, yet others have raised concerns that the protections have not gone far enough.

Ms. Williams, what can you share about the process the FWS undertook to update the Mexican gray wolf management regulations? In particular, can you discuss how the FWS engaged with animal protection advocates and ranchers in making the new determination?

Ms. WILLIAMS. Senator Kelly, thank you for that question. I can appreciate it is a topic that is top of mind in your State and New Mexico. Our team working on Mexican gray wolves or Mexican wolves are really terrific, and they are so committed to what they do. They understand that on the ground these recovery efforts do have impacts to ranchers, to the communities, and yet, that their work is scrutinized well beyond those in your State and in New Mexico.

So, all of our work, frankly, on wolves, regardless of the State or the species of wolf, we know there is intense interest and scrutiny. What I can say specifically to answer your question is, I know that our region and our staff really try to undertake the most robust, public process they could in getting to this decision, But I recognize that we can't make everybody happy, and probably that there aren't any perfect answers. But they are trying hard to address all of the comments and concerns that come in, and trying to have a robust process where people can feel heard.

Senator KELLY. So your understanding is that Fish and Wildlife did do a robust engagement with both ranchers and animal protection advocates?

Ms. WILLIAMS. My understanding, Senator, is yes. I don't know that the outreach was necessarily targeted, but I know that we engaged with any group that wanted to.

Senator KELLY. Well, thank you. I have a couple more minutes here.

Ms. Williams, I understand that in February, the Fish and Wildlife Service began settlement proceedings in an attempt to resolve litigation related to regulatory actions taken by the Fish and Wildlife Service to open up some Federal refuges to hunting and fishing. Understanding that there is ongoing litigation, is there anything you can share about why fish and wildlife entered into these settlement discussions, and what you hope to see as an outcome?

Ms. WILLIAMS. Senator Kelly, thank you for that question. This is an issue that I am happy to address and is also top of mind. First, I just want to say that this Administration, the department, the Fish and Wildlife Service and me, as a hunter and angler myself, we are absolutely committed to providing hunting and angling opportunities on our national wildlife refuges. That commitment has not changed.

What did come in is that we are keeping abreast of the science that does demonstrate the impacts of lead on the environment to wildlife and to people, and then we were sued on increased opportunities and did enter into discussions.

What I can say is that we have not made a decision going forward on how we use public opportunities and lead ammunition and tackle. We already, at the Service, do not use lead ammunition and tackle in our own management activities. So really, this is talking about waterfowl, already don't use lead ammunition. This is talking about those opportunities for hunting and fishing outside of management activities and waterfowl hunting.

So, anything that we might do in the future to address use of lead on refuges, we would do in a public fashion and would also consult with you. It is something that we are thinking about, we know the science demonstrates a need to address. At the same time, we will look into this and address it in a collaborative and public fashion.

Senator KELLY. Thank you, Ms. Williams.

Thank you, Mr. Chairman.

Senator CARPER. Senator Kelly, I know you have a busy morning. Thanks for making time to join us for this hearing. Senator Sullivan, good to see you. I am just admiring that tie you are wearing. You look so natty today.

Senator SULLIVAN. You, too. It is my Navy tie.

Director Williams, thank you. Thanks for visiting Alaska. I am going to ask you about your trip. Did you make it to the North Slope, by the way, with Secretary Haaland? You were in those meetings, too?

Ms. WILLIAMS. Yes, Senator Sullivan. I have been to Alaska before, but I do have to say, it was in incredible trip, and I am very grateful to have gotten up to Utqiagvik.

Senator SULLIVAN. Good. Well, I am grateful too. I really am grateful that you got out there. I know I had staff up there. Unfortunately, I couldn't make that.

I want to talk about Willow, which I am sure you have heard about. You might remember, you and I talked a lot about it during your confirmation process. It is an energy project that has literally been permanent since back to the Clinton years. It is not really

controversial. The Obama administration permitted it; the Trump Administration finalized it.

Now, with the need for more energy, particularly given the Russian invasion of Ukraine and the impacts on our Country, there has been a commitment, directly, actually, from President Biden to me and Senator Murkowski when I addressed this issue in the Oval Office with him last year around this time. It has got the full support of the community in Utqiagvik, as you know, AFN, Alaska Federation of Natives. This is as widespread support as possible. All of the unions, national unions, have weighed in the commitment that I was understood very recently, I see that a Biden Administration official said they are going to make this supplemental EIS by the end of this quarter. That is still on time.

But you guys actually have a role to play on the biological opinion, the bi-op. Not under you, but the Fish and Wildlife is infamous for using its entire statutory limit deadline for slow-rolling BLM on some of these issues. I am not saying you have done it, but that is a history.

Can you commit to me that the Fish and Wildlife Service will not use any stall tactics to further delay the Willow Project? These are hardworking men and women in my State. This project will create thousands of jobs. We have already missed three construction seasons. The reason for this commitment by the end of the quarter, from the President and his team, is to make sure we don't miss another construction season. People need to work.

Can I get your commitment on that bi-op? I know you are tracking it closely.

Ms. WILLIAMS. Senator Sullivan, first, I just want to thank you for your home State hosting us in such a warm, welcoming fashion.

Senator SULLIVAN. They are great people. That is why I get angry in this committee, because unfortunately, a lot of the Biden Administration officials and decisions are crushing my great people, but I am glad you saw them. They are wonderful.

Utqiagvik, as you saw, is very pro-resource development. I was shocked by Deb Haaland's record of decision 72 hours after she got back from Utqiagvik saying the people wanted to shut down NPRA, don't even get me going on that. They are great people. I am glad you agree.

Ms. WILLIAMS. So, Senator Sullivan, yes, I would never expect the Fish and Wildlife Service to slow-walk anything. I know that we are a cooperating agency with BLM on this project.

Senator SULLIVAN. Right, but you can delay it if we don't get the bi-op decision in a timely fashion.

Ms. WILLIAMS. I can commit to the Fish and Wildlife Service working expeditiously and always within the law on the consultation here. I hear you and understand its importance.

Senator SULLIVAN. Great. It is not just important to me; the President of the United States made a commitment to me and Senator Murkowski and our late, great departed Congressman, Don Young. So it is important to us, important to all the unions, important to the Native people.

The President's commitment is on the line. The integrity of the President of the United States directly, not one of his staffers, not

one of his cabinet members, the President. So, I hope we can all commit to that.

Let me just ask you, I am going to put a picture up. That is you, actually. You remember that? That is at Coal Bay. That is Deb Haaland, and that is Director Williams right there.

Mr. Chairman, if it is OK, I am going to go a little long on this question, but it is a really important question, if you don't mind.

Director Williams, that is you at Coal Bay. You are going up that ladder. You know the issue I am going to raise, this is a very important issue, again, of the King Cove Road, which again, has taken on gigantic symbolism in my State. Again, Native people being harmed by their own Federal Government.

There have been 157 medevacs in the 8 years since Sally Jewell coldly rejected the 11-mile, single lane gravel road that King Cove and the Native community there has been trying to get done for 30 years.

Eighteen deaths have been associated with the lack of land access, 18, which is why in a hearing I held on the Commerce Committee in 2017 when I chaired the Oceans and Fisheries Subcommittee, the Commandant of the Coast Guard said, I cannot foot-stamp loudly enough of the critical need for this 11-mile stretch of road to provide the lifeline that this community needs for their life. This is the Commandant.

As you know, the brave men and women of the Coast Guard have to fly those very dangerous missions. That picture depicts you climbing the ladder at the Coal Bay Dock. If a plane cannot land in King Cove, which is often the case, 100 days out of the year, they usually have horrible weather, you probably saw some, that they can't do rescue missions. So, this would be the equivalent of someone being medevaced two and half hours from King Cove to Coal Bay to the big airport at Coal Bay.

I mention that because, could you imagine if that was snowy or freezing weather, or you were 8 months pregnant or in terrible health or a senior, to get up that ladder? You did it. It looks like it was a nice day there, but it is hard to do, even on a nice day.

So, what were your impressions? You want to talk about great people; Utqiagvik has great people, the King Cove people are just the best. They are incredible.

By the way, they are all veterans, Mr. Chairman. All of these Native communities have the highest rates of military service of any ethnic group in the Country, of Alaska Natives and lower 48 Indians, so patriotism runs so deep in these communities.

But what were your impressions, and are you getting ready with the Secretary to make a recommendation to finally, finally, after 30 years, support a simple, single lane gravel road between King Cove and Coal Bay, so that if you are pregnant at 9 months and there is a medevac, you don't have to climb up that ladder?

Ms. WILLIAMS. Senator Sullivan, thank you for that question. I understand the importance of this issue. I know that you care very deeply about it.

Senator SULLIVAN. Everybody in Alaska does. It is very interesting. Democrat, Republican, Native, non-Native, if you ask the average Alaskan citizen, what do you think about the King Cove

Road? Everybody will know what it is, and that is out on the Aleutian Island chain, as you know, way the heck out there.

Ms. WILLIAMS. Well, I think a few things in your question, one, I want to be very polite and respectful, but I am glad that I got to take my Xtratufs and that they made it into the photo. Sorry, I just had to say that.

Senator SULLIVAN. Hope those were made in America, not the China version.

Ms. WILLIAMS. So, the photo, and I am very much glad that I got to go to King Cove, go to Coal Bay, and indeed, climb on that ladder. A couple of thoughts: one, yes, the value of going to the community and hearing from the community. And I would add the value for me personally and for the Service in going there with this Secretary of the Interior and listening with her and trying to listen in new ways. Also to see a community, just how moving it was for them to see a Native American Secretary of the Interior for the first time, and thus the ability——

Senator SULLIVAN. Well, I hope this Native American Secretary of the Interior treats the Native people of my State with respect. So far, with all due respect to Secretary Haaland, she hasn't been doing that. It is great that she has that background, but the true test of how she cares about the Native people is the actions she is going to take. This is a big test; so is Willow.

Ms. WILLIAMS. So Senator Sullivan, then, to the question, one, as you know, this is an ongoing litigation. But with going there, I know and saw firsthand both mine, but especially the Secretary's interest in this, a recognition of the challenges that King Cove continues to face and the need to continue to see a balanced path. Because it is an ongoing litigation, I can answer that I, and I believe that the Secretary remains open to having all options on the table.

Senator SULLIVAN. Mr. Chairman, if I may, and I am sorry. This is a really important question.

Senator CARPER. We are going to have to wrap up very soon, please.

Senator SULLIVAN. My final question: the Secretary said she was going to go to King Cove. She said she would make her decision on whether to support the litigation after her trip.

The trip took way too long, in my view, but she finally made it out there, and again, I appreciate you going, too. I hope you are not using the excuse of ongoing litigation to not make a decision on whether you support the road in the litigation. That was the whole purpose of her trip.

Ms. WILLIAMS. Senator Sullivan, I think I am answering you sincerely in saying that the Secretary remains open or wants to have all options on the table.

Senator SULLIVAN. OK. Thank you, Mr. Chairman and Director Williams. Thanks again for going to Alaska. I really appreciate it.

Senator CARPER. I have maybe one or two other quick questions, and then we will let you go. The Lacey Act in interState commerce in injurious species is what I want to ask about.

The Fish and Wildlife Service, as you know, has authority under the Lacey Act to prohibit the importation and some transport of certain types of wildlife that may be injurious to humans. This au-

thority is important to protect our Nation from high-risk species that may cause harm to us and to other creatures.

However, the courts have recently ruled that the Lacey Act does not allow the Fish and Wildlife Service to regulate interState commerce in injurious species, notwithstanding decades of generally accepted practice, during which the Fish and Wildlife Service has exercised this authority. The budget requests mentions that this court decision has created challenges for the Service.

Could you elaborate for us about on why it is important for the Fish and Wildlife Service to regulate interState commerce with respect to injurious species? Is there anything else you might like to share with our committee today about how the 2023 budget would enable the Service to effectively implement the Lacey Act?

Ms. WILLIAMS. Thank you for that question, Chairman Carper, and for your leadership on this issue. It has been really important.

As you noted, the Lacey Act is critical here in that, if the Fish and Wildlife Service were able, as we had in the past, to regulate the importation and transport, so that interState transport of invasive species that have been determined to be injurious, our ability to do that can help prevent invasive species, these high-risk, injurious invasive species from taking hold so that we can prevent their establishing populations, which we know is so costly to the economy; it is costly to ecological services of other species, and it is really something that, were we able to take these preventive measures, it benefits the American people.

I can think of examples in the Great Lakes of invasive species there and across the Country. The ability, through this budget request, to address invasive species that are determined to be injurious, really, an ounce of prevention prevents a pound of pain.

Senator CARPER. Last question: I was reminded of this on a recent visit with one of our two National Wildlife Refuges about the importance of volunteers at our refuges in Delaware and across the Country, The National Wildlife Refuges are the crown jewel of our Nation's network of public lands. I visit our two refuges in Delaware, actually, fairly regularly. In fact, I visited Bombay Hook National Wildlife Refuge just last month. I know that you have enjoyed visiting our refuges, among many others as well.

Thankfully, every State, as I said earlier, every State or territory has at least one National Wildlife Refuge, and some more than one. Thankfully, every State has National Wildlife Refuges that provide important habitat recreational opportunities for all Americans.

I talked to people during the course of the pandemic over the last year and a half and talked about being cooped up at home and not able to do anything, not being able to recreate. I asked them, do you have any State parks? Well, yes, they do. Do you have any national parks? Maybe one or two. Do you have any National Wildlife Refuges? There is no reason to be cooped up at home with all these great places to go and to be exposed and be on the outside, on the outdoors, and to see beautiful things, and to learn a lot. I hope more people continue to take advantage of those opportunities.

I am glad that the 2023 budget request prioritizes the stewardship of our refuges, but given the fiscal constraint, it is important to leverage our Federal investment. That is why Senator Capito and I introduced the Keep America's Refuges Operational Act last

week to reauthorize appropriations for the National Wildlife Refuge system volunteer program.

Would you speak to the importance of the National Wildlife Refuge System Volunteer Program and how it leverages Federal investments to help keep our refuge system operational?

Ms. WILLIAMS. Thank you, Chairman Carper and Ranking Member Capito, for your leadership in introducing the Keep America's Refuges Operational Act. As you say, our National Wildlife Refuge system is a gem. It is so important to so many Americans and to the fish and wildlife and habitat that it conserves for future generations.

But the Fish and Wildlife Service, we wouldn't be able to really operate our refuge system the way we do now without the incredible dedication and support of volunteers. As an example, in Fiscal Year 2021, volunteers contributed nearly 650,000 hours of their time in support of the refuges during the pandemic, whereas you noted, the refuges were just so important to our physical and emotional wellbeing.

The support of our volunteers is equivalent to almost 318 full-time refuge employees. My heart goes out to them in appreciation and your leadership and support for these volunteers. They are just critical to this gem for the American public.

Senator CARPER. Thanks for that response. I would just say to all the people across our Country, including in Delaware, who are volunteers, our thanks to each of you.

We are starting voting, I think, right now. Before we wrap, I just wanted to give you an opportunity to maybe make a closing comment, and then I will have a little short statement that I will make. Anything else you would like to mention?

Ms. WILLIAMS. Chairman Carper, I just want to thank you for this opportunity and to emphasize that the Fiscal Year budget request for 2023 really invests in the delivery of conservation in this Country and builds on much-needed capacity and resources for the Fish and Wildlife Service to really fulfill our mission in working with others to conserve, protect, and enhance these resources that are so near and dear to Americans. Thank you for the opportunity and for believing in our mission, as we do, as well.

Senator CARPER. Thank you for that.

In closing, I want to thank you on behalf of our committee for your presence today. I think over half of our members have been able to come. There is a lot going on in the Senate today in committees. We all serve on a number of committees, as you know, so we are grateful to our colleagues who were able to join us here.

We are grateful for your service to our Country at a time when we face both great conservation challenges, but also, they come with great opportunities.

Before we adjourn, a little bit of housekeeping. I want to ask unanimous consent to submit for the record a variety of materials that relate to today's budget hearing. People say to me, what is one of my favorite things in the U.S. Senate? I love asking unanimous consent requests when I am the only one in the room, because there is nobody else to object. So, I make that unanimous consent request, knowing that no one will object. So ordered.

[The referenced information follows:]

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Critics say the government has limited public input amid the COVID-19 pandemic.

By **Evan Simon**
July 09, 2020, 12:17 PM

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Traditional subsistence hunting has always been a pillar of life along Alaska's remote North Slope. Dependable migrations of bowhead whales, Arctic grayling fish, and the country's last remaining caribou herds have provided for generations of indigenous Alaskans who make their home on America's northernmost edge.

"We depend on a clean environment to feed our families during the year," Rosemary Ahtuangaruak, a 66-year-old resident of the village of Nuiqsut, told ABC News. The grandmother of twenty says she owns a harpoon and still participates in the whale hunt on Cross Island each fall.

Rosemary's village is among the few largely indigenous communities scattered throughout the region's vast Arctic oil fields. A small grid of homes located at the limits of most modern transportation routes with just one grocery store, more than three-quarters of the Inupiat Eskimo village relies on traditional subsistence hunting as their primary source of food.

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global pandemic forced roads to close and the region's only airline to declare bankruptcy, cutting off an already isolated village from outside supply lines.



Caribou and geese at Teshekpuk Lake in North Slope Borough, Alaska, May 26, 2019.

Bonnie Jo Mount/The Washington Post via Getty Images, FILE

With the nearest hospital hundreds of miles away and the virus pushing northward, some fear the village -- with a population of just 500 -- would be wiped off the map if community spread took hold.

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"It's life or death," Siqiniq Maupin, a community advocate based in Fairbanks whose family lives in Nuiqsut, told ABC News. "We have people that need to hunt and be out on the land right now because we just don't know what's going to happen this winter."

But in the midst of the crisis, as the tribal government frantically moved to obtain medical supplies and shut down non-essential

controversial plan to massively expand oil and gas drilling in the area.

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In April, the Bureau of Land Management -- the agency within the United States Department of the Interior responsible for the administration of public lands -- moved forward with "virtual public comment hearings" on revised plans for the controversial ConocoPhillips Willow Oil Project.

The Willow project aims to add a gravel mine and up to 250 oil and gas wells to the existing energy extraction sites already surrounding Nuiqsut on nearly all sides. First proposed in 2018, the project has long been opposed by some tribal leaders and environmental groups for its potential impacts on wildlife and public health.



An aerial view of Nuiqsut, AK, May 28, 2019.

Bonnie Jo Mount/The Washington Post via Getty Images

"It's a massive project that threatens wildlife, exacerbates climate change and impacts indigenous culture and food security," Adam Kolton, executive director of the Alaska Wilderness League, told ABC News. "We were concerned before the pandemic but to see the Bureau of Land Management continue to kind of move at warp speed during the pandemic ... makes no sense at all."

ConocoPhillips' declined to be interviewed for this report, but a company spokesman denied the project would impact subsistence hunting or public health in a statement to ABC News.

"The Willow project will be one of the first North Slope projects designed and built-in compliance with new EPA rules that reduce emissions and minimize environmental impacts," the spokesperson wrote.

The Willow development's virtual hearings -- conducted via Zoom -- were the culmination of a contentious public comment period for the project's revised environmental review that commenced on March 20, just a week after President Donald Trump declared COVID-19 to be a national emergency and four days after he advised all Americans to avoid gatherings of 10 or more people.



Community Advocate Siqiniq Maupin speaks at the Arctic Slope Regional Corporation meeting held in Utqiagvik.

Courtesy Siqiniq Maupin

The release of the Willow project's new environmental review would typically result in more in-person meetings within the village to ensure public awareness and input regarding the proposed changes, but the Bureau of Land Management relied on teleconferencing for the remote indigenous community, ignoring repeated requests from the tribal government, congressional leaders, and environmental groups to suspend the process in light of the region's lack of internet access and the pandemic's impact on public participation.

"They kept getting cut off, losing reception, words weren't being heard," Martha Itta, a lifetime resident and tribal administrator for the village who called into the hearings, told ABC News. "It was a really poor process."



Nuiqsut Tribal Administrator Martha Itta wears a face mask in front her tribal village offices.

Courtesy Martha Itta

Despite the technical challenges and emotional pleas from village members for an extension, the Bureau of Land Management closed the public comment period on May 4, effectively cutting off organized public input as the agency finalizes its plan for the project en route to getting final approval. The agency is still accepting comments via mail and the Bureau of Land Management website.

Alaska Bureau of Land Management officials defended the virtual hearings and emphasized the importance of maintaining "a capable and functioning government," in an email to ABC News, saying that the agency was using technology to both protect its employees and "ensure connection and service to the public."

"These virtual meetings are providing more people with access to participate and have their voices heard," Alaska Bureau of Land Management officials wrote in a statement to ABC News, saying the virtual meetings drew approximately 50 more people than in-person meetings conducted earlier in the review process.

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"Public input is fundamental and of the highest importance to the Bureau," the spokesperson wrote.

But some Nuiqsut residents say the agency's rush to expand oil operations during a pandemic deliberately ignored their concerns. Just last month, the agency followed up the Willow project's virtual hearings with a massive plan to offer oil companies 18.6 million more acres of public lands across Alaska's Northwest, including previously protected wildlife areas such as Teshekpuk Lake, a vital subsistence hunting location for indigenous villages including Nuiqsut, where caribou herds, polar bears, and millions of migratory birds can be found.

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"The [oil development] process is sacrificing our village," Ahtuangaruak told ABC News. "It shouldn't be forced down our throats when we are not effectively able to participate."

'A multi-fronted assault on the environment'

The Willow project is one of several plans the federal government is currently advancing that could turn over vast swaths of America's landscapes to oil and gas interests while the public's attention is focused on the ongoing pandemic and civil unrest.

Since President Trump's March 13 national emergency declaration, the Bureau of Land Management has leased more than 100,000 acres of public lands to fossil fuel companies across the country and pushed an array of extraction-friendly proposals that could impact iconic areas ranging from the Alaskan Arctic to the American Southwest.

Public lands surrounding Arches National Park, Canyonlands National Park, Bears Ears National Monument, Chaco Canyon National Historic Park and the Arctic National Wildlife Refuge are just some of the treasured American landscapes that would see oil, gas, and mineral development under the various proposals currently underway.



Ancient Pueblo ruins are preserved in the remote desert of central New Mexico, Aug.20, 2019, at the Chaco National Monument.

Andrew Lichtenstein/Corbis via Getty Images

"People are hurting around the country," Bob Deans of the Natural Resources Defense Fund told ABC News. "And unfortunately, the administration chooses this opportunity to wage a multi-fronted assault on the environment and public health."

The controversial moves have garnered little attention outside of directly affected communities and have some critics claiming the administration is using the cover of a global pandemic to advance oil and gas interests on public lands.

"The administration is hoping we'll be too distracted to understand what's at stake," Deans said. "This is short-term profits for big polluters and leaves the rest of us to pay the price."

The Trump administration's drive to drill public lands for fossil fuels is perhaps most apparent in Alaska. There, on the country's last great frontier, the Bureau of Land Management has not only gone forward with controversial virtual public comment hearings for the ConocoPhillips' Willow Project, but it is promising a historic increase in oil and gas development across the state's public lands in the months to come -- despite the global oil glut underway.

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In addition to the Willow Project's central processing facility and infrastructure pad, access and infield roads, pipelines, a gravel mine, an airstrip, and up 250 new wells, the agency is also proposing the construction of an entirely separate 20-foot-high, 211-mile-long gravel road intended solely for industrial copper mining in the region.

vow to conduct oil and gas lease sales inside the pristine Arctic National Wildlife Refuge before the year's end. The move would be an unprecedented step toward opening America's largest wilderness area to oil and gas development.

In addition to transforming some of Alaska's most iconic landscapes and exacerbating climate change in the already melting Arctic, critics argue the new developments threaten to cut indigenous villages off from one of their most important food sources: migrating caribou herds.



Arctic National Wildlife Refuge in Alaska.

Patrick J. Endres/Getty Images

"It's just so overwhelming right now," Maupin said. "We have so many projects happening at the same time over such a large state that we can't attend every single hearing."

Bureau of Land Management and Department of the Interior leadership declined to be interviewed for this story. William Perry Pendley, the Bureau of Land Management's temporary head, has stated in the past that "it is crucial that we fulfill our statutory and regulatory responsibilities during this difficult time to provide for our future economic stability when Americans do return to work."

But according to former California State Bureau of Land Management Director Jim McKenna, a 40-year agency veteran, the Bureau of Land Management appears to be ignoring the conservation aspect of its mission.

"Oil and gas leasing now in the midst of a pandemic oil glut makes no sense," McKenna told ABC News. "It flies in the face of public interest."

According to McKenna, the flood of agency activity during the pandemic shows the current leadership's "very cavalier attitude towards the public."



An oil pipeline stretches across the landscape outside Prudhoe Bay in North Slope Borough, Alaska, May 25, 2019.

Bonnie Jo Mount/The Washington Post via Getty Images

Pendley, the agency's temporary head, spent much of his career as an attorney representing oil and gas interests in public land disputes, arguing that the federal government should transfer or sell most of its public lands to states.

In May, conservation groups filed a federal lawsuit against the Trump administration for extending Pendley's tenure for the fifth time without Senate approval. Late last month, the White House said it intends to officially nominate Pendley to lead the Bureau of Land Management.

According to McKenna, many of his former colleagues are "dispirited" at the direction the agency has taken and "don't feel like they can say things that are true out loud."

"This isn't the agency that I grew up in," McKenna said.

A widespread sense of distrust

Historically, oil and gas development has brought monetary wealth to some indigenous Alaskans, particularly those with shares in Alaskan Native Corporations who receive regular payments from developers -- but critics say that with the added resources also came pollution, health risks and a noted impact on the land and waters local populations have depended on for centuries.

Perhaps no village embodies this contrast better than Nuiqsut, which sits directly beside the National Petroleum Reserve and has seen an explosion of oil and gas development over the past several decades.

have lights to the east of us from development at Prudhoe Bay, to the north of us from the offshore development in the Beaufort Sea, to the west of us from the National Petroleum Reserve, and now to the south of us from the new developments."

As Alaska's largest oil producer with most of its key operations in the North Slope, ConocoPhillips' presence is hard to miss in the region. In addition to its ubiquitous processing and extraction facilities surrounding Nuiqsut -- where children can see active drill pads from their school steps -- the oil company sponsors educational events such as the village's health fair and science symposium, as well as a nearby playground.



A ConocoPhillips building stands in Anchorage, Alaska, Feb. 14, 2017.

Daniel Acker/Bloomberg via Getty Images, FILE

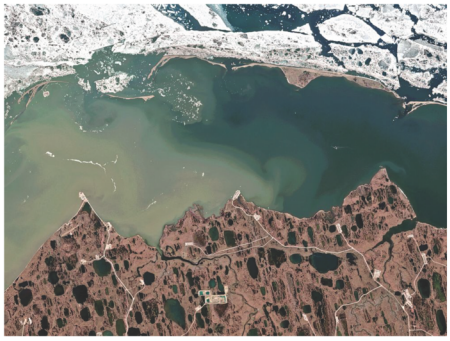
The company is also a major political force, spending nearly $5 million dollars on national political lobbying in 2019, and it is among the top five donors to Alaskan Republican Senator Lisa Murkowski -- giving nearly $40,000 to her campaigns over the past five years as the company grew its holdings in the state.

During her career as a community health aide from 1986-2000, Ahtuangaruak said, she started noticing more respiratory illnesses in her village as development grew around it. She is among many in the village who believe the oil and gas infrastructure has compromised their health.

"[When] I stopped working at the clinic, there were 70 [respiratory illness cases] -- but when I started, there was just one," she said. "There were nights I was up all night helping people breathe."

In response to the community's widespread concerns about air pollution, the state of Alaska conducted multiple assessments of the area's air quality and found that pollutant concentrations were "generally well below the national ambient air quality standards,"

rates.



Milne Point is located on Alaska's North Slope, Northwest of Prudhoe Bay.

Gallo Images via Getty Images

However, ConocoPhillips owns the only air monitoring instruments in the area, leading many residents to doubt the government's findings. The instruments are operated by a consulting company and its reports are prepared for ConocoPhillips before being sent to government and tribal agencies as well as audited quarterly by another independent party. Yet ConocoPhillips' multiple oil and wastewater spills in the region, including in 2009 and 2017 -- along with one of the company's subsidiaries pleading guilty to failing to maintain proper records of an oil spill and attempting to hide a spill in 2004 -- have only added to the community's sense of distrust.

"ConocoPhillips has consistently proven that we can safely, responsibly, and sustainably operate on Alaska's North Slope," a company spokesman wrote to ABC News.

"The 2004 incident you are referring to was a records-keeping violation following a deck spill during a routine maintenance operation," the spokesman wrote. ConocoPhillips's subsidiary, Polar Tankers, "immediately terminated the ship's captain" and agreed to pay a $500,000 fine and a $2 million community-service payment to the National Fish and Wildlife Foundation.

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its health, safety and the environment performance. However, this has no connection to our North Slope operations," the spokesman said.

This coming winter was expected to be a major production year for ConocoPhillips in Alaska, but the oil glut caused by the pandemic forced the company to scale back its ambitions in the Arctic. The Bureau of Land Management's virtual hearing announcement for the Willow project came two days after ConocoPhillips announced it was cutting roughly $200 million from its Alaska budget -- mainly by slowing production in the North Slope.

"Significant public comment on Willow development occurred well before the COVID pandemic," the ConocoPhillips' spokesperson wrote. "We are supportive of the BLM's efforts to continue permitting projects on a timely basis."

At the time of the announcement, Pendley, the Bureau of Land Management head, said the move to go forward with the virtual hearings was "in the spirit of service to the public," while Bureau of Land Management Alaska officials said the hearings actually increased public participation.

"It's completely insulting," Maupin, the community advocate, told ABC News, saying that if there was any increase in participation it was "because people are crying, asking you not to inhumanely hold these processes during a pandemic."



Martha Itta tribal administrator of Nuiqsut, Siqiniq Maupin Community Advocate, Bernadette Demientieff, Community Advocate ED of the Gwich'in Steering Committee at Frontline Oil and Gas Conference held in 2019 Ponca, Oklahoma.

Courtesy Siqiniq Maupin

"This entire process was a joke, and it's really sad that so many people had to endure that," she said.

Itta wrote a scathing letter to the Bureau of Land Management describing her experiences and demanding the process be halted.

Despite the recent setbacks, Rosemary Ahtuangaruak has vowed to continue her opposition to the Bureau of Land Management's plans for her village -- but she's concerned that few outside her community are paying close enough attention.

"We need our nation to respond," Ahtuangaruak told ABC News. "Otherwise, they are going to push forward to protect profitability at all costs. Stand up and protect the life, health and safety of people who are living nearby and protect this beautiful area for generations to come."

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Data contradict common perceptions about a controversial provision of the US Endangered Species Act

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Edited by Michael Kraft, University of Wisconsin, Green Bay, WI, and accepted by the Editorial Board October 30, 2015 (received for review August 25, 2015)

Separating myth and reality is essential for evaluating the effectiveness of laws. Section 7 of the US Endangered Species Act (Act) directs federal agencies to help conserve threatened and endangered species, including by consulting with the US Fish and Wildlife Service (FWS) or National Marine Fisheries Service on actions the agencies authorize, fund, or carry out. Consultations ensure that actions do not violate the Act's prohibitions on "jeopardizing" listed species or "destroying or adversely modifying" these species' critical habitat. Because these prohibitions are broad, many people consider section 7 the primary tool for protecting species under the Act, whereas others believe section 7 severely impedes economic development. This decades-old controversy is driven primarily by the lack of data on implementation: past analyses are either over 25 y old or taxonomically restricted. We analyze data on all 88,290 consultations recorded by FWS from January 2008 through April 2015. In contrast to conventional wisdom about section 7 implementation, no project was stopped or extensively altered as a result of FWS finding jeopardy or adverse modification during this period. We also show that median consultation duration is far lower than the maximum allowed by the Act, and several factors drive variation in consultation duration. The results discredit many of the claims about the onerous nature of section 7 but also raise questions as to how federal agencies could apply this tool more effectively to conserve species. We build on the results to identify ways to improve the effectiveness of consultations for imperiled species conservation and increase the efficiency of consultations.

Endangered Species Act | section 7 consultation | imperiled species | US Fish and Wildlife Service

Without accurate information about how the government implements a law, public perceptions of the law may be driven by anecdotes, unsupported generalizations, or misinformation. Controversial laws may be particularly susceptible to this problem because inaccurate information can solidify deeply held beliefs about those laws, impeding efforts to ground legal reforms in science. Advances in data analytics are helping to overcome these problems by enabling researchers to systematically analyze how laws are actually implemented. By distinguishing perception from reality, researchers can offer novel insights on how to more effectively administer laws (1–3). Some of the most controversial aspects of biodiversity laws, however, have rarely been systematically evaluated, despite polarized public opinion on those laws.

In 1973, President Richard Nixon signed into law the US Endangered Species Act (Act) in response to the growing number of species threatened with extinction. The Act remains the premier law for protecting the 1,591 species listed as threatened or endangered in the US and their habitat (https://ecos.fws.gov/tess_public/pub/boxScore.jsp). Because the Act has the power to regulate many land use activities, some lawmakers and industries have sought to weaken or overturn the Act since shortly after its passage. The rhetoric surrounding these proposals often focuses on proposed projects being stopped or severely delayed by the Act (4). Attempts to legislatively undermine the Act have never been more numerous: the 114th Congress has thus far introduced more than 80 bills or amendments to reduce or remove the protections of the Act, such as the National Defense Authorization Act (5). Many of the proposals target section 7 of the Act (Box 1) because it contains some of the strictest prohibitions in the law—at least on paper.

Conservationists often tell a different narrative about section 7. These individuals argue that federal agencies are failing to strictly apply section 7 prohibitions in the face of increasing pressure to minimize the economic impacts of protecting wildlife (6). Massive infrastructure projects are authorized with inadequate conservation requirements, whereas thousands of smaller projects fragment and erode habitat in ways that are rarely tracked (7). Gone are the days when section 7 made national headlines because it restricted the logging of old-growth forests or halted the completion of a $100 million dam on the Little Tennessee River. These arguments suggest that the section 7 of today is a paper tiger, leaving many species vulnerable to further habitat loss and diminished chances of recovery.

Despite these conflicting storylines about section 7, there have been very few systematic analyses of the tool. The US House of Representatives report to Congress on the 1982 amendments to the Act considered 8,817 informal and 1,945 formal FWS consultations from 1979 to 1981 (8). The report found 192 (1.8%) consultations resulted in jeopardy and only two projects were stopped, partly because of the Act (8, 9). A white paper from World Wildlife Fund (10) examined 71,560 informal and 2,000 formal FWS consultations from 1987 to 1991 and found that only 350 (0.47%) consultations resulted in jeopardy. Of those projects, only 18 (0.02%) were blocked or cancelled because of section 7. Owen (11) analyzed 4,048 biological opinions for fish species from both Services between 2005 and 2009 and found that jeopardy and destruction/adverse modification conclusions were rare (7.2% and 6.7% of formal consultations, respectively). Thus, our current

Significance

The US Endangered Species Act is the most comprehensive law any nation has enacted to protect imperiled species. Many of its protections come from section 7 of the Act, but how government regulators use this tool is poorly understood. Our analysis is the first to systematically evaluate how the US Fish and Wildlife Service has implemented section 7 over an extend timeframe and across all listed species. The results inform current efforts to improve the conservation effectiveness of section 7 and rebut certain claims about the regulatory burdens of complying with section 7.

Author contributions: J.W.M. and Y.-W.L. designed research, performed research, analyzed data, and wrote the paper.

Conflict of interest statement: The authors are employed by Defenders of Wildlife; the results do not necessarily reflect the positions of Defenders of Wildlife.

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Data deposition: The code for the application used in the analyses available at GitHub (https://github.com/Defenders-ESC/section7_explorer). The data is available both from the GitHub repository and from within the web application.

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Box 1: Overview of section 7 consultations and key terms

Section 7 of the Act requires all federal agencies to ensure that the actions they fund, authorize, or carry out are not likely to "jeopardize" a species or "destroy or adversely modify" critical habitat. Federal agencies must consult with the US Fish and Wildlife Service (FWS) or the National Marine Fisheries Service (NMFS) to fulfill this mandate. Consultations typically start as discussions between the Service and a federal agency to determine whether the agency's proposed actions may affect a listed species. How FWS biologists are assigned to consultations varies by field office: in some cases, species experts take the lead; in other cases, biologists cover specific geographic areas or particular activities. This "informal consultation" ends if the Service determines that the activity is "not likely to adversely affect" a species. Otherwise, "formal consultation" is required. During formal consultation, the Service evaluates whether the proposed action will violate the prohibitions on jeopardy or destruction/adverse modification. If neither of these outcomes is likely but take is expected, then the Service will prescribe "reasonable and prudent measures" (RPMs) that are designed to minimize the effects of the action and the amount of take. If either jeopardy or destruction/adverse modification is likely, the Service must suggest "reasonable and prudent alternatives" (RPAs)—conservation measures that reduce or partly offset the harm from the proposed action, to avoid jeopardy or adverse modification. If no such alternatives are available, the action cannot proceed without violating the Act unless it is exempted by a special committee known as the "God Squad." Formal consultations end with a Service "biological opinion," which must be finalized within 135 d after formal consultation begins, unless an extension is agreed on.

knowledge of how the Services implement section 7 is based on dated or taxonomically restricted research.

To illustrate how administrative data can provide novel insights on the implementation of a polarizing law, we analyze the results of all section 7 consultations recorded by FWS from 2008 through April 2015. We obtained the records for these consultations from FWS's Tracking and Integrated Logging System (TAILS) database and verified questionable entries by reviewing original documents. Using this data (described in detail in *Materials and Methods*) we find that, unlike during previous decades, no project has been stopped or extensively altered as a result of FWS concluding either jeopardy or destruction/adverse modification of critical habitat. We also find that the median duration of formal consultations is well within the maximum timeframe allowed by the Act. We discuss how these results can help identify opportunities to improve the efficiency of consultations without sacrificing their effectiveness at conserving species. Lastly, we describe a web application that allows any interested user, from citizens to lawmakers, to explore the consultation data in detail.

Results

The TAILS database shows that 1,394 FWS biologists ($\bar{x}$ = 602 biologists per year; range, 379–690) recorded 81,461 informal and 6,829 formal consultations from January 2008 through April 2015 (Fig. 1*A*). These numbers exclude 110,850 consultations recorded as technical assistance over the same time period. At the national level, the number of both formal and informal consultations has declined through time (mean change per year, −1,057.7 consultations, SE = 259.6; $F = 16.6$, $df = 1,6$, $P = 0.0065$), but that decline is not always present at smaller scales, such as individual FWS field offices (e.g., North Dakota Ecological Services Field Office; Fig. 1*B*). The characteristics of consultations are spatially structured: although most consultations occur in the eastern United States (Fig. 2*A*), formal consultations are much more common in the west (Fig. 2*B*). The most commonly consulted-on species is the Indiana bat (*Myotis sodalis*; Fig. 3*A*, the most commonly consulting agency is the Army Corps of Engineers (Fig. 3*B*), and the most common category of activity requiring consultation is "development" (Fig. 3*C*). We estimate that only 3,454 (3.9%) consultations during the period were for conservation actions such as habitat restoration.

Of the 6,829 (7.7%) formal consultations, only two (0.0023%) resulted in jeopardy, one of which also resulted in destruction/adverse modification of critical habitat. That consultation covered a US Forest Service proposal to apply fire retardants on national forests and resulted in jeopardy and/or destruction/adverse modification for 45 species. The biological opinion for that consultation was rejected by a court and redone in 2011; the revised consultation concluded no jeopardy or destruction/adverse modifications. The only remaining consultation with a jeopardy conclusion focused on the effects to the delta smelt (*Hypomesus transpacificus*) from a water management project in California's Central Valley. Even that project, however, was allowed to proceed if the permittees adopted RPAs to minimize and partially offset the adverse effects of the project.

The median duration of informal consultations was 13 d [approximate 95% confidence interval (CI) = 12–13 d], and the median duration of formal consultations was 62 d (approximate 95% CI = 60–65 d; range, 1–4,426 d). The median duration of programmatic consultations, which are consultations on plans, programs, or regulations that authorize future actions, was 13 d (n = 3,092; approximate 95% CI = 10–16 d) for informal consultations and 82 d for formal (n = 1,142; approximate 95% CI = 62–107 d). In many instances, those future actions require their own consultation, which lasted 17 d (n = 2,401; approximate 95% CI = 17–18) and 24 d (n = 845; approximate 95% CI = 21–27) for informal and formal consultations, respectively. The durations of 1,381 formal consultations were longer than the 135-d limit prescribed in Services regulations absent an extension approved by the consulting agency (20% of formal). Of these, FWS had marked 1,297 consultations as not being completed on time, indicating ∼100 consultations were completed under a mutually agreed extension. We observed significant variation in the duration of formal consultations among FWS regional offices ($F = 27.77$; $df = 8$ and 6,112; $P < 2.2 \times e^{-16}$), with more formal consultations generally corresponding to longer average duration. Beyond simple descriptive statistics of consultation duration, we also sought to explain why the duration varies. Using regression analysis (*Materials and Methods*), we found that the best predictors of variation in duration were whether the consultations were formal, the identity of the FWS biologist performing the consultation, and the number of species evaluated in the consultation. Although the identity of the lead biologist had the

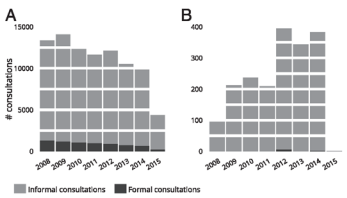


Fig. 1. The numbers of both informal and formal consultations have declined nationally since 2008 (*A*), but local trends reflect changing local activities, such as oil and gas development in North Dakota (*B*). The decline in both informal and formal consultations at the national level is statistically significant at $\alpha < 0.01$. The surge in consultations in North Dakota is driven by consultations for oil and gas development plus related infrastructure, including housing, roads, and communications (e.g., cell towers).

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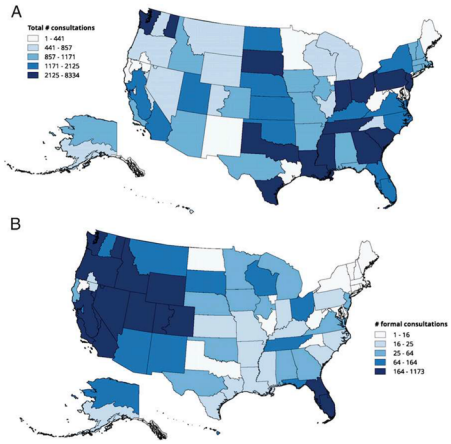


Fig. 2. Although the majority of consultations occur in the eastern United States (*A*), formal consultations are concentrated in the western states (*B*). Exceptions to the pattern exist, such as the high number of consultations in eastern and western Washington, and the high number of formal consultations in Florida. In addition to state boundaries, the maps show approximate boundaries for FWS Ecological Services field offices (i.e., the area covered by each office). Five states (Vermont, New Hampshire, Massachusetts, Rhode Island, and Connecticut) are covered by the New England Field Office. All of Iowa and part of Illinois are covered by the Rock Island Field Office. Choropleth divisions are based on quantiles.

largest sum of squares, whether consultations were formal had the largest mean square (Table 1); formal consultations add an estimated 43.8 d (SE = 0.436) to consultation duration. TAILS does not include data on the quality, comprehensiveness, or scope (e.g., area affected by the action) of the consultations, each of which can affect the duration.

Educating policy makers and the public is key to improving policy implementation. To that end, we created a web-based application that allows users to explore our version of the TAILS database, which corrected for errors we found in the FWS dataset (defenders.org/section7; also see *Materials and Methods*). After selecting a state, species, or any of 10 other variables of interest, the application generates interactive plots and maps to visualize the results. The application also allows users to run two separate searches simultaneously and compare the results. Any of the TAILS data can be downloaded by users for additional analyses; the only data-masking we applied was hashing the names of the FWS biologists to protect their identity while still allowing future analyses to consider biologist identity as a covariate.

Discussion

Deciding policy based on anecdote rather than comprehensive data are fraught with problems. The Act is widely considered the strongest law in the world for protecting imperiled species and their habitat (12), but little is known about how federal agencies actually implement one of the most important provisions of the law—section 7 consultations. As a result, some view implementation as a significant hindrance to economic development (13, 14) while others view it as not halting or modifying enough development projects that harm listed species. Using data that span all consultations recorded by FWS since 2008, we show that FWS very rarely concludes jeopardy or destruction/adverse modification and that the median duration of formal consultations is far below the statutory limit. The first result questions the extent to which consultations are adequately protecting species, and both results counter many of the claims about the regulatory burdens and delays of complying with section 7.

None of the 88,290 actions consulted on with FWS during the past 7 y has been stopped or extensively altered as a result of FWS finding jeopardy or destruction/adverse modification. After considering court-ordered revisions of one consultation,

Table 1. Whether consultations are formal or informal explains more variation in consultation duration than any other variable examined

Predictor variable	*df*	SS	MS	*F*	*P* (>*F*)
Lead biologist	1,233	20,890,804	16,943	26.905	$<2 \times e^{-16}$
Formal consultation (true)	1	6,428,433	6,428,433	10,208.088	$<2 \times e^{-16}$
Fiscal year	7	40,640	5,806	9.219	$1.88 \times e^{-11}$
Number species evaluated	1	10,5127	105,127	166.937	$<2 \times e^{-16}$
Consultation complexity	3	190,026	63,342	100.585	$<2 \times e^{-16}$
Action category	91	338,187	3,716	5.901	$<2 \times e^{-16}$
Residuals	84,485	53,203,515	630		

SS, sum of squares; MS, mean square.

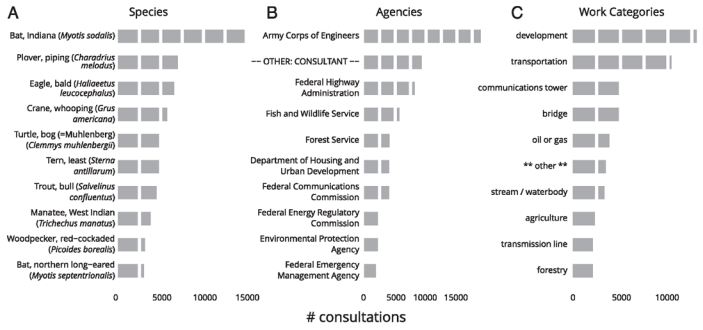


Fig. 3. Consultations are not evenly divided among species (*A*), consulting agencies (*B*), or the types of work undergoing consultation (*C*). These high-level overviews provide a glimpse into the breadth of section 7. The top 10 species are dominated by wideranging species in the eastern United States and a small number of narrow-range species that coincide with areas of heavy development. The US Army Corps of Engineers, which administers section 404 of the Clean Water Act, consults far more than any other single agency. Development and transportation projects, which occur nationwide, account for over 50% of all consultations.

none resulted in destruction/adverse modification of critical habitat and only one remaining consultation resulted in jeopardy. That project, however, was still allowed to proceed by adopting RPAs to minimize and partially offset its effects. These results stand in stark contrast to every broad analysis of section 7 completed to date (Table 2). From 1979 to 1981, FWS completed 8,817 informal and 1,945 formal consultations, finding jeopardy for 173 projects (8.9% of formal consultations) (8). Of those 173 projects, 8 were cancelled or withdrawn, partly or entirely because of section 7 (9). The percentage of jeopardy findings increased to 17.5% during 1987 to 1991: among the 2,000 projects requiring formal consultation, 350 had jeopardy findings, of which 18 were stopped by section 7 and another 35 had the potential to ultimately be blocked (10). For comparison, if the consultation process had not changed since 1987 to 1991, we would expect nearly 1,200 consultations with jeopardy conclusions, and over 60 jeopardy conclusions that could stop a project, during 2008 to early 2015. Similarly, Owen's analysis of over 4,000 fish-related biological opinions from both Services found many more jeopardy and destruction/adverse modification conclusions (n = 78 for FWS) from 2005 to 2009 than we found from 2008 to 2015. If the consultation process had not changed since 2005 to 2008, we would expect ~490 jeopardy opinions during 2008 to early 2015. Note that our data do not address potential projects that were never proposed or were withdrawn because FWS had proposed a jeopardy finding (15).

There are at least three likely reasons for the observed change in jeopardy or adverse modification outcomes. First, and perhaps the one envisioned by the drafters of the Act, can be characterized as policy learning (e.g., ref. 16): that federal agencies have now learned to plan and propose projects that minimize harm to listed species. Some agencies are proposing projects with reduced impacts because they are coordinating more closely with FWS to shape the projects well before consultations begin. A second and undesirable reason for the drop in jeopardy findings is that FWS—in the face of persistent budget cuts, increasing workload, and mounting political pressure to minimize the economic impacts of endangered species conservation—is approving more projects that should have been altered to comply with the conservation standards under the Act (15). One method of achieving this outcome is by reinterpreting the jeopardy and destruction/adverse modification prohibitions such that they are more difficult to trigger. The definitions of both phrases are ambiguous enough to enable this gradual reinterpretation without a rulemaking or official change in agency policy. This second reason is a policy failure arising from insufficient resources and sociopolitical support for FWS (17). A third explanation is that federal agencies are now more inclined to continue negotiating the scope of their proposed projects in response to FWS issuing a draft biological opinion with a jeopardy or destruction/adverse modification conclusion (18). If negotiations are successful, the final biological opinion will have neither of those conclusions. We understand that all three scenarios are likely at play, but we do not know their prevalence.

Although the number of jeopardy conclusions is far lower than the numbers found in previous studies, it is unclear whether listed species are receiving less protection as a result. One reason is that the rate of formal consultation from 2008 to 2015 (7.7%) is considerably higher than the 2.8% observed by Barry et al. from 1987 to 1991 (10) but considerably lower than the 22.1% from 1979 to 1981, when there were far fewer consultations and formal consultation procedures were not yet clarified. Most of the >6,000 formal consultations in our dataset likely require permittees to apply RPMs, which are minor project modifications intended to minimize harm from the project (19) and are not required for projects that end with informal consultation. An example is avoiding construction during a listed bird's nesting season. Between the conservation benefits of RPMs and the likelihood that some federal agencies are now proposing projects with fewer harmful effects, certain listed species may be receiving as much protections as they did in the past because of the higher percentage of formal consultations. Other species, however, will likely continue to decline in this scenario because RPMs and other conservation measures are generally not designed to fully offset the harmful effects of projects and implementation of RPMs is rarely monitored. The cumulative effect of hundreds of these small projects is reduced populations or habitat, an outcome that some people refer to as "death by a thousand cuts" (20). Exploring the effects of the over 88,000 consultations on species recovery is essential to understanding the effectiveness of the Act.

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Improving the efficiency of section 7 consultations is a goal that would benefit the Services and the regulated community. We found that although the median duration of formal consultations is approximately one-half the maximum allowed by statute, a substantial proportion (20%) of formal consultations take longer than the 135 d allowed (absent an extension). One possibility for improving the speed of consultations is for the Services to find ways to expedite analyses of the effects of an action on listed species. To that end, FWS is currently creating the Information for Planning and Conservation (IPaC) system, which is expected to dramatically streamline informal consultations and introduce both efficiencies and needed standards for formal consultations (21). However, there are limits to how much the duration of consultations can be shortened, particularly for complex activities. Consultations often require months or years to complete because of inadequate data on species, which may suspend FWS's analysis until better data are collected and provided. Delays may also arise because federal agencies provide incomplete information about their proposed projects.

Our analyses show that the regulated community has two particular opportunities to contribute significantly to both conservation of listed species and to improved consultation efficiency. The variable with the largest mean square was whether consultations were formal, with formal consultations adding an estimated 43.8 d to the expected consultation duration. This result indicates that the most direct way to reduce consultation duration is for action agencies to plan and propose projects that are not likely to adversely affect listed species and, hence, do not require formal consultation. That is, species benefit by not being adversely affected by federal actions, and the regulated community benefits by faster (informal) consultations. As noted above, one possible explanation for the lack of jeopardy or destruction/adverse modification conclusions is that agencies have learned to modify actions before or during section 7 consultation to avoid such conclusions. If FWS increases the use of informal consultations to enhance efficiency, it would also need to improve compliance monitoring and enforcement to ensure that permittees actually implement required conservation measures.

The data also show the efficiencies introduced through consultations on federal agency programs that authorize future actions under the program (e.g., a Bureau of Land Management program to begin developing solar energy projects in six western states). Although these initial, program-level consultations take slightly longer than standard consultations, subsequent formal consultations on the individual activities tied to the program take less than half the time of standard formal consultations (e.g., consultations on the individual solar energy projects). In theory, wider adoption of programmatic consultations would allow better analysis of the overall effects on listed species than if those actions were each approved separately through standard consultations. In practice, however, federal agencies need to improve how they assess the cumulative effects of individual projects (22). If they succeed at this, individual projects could be approved more quickly without undermining conservation.

Although the TAILS data and our analyses can address certain questions about section 7 consultations, these data cannot address the broader conservation question: Has consultation improved the conservation of listed species? There are at least two components to this question. First is the question of whether species are improving, stable, or declining (23) and then determining what proportion of the trends are attributable to consultation. Key to understanding the mechanism is determining whether the analyses underlying consultations are robust enough to afford protections as intended in the Act. Our analysis of consultation duration reflects what FWS reports in its annual budget justification: the majority of formal consultations are completed on time (FWS 2015). In contrast, NMFS reported that less than 30% of its consultations in 2014 were completed on time (24). A recent analysis that included comparisons of consultations found that NMFS used better science than FWS (25), which may explain the difference in consultation duration. Although addressing the cause of this difference is beyond the scope of the present paper, we expect that more detailed and thorough consultations require more time to complete but will improve conservation outcomes in the long run.

The second question is perhaps the most important for conservation and yet the least understood: Are federal actions improving—or at least not impairing—the status of listed species? We currently have limited information on whether agencies are consulting with the Services to the full extent required by the Act. By extension, we do not know the extent to which state and local governments or private parties have pursued permits or funding from federal agencies that should have triggered consultation. We also do not know whether biological opinions and other consultation documents accurately describe the location and scope of projects as completed. Furthermore, we do not know whether permittees actually comply with the conservation requirements from biological opinions and assessments. NMFS has enabled the public to more easily answer some of these questions by posting the results of all their consultations online on the Public Consultation Tracking System website (https://pcts.nmfs.noaa.gov). What neither of the Services have made readily accessible, however, are the monitoring reports required by many biological opinions. Without these documents, it is often impossible to know whether RPMs and other conservation commitments have been performed, much less if they are effective for species (15). Although these important questions cannot be answered with the TAILS data, determining the answers is crucial to understanding the effectiveness of the Act. The significant drop in the number of jeopardy and destruction/adverse modification findings makes the answers especially important to evaluating whether consulted-on projects are impairing the conservation of listed species.

Actual data and their analysis are essential to understanding how laws and policies are implemented, and that understanding is core to making informed decisions that improve outcomes and efficiency. The framers of the Act recognized the central importance of using the best available data and science for conserving imperiled species. Using the best available data and very simple statistics, we have shown that FWS rarely finds jeopardy or destruction/adverse modification and that the duration of most formal consultations is far shorter than the maximum allowed by law. Not one project has been stopped or significantly altered as a result of FWS reaching either of these findings. Although our analyses raise a host of questions—e.g., whether consultation is improving conservation outcomes for listed species—our findings should lay to rest some of the common misconceptions about the law. With those misconceptions aside, effort can focus on improving both the conservation

Table 2. Rate at which the US Fish and Wildlife Service calls jeopardy has varied over the past three decades and decreased substantially since 2008

	US House of Representatives 1982 Report	Barry et al. (10)	Owen (11)	Present study
Time frame	1979 to 1981	1987 to 1991	2005 to 2009*	2008 to 2015
Informal consultation	8,817	71,560	NA	81,461
Formal consultation	1,945	2,000	1,085	6,829
Jeopardy	173 (8.9%)	350 (17.5%)	78 (7.2%)	2 (0.03%)

*Nos. include only FWS fish-related consultations.

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effectiveness and implementation efficiency of the Act to recover imperiled species.

Methods and Materials

We acquired a copy of the data for all formal and informal consultations as recorded in the TAILS database by FWS biologists since 2008, from FWS in July 2014, and a data update in mid-May 2015. The variables and an explanation of each are provided in *SI Appendix*. After the update, the dataset consisted of over 2 million rows of data, with each species evaluated in each consultation afforded a single row because conclusions are made on a per-species basis rather than per-consultation basis.

We performed extensive data checks and corrected errors in our copy of TAILS: errors are expected when >1,300 people working over 7 y are entering data. We corrected apparent date errors for the start and end of consultation, most of which were simple typos; homogenized the names of action agencies; corrected work categories for which duplicates occurred because of simple typos; and set the Boolean "formal consultation" field to "true" if the conclusions for any species in a consultation could only be reached through formal consultation (e.g., if a jeopardy determination had been recorded). Because FWS uses different species names and style conventions between different databases (e.g., TAILS vs. annual expenditure reports to Congress), we homogenized all names against the most recent expenditure report (2013) names and style convention [i.e., common group, common specific (*Genus species* [*var/ssp*])] to improve interoperability. Last, because there are effectively only a small number of possible conclusions (e.g., not likely to adversely affect vs. likely to adversely affect, no jeopardy, no adverse modification) but a variety of ways the conclusions were recorded in TAILS, we standardize all conclusions following Table S1.

During the data check phase, we identified 198 consultations that were recorded in TAILS as formal consultations but lacked lists of species evaluated during consultation, or for which the TAILS record included either jeopardy or destruction/adverse modification conclusions. To ensure the species and conclusions were correct, we requested biological opinions or other original consultation documents from FWS through a Freedom of Information Act request. We reviewed all responses and updated the data as necessary. During the updating, we identified another four consultations with questionable conclusions and used phone calls and emails to FWS biologists to obtain the correct data. Although such a large dataset likely contains other minor errors that we were unable to detect, we assume here that those errors are unbiased and equally distributed above and below the median and mean estimates.

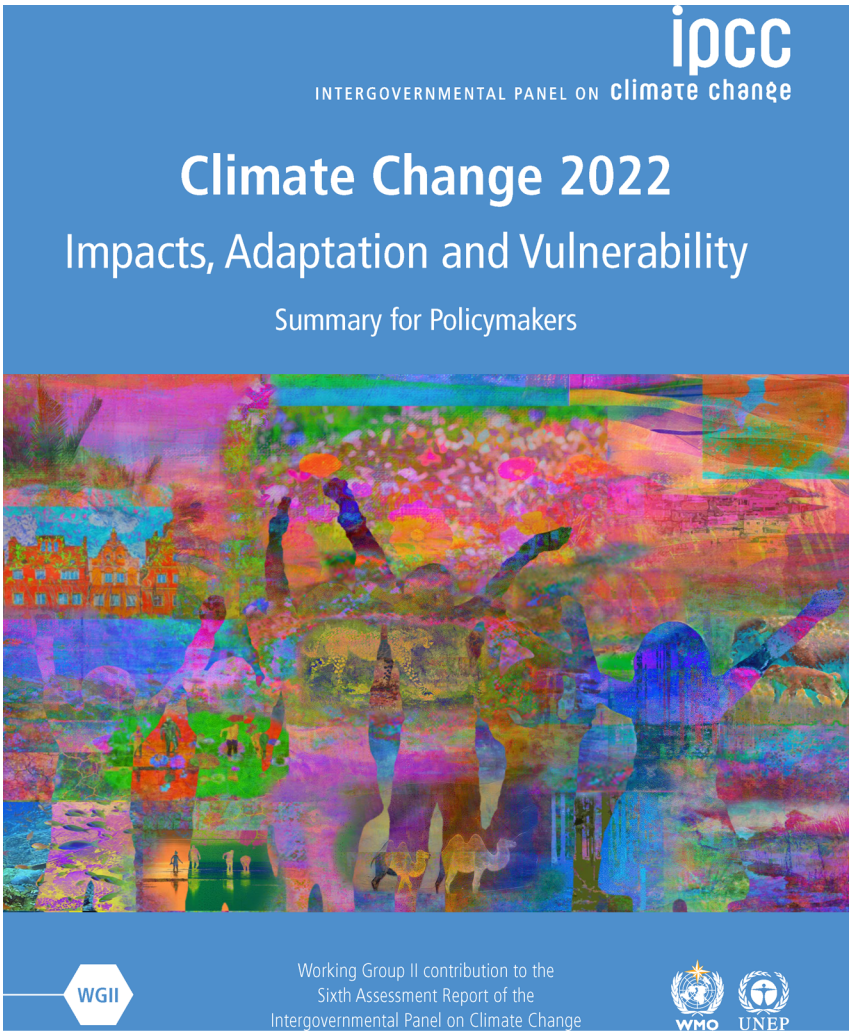
To facilitate analysis and data sharing, we created several additional variables from the TAILS data. Consultation duration (in days) was calculated as (*i*) conclusion date minus start date for informal consultations and (*ii*) conclusion date minus start of formal consultation date for formal consultations. The clock for meeting the regulatory deadline of 135 d for formal consultation starts when the action agency requests formal consultation. The duration calculation, however, may be an overestimate because the clock stops if FWS requires the action agency to provide more information. To protect the identity of FWS biologists performing the consultations while still allowing analysis of individual-level effects on consultation duration and other factors, we used the Message Digest 5 (MD5) algorithm in the digest package for R 3.1.2 (26) to hash the names. Last, to reduce the size of the database and improve the efficiency of the web applications (see below), we collapsed the TAILS data from species x consultation per row to a single row per consultation with lists of species and conclusions embedded in each row.

We calculated median consultation durations and approximate 95% CIs of the median after removing missing data. Standard analysis of variance was used to test for differences in means among categories. To evaluate the factors most likely to influence consultation duration, we removed 2,468 consultations (2.8%) with duration above the 98th percentile of all durations; these extreme values are strongly influenced by factors other than those recorded in TAILS, and their removal dramatically improved the fit of the models (from $R^2 \approx 0.17$ to $R^2 \approx 0.34$). We then used a linear model, with the functions lm and aov in R, to estimate the effects of six variables (identity of the lead biologist, whether the consultation was formal or not, the fiscal year of the consultation, the number of species evaluated, the complexity of the consultation, and the type of action being consulted on) on consultation duration. The distribution of residuals was checked to ensure the normality assumption was met.

A primary goal of this work is to help the public understand how consultations are implemented. We used the Shiny framework for R (shiny.rstudio.com) to create an interactive web application for different audiences. The code for the application and used in the analyses described above is available at GitHub (https://github.com/Defenders-ESC/section7_explorer) and is licensed under the GNU Public License version 2. The application itself is licensed under a Creative Commons Attribution/Share-Alike license so that figures, maps, and other details can be used (with attribution) by anyone who is interested. Because the TAILS data are created by US Government employees, the data are in the public domain and can be downloaded from within the application. We will be updating the data underlying the application on a quarterly basis.

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WGII
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Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

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Summary for Policymakers

SPM

Summary for Policymakers

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Table of Contents

A: Introduction 7

Box SPM.1 | AR6 Common Climate Dimensions, Global Warming Levels and Reference Periods 9

B: Observed and Projected Impacts and Risks 10

Observed Impacts from Climate Change 11
Vulnerability and Exposure of Ecosystems and People 14
Risks in the near term (2021–2040) 15
Mid to Long-term Risks (2041–2100) 16
Complex, Compound and Cascading Risks 20
Impacts of Temporary Overshoot 21

C: Adaptation Measures and Enabling Conditions 22

Current Adaptation and its Benefits 22
Future Adaptation Options and their Feasibility 23
Limits to Adaptation 28
Avoiding Maladaptation 29
Enabling Conditions 29

D: Climate Resilient Development 30

Conditions for Climate Resilient Development 31
Enabling Climate Resilient Development 31
Climate Resilient Development for Natural and Human Systems 33
Achieving Climate Resilient Development 35

A: Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group II (WGII) contribution to the Sixth Assessment Report (AR6) of the IPCC[1]. The report builds on the WGII contribution to the Fifth Assessment Report (AR5) of the IPCC, three Special Reports[2], and the Working Group I (WGI) contribution to the AR6 cycle.

This report recognizes the interdependence of climate, ecosystems and biodiversity[3], and human societies (Figure SPM.1) and integrates knowledge more strongly across the natural, ecological, social and economic sciences than earlier IPCC assessments. The assessment of climate change impacts and risks as well as adaptation is set against concurrently unfolding non-climatic global trends e.g., biodiversity loss, overall unsustainable consumption of natural resources, land and ecosystem degradation, rapid urbanisation, human demographic shifts, social and economic inequalities and a pandemic.

The scientific evidence for each key finding is found in the 18 chapters of the underlying report and in the 7 cross-chapter papers as well as the integrated synthesis presented in the Technical Summary (hereafter TS) and referred to in curly brackets {}. Based on scientific understanding, key findings can be formulated as statements of fact or associated with an assessed level of confidence using the IPCC calibrated language[4]. The WGII Global to Regional Atlas (Annex I) facilitates exploration of key synthesis findings across the WGII regions.

The concept of risk is central to all three AR6 Working Groups. A risk framing and the concepts of adaptation, vulnerability, exposure, resilience, equity and justice, and transformation provide alternative, overlapping, complementary, and widely used entry points to the literature assessed in this WGII report.

Across all three AR6 working groups, **risk**[5] provides a framework for understanding the increasingly severe, interconnected and often irreversible impacts of climate change on ecosystems, biodiversity, and human systems; differing impacts across regions, sectors and communities; and how to best reduce adverse consequences for current and future generations. In the context of climate change, risk can arise from the dynamic interactions among climate-related **hazards**[6] (see Working Group I), the **exposure**[7] and **vulnerability**[8] of affected human and ecological systems. The risk that can be introduced by human responses to climate change is a new aspect considered in the risk concept. This report identifies 127 key risks[9]. {1.3, 16.5}

The vulnerability of exposed human and natural systems is a component of risk, but also, independently, an important focus in the literature. Approaches to analysing and assessing vulnerability have evolved since previous IPCC assessments. Vulnerability is widely understood to differ within communities and across societies, regions and countries, also changing through time.

Adaptation[10] plays a key role in reducing exposure and vulnerability to climate change. Adaptation in ecological systems includes autonomous adjustments through ecological and evolutionary processes. In human systems, adaptation can be anticipatory or reactive, as well as incremental

1 Decision IPCC/XLVI-3, The assessment covers scientific literature accepted for publication by 1 September 2021.

2 The three Special Reports are: 'Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR1.5)'; 'Climate Change and Land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL)'; 'IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)'.

3 Biodiversity: Biodiversity or biological diversity means the variability among living organisms from all sources including, among other things, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

4 Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, e.g., *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Assessed likelihood is typeset in italics, e.g., *very likely*. This is consistent with AR5 and the other AR6 Reports.

5 Risk is defined as the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems.

6 Hazard is defined as the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. Physical climate conditions that may be associated with hazards are assessed in Working Group I as climatic impact-drivers.

7 Exposure is defined as the presence of people; livelihoods; species or ecosystems; environmental functions, services and resources; infrastructure; or economic, social or cultural assets in places and settings that could be adversely affected.

8 Vulnerability in this report is defined as the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

9 Key risks have potentially severe adverse consequences for humans and social-ecological systems resulting from the interaction of climate related hazards with vulnerabilities of societies and systems exposed.

10 Adaptation is defined, in human systems, as the process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities. In natural systems, adaptation is the process of adjustment to actual climate and its effects; human intervention may facilitate this.

From climate risk to climate resilient development: climate, ecosystems (including biodiversity) and human society as coupled systems

(a) Main interactions and trends

(b) Options to reduce climate risks and establish resilience

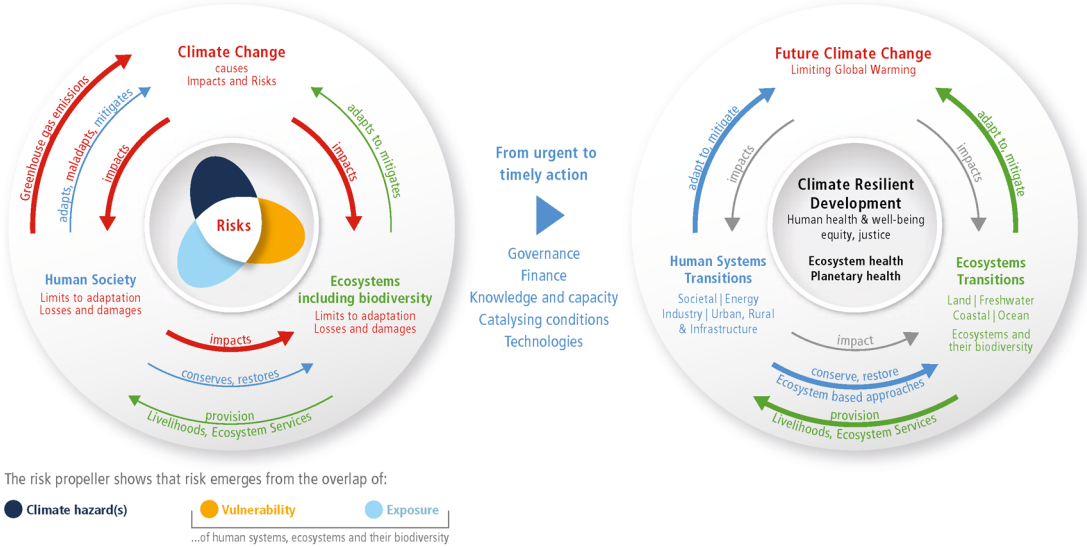


Figure SPM.1 | This report has a strong focus on the interactions among the coupled systems climate, ecosystems (including their biodiversity) and human society. These interactions are the basis of emerging risks from climate change, ecosystem degradation and biodiversity loss and, at the same time, offer opportunities for the future.

(a) Human society causes climate change. Climate change, through hazards, exposure and vulnerability generates impacts and risks that can surpass limits to adaptation and result in losses and damages. Human society can adapt to, maladapt and mitigate climate change, ecosystems can adapt and mitigate within limits. Ecosystems and their biodiversity provision livelihoods and ecosystem services. Human society impacts ecosystems and can restore and conserve them.

(b) Meeting the objectives of climate resilient development thereby supporting human, ecosystem and planetary health, as well as human well-being, requires society and ecosystems to move over (transition) to a more resilient state. The recognition of climate risks can strengthen adaptation and mitigation actions and transitions that reduce risks. Taking action is enabled by governance, finance, knowledge and capacity building, technology and catalysing conditions. Transformation entails system transitions strengthening the resilience of ecosystems and society (Section D). In a) arrow colours represent principle human society interactions **(blue)**, ecosystem (including biodiversity) interactions **(green)** and the impacts of climate change and human activities, including losses and damages, under continued climate change **(red)**. In b) arrow colours represent human system interactions **(blue)**, ecosystem (including biodiversity) interactions **(green)** and reduced impacts from climate change and human activities (grey). {1.2, Figure 1.2, Figure TS. 2}

and/ or transformational. The latter changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts. Adaptation is subject to hard and soft limits[11].

Resilience[12] in the literature has a wide range of meanings. Adaptation is often organized around resilience as bouncing back and returning to a previous state after a disturbance. More broadly the term describes not just the ability to maintain essential function, identity and structure, but also the capacity for transformation.

This report recognises the value of diverse forms of knowledge such as scientific, as well as Indigenous knowledge and local knowledge in understanding and evaluating climate adaptation processes and actions to reduce risks from human-induced climate change. AR6 highlights adaptation solutions which are effective, feasible[13], and conform to principles of justice[14]. The term climate justice, while used in different ways in different contexts by different communities, generally includes three principles: *distributive justice* which refers to the allocation of burdens and benefits among individuals, nations and generations; *procedural justice* which refers to who decides and participates in decision-making; and *recognition* which entails basic respect and robust engagement with and fair consideration of diverse cultures and perspectives.

Effectiveness refers to the extent to which an action reduces vulnerability and climate-related risk, increases resilience, and avoids maladaptation[15].

This report has a particular focus on transformation[16] and system transitions in energy; land, ocean, coastal and freshwater ecosystems; urban, rural and infrastructure; and industry and society. These transitions make possible the adaptation required for high levels of human health and well-being, economic and social resilience, ecosystem health[17], and planetary health[18] (Figure SPM.1). These system transitions are also important for achieving the low global warming levels (Working Group III) that would avoid many limits to adaptation[11]. The report also assesses economic and non-economic losses and damages[19]. This report labels the process of implementing mitigation and adaptation together in support of sustainable development for all as climate resilient development[20].

Box SPM.1 | AR6 Common Climate Dimensions, Global Warming Levels and Reference Periods

Assessments of climate risks consider possible future climate change, societal development and responses. This report assesses literature including that based on climate model simulations that are part of the fifth and sixth Coupled Model Intercomparison Project Phase (CMIP5, CMIP6) of the World Climate Research Programme. Future projections are driven by emissions and/or concentrations from illustrative Representative Concentration Pathways (RCPs)[21] and Shared Socioeconomic Pathways (SSPs)[22] scenarios, respectively[23]. Climate impacts literature is based primarily on climate projections assessed in AR5 or earlier, or assumed global warming levels, though some recent impacts literature uses newer projections based on the CMIP6 exercise. Given differences in the impacts literature regarding

11 Adaptation limits: The point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions.
Hard adaptation limit—No adaptive actions are possible to avoid intolerable risks.
Soft adaptation limit—Options may exist but are currently not available to avoid intolerable risks through adaptive action.

12 Resilience in this report is defined as the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation. Resilience is a positive attribute when it maintains such a capacity for adaptation, learning, and/or transformation.

13 Feasibility refers to the potential for an adaptation option to be implemented.

14 Justice is concerned with setting out the moral or legal principles of fairness and equity in the way people are treated, often based on the ethics and values of society. *Social justice* comprises just or fair relations within society that seek to address the distribution of wealth, access to resources, opportunity and support according to principles of justice and fairness. *Climate justice* comprises justice that links development and human rights to achieve a rights-based approach to addressing climate change.

15 Maladaptation refers to actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.

16 Transformation refers to a change in the fundamental attributes of natural and human systems.

17 Ecosystem health: a metaphor used to describe the condition of an ecosystem, by analogy with human health. Note that there is no universally accepted benchmark for a healthy ecosystem. Rather, the apparent health status of an ecosystem is judged on the ecosystem's resilience to change, with details depending upon which metrics (such as species richness and abundance) are employed in judging it and which societal aspirations are driving the assessment.

18 Planetary health: a concept based on the understanding that human health and human civilisation depend on ecosystem health and the wise stewardship of ecosystems.

19 In this report, the term 'losses and damages' refers to adverse observed impacts and/or projected risks and can be economic and/or non-economic.

20 In the WGII report, climate resilient development refers to the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development for all.

21 RCP-based scenarios are referred to as RCPy, where 'y' refers to the level of radiative forcing (in watts per square meter, or W m^{-2}) resulting from the scenario in the year 2100.

22 SSP-based scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socioeconomic Pathway describing the socioeconomic trends underlying the scenarios, and 'y' refers to the level of radiative forcing (in watts per square meter, or W m^{-2}) resulting from the scenario in the year 2100.

23 IPCC is neutral with regard to the assumptions underlying the SSPs, which do not cover all possible scenarios. Alternative scenarios may be considered or developed.

Box SPM.1 (continued)

socioeconomic details and assumptions, WGII chapters contextualize impacts with respect to exposure, vulnerability and adaptation as appropriate for their literature, this includes assessments regarding sustainable development and climate resilient development. There are many emissions and socioeconomic pathways that are consistent with a given global warming outcome. These represent a broad range of possibilities as available in the literature assessed that affect future climate change exposure and vulnerability. Where available, WGII also assesses literature that is based on an integrative SSP-RCP framework where climate projections obtained under the RCP scenarios are analysed against the backdrop of various illustrative SSPs[22]. The WGII assessment combines multiple lines of evidence including impacts modelling driven by climate projections, observations, and process understanding. {1.2, 16.5, 18.2, CCB CLIMATE, WGI AR6 SPM.C, WGI AR6 Box SPM.1, WGI AR6 1.6, WGI AR6 12, AR5 WGI}

A common set of reference years and time periods are adopted for assessing climate change and its impacts and risks: the reference period 1850–1900 approximates pre-industrial global surface temperature, and three future reference periods cover the near-term (2021–2040), mid-term (2041–2060) and long-term (2081–2100). {CCB CLIMATE}

Common levels of global warming relative to 1850–1900 are used to contextualize and facilitate analysis, synthesis and communication of assessed past, present and future climate change impacts and risks considering multiple lines of evidence. Robust geographical patterns of many variables can be identified at a given level of global warming, common to all scenarios considered and independent of timing when the global warming level is reached. {16.5, CCB CLIMATE, WGI AR6 Box SPM.1, WGI AR6 4.2, WGI AR6 CCB11.1}

WGI assessed the increase in global surface temperature is 1.09 [0.95 to 1.20][24] °C in 2011–2020 above 1850–1900. The estimated increase in global surface temperature since AR5 is principally due to further warming since 2003–2012 (+0.19 [0.16 to 0.22] °C).[25] Considering all five illustrative scenarios assessed by WGI, there is at least a greater than 50% likelihood that global warming will reach or exceed 1.5°C in the near-term, even for the very low greenhouse gas emissions scenario[26]. { WGI AR6 SPM A1.2, WGI AR6 SPM B1.3, WGI AR6 Table SPM.1, WGI AR6 CCB 2.3}

B: Observed and Projected Impacts and Risks

Since AR5, the knowledge base on observed and projected impacts and risks generated by climate hazards, exposure and vulnerability has increased with impacts attributed to climate change and key risks identified across the report. Impacts and risks are expressed in terms of their damages, harms, economic, and non-economic losses. Risks from observed vulnerabilities and responses to climate change are highlighted. Risks are projected for the near-term (2021–2040), the mid (2041–2060) and long term (2081–2100), at different global warming levels and for pathways that overshoot 1.5°C global warming level for multiple decades[27]. Complex risks result from multiple climate hazards occurring concurrently, and from multiple risks interacting, compounding overall risk and resulting in risks transmitting through interconnected systems and across regions.

24 In the WGI report, square brackets [x to y] are used to provide the assessed ***very likely*** range, or 90% interval.

25 Since AR5, methodological advances and new datasets have provided a more complete spatial representation of changes in surface temperature, including in the Arctic. These and other improvements have also increased the estimate of global surface temperature change by approximately 0.1°C, but this increase does not represent additional physical warming since AR5.

26 Global warming of 1.5°C relative to 1850–1900 would be exceeded during the 21st century under the intermediate, high and very high greenhouse gas emissions scenarios considered in this report (SSP2-4.5, SSP3-7.0 and SSP5-8.5, respectively). Under the five illustrative scenarios, in the near term (2021–2040), the 1.5°C global warming level is ***very likely*** to be exceeded under the very high greenhouse gas emissions scenario (SSP5-8.5), ***likely*** to be exceeded under the intermediate and high greenhouse gas emissions scenarios (SSP2-4.5 and SSP3-7.0), ***more likely than not*** to be exceeded under the low greenhouse gas emissions scenario (SSP1-2.6) and ***more likely than not*** to be reached under the very low greenhouse gas emissions scenario (SSP1-1.9). Furthermore, for the very low greenhouse gas emissions scenario (SSP1-1.9), it is ***more likely than not*** that global surface temperature would decline back to below 1.5°C toward the end of the 21st century, with a temporary overshoot of no more than 0.1°C above 1.5°C global warming.

27 Overshoot: In this report, pathways that first exceed a specified global warming level (usually 1.5°C, by more than 0.1°C), and then return to or below that level again before the end of a specified period of time (e.g., before 2100). Sometimes the magnitude and likelihood of the overshoot is also characterized. The overshoot duration can vary from at least one decade up to several decades.

Observed Impacts from Climate Change

B.1 Human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability. Some development and adaptation efforts have reduced vulnerability. Across sectors and regions the most vulnerable people and systems are observed to be disproportionately affected. The rise in weather and climate extremes has led to some irreversible impacts as natural and human systems are pushed beyond their ability to adapt. (*high confidence*) (Figure SPM.2) {TS B.1, Figure TS.5, 1.3, 2.3, 2.4, 2.6, 3.3, 3.4, 3.5, 4.2, 4.3, 5.2, 5.12, 6.2, 7.2, 8.2, 9.6, 9.8, 9.10, 9.11, 10.4, 11.3, 12.3, 12.4, 13.10, 14.4, 14.5, 15.3, 16.2, CCP1.2, CCP3.2, CCP4.1, CCP5.2, CCP6.2, CCP7.2, CCP7.3, CCB DISASTER, CCB EXTREMES, CCB ILLNESS, CCB MIGRATE, CCB NATURAL, CCB SLR}

B.1.1 Widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure have resulted from observed increases in the frequency and intensity of climate and weather extremes, including hot extremes on land and in the ocean, heavy precipitation events, drought and fire weather (*high confidence*). Increasingly since AR5, these observed impacts have been attributed[28] to human-induced climate change particularly through increased frequency and severity of extreme events. These include increased heat-related human mortality (*medium confidence*), warm-water coral bleaching and mortality (*high confidence*), and increased drought-related tree mortality (*high confidence*). Observed increases in areas burned by wildfires have been attributed to human-induced climate change in some regions (*medium* to *high confidence*). Adverse impacts from tropical cyclones, with related losses and damages[19], have increased due to sea level rise and the increase in heavy precipitation (*medium confidence*). Impacts in natural and human systems from slow-onset processes[29] such as ocean acidification, sea level rise or regional decreases in precipitation have also been attributed to human induced climate change (*high confidence*). {1.3, 2.3, 2.4, 2.5, 3.2, 3.4, 3.5, 3.6, 4.2, 5.2, 5.4, 5.6, 5.12, 7.2, 9.6, 9.7, 9.8, 9.11, 11.3, Box 11.1, Box 11.2, Table 11.9, 12.3, 12.4, 13.3, 13.5, 13.10, 14.2, 14.5, 15.7, 15.8, 16.2, CCP1.2, CCP2.2, Box CCP5.1, CCP7.3, CCB DISASTER, CCB EXTREME, CCB ILLNESS, WGI AR6 SPM.3, WGI AR6 9, WGI AR6 11.3–11.8, SROCC Chapter 4}

B.1.2 Climate change has caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open ocean marine ecosystems (*high confidence*). The extent and magnitude of climate change impacts are larger than estimated in previous assessments (*high confidence*). Widespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity, as well as shifts in seasonal timing have occurred due to climate change (*high confidence*), with adverse socioeconomic consequences (*high confidence*). Approximately half of the species assessed globally have shifted polewards or, on land, also to higher elevations (*very high confidence*). Hundreds of local losses of species have been driven by increases in the magnitude of heat extremes (*high confidence*), as well as mass mortality events on land and in the ocean (*very high confidence*) and loss of kelp forests (*high confidence*). Some losses are already irreversible, such as the first species extinctions driven by climate change (*medium confidence*). Other impacts are approaching irreversibility such as the impacts of hydrological changes resulting from the retreat of glaciers, or the changes in some mountain (*medium confidence*) and Arctic ecosystems driven by permafrost thaw (*high confidence*). (Figure SPM.2a). { TS B.1, Figure TS.5, 2.3, 2.4, 3.4, 3.5, 4.2, 4.3, 4.5, 9.6, 10.4, 11.3, 12.3, 12.8, 13.3, 13.4, 13.10, 14.4, 14.5, 14.6, 15.3, 16.2, CCP1.2, CCP3.2, CCP4.1, CCP5.2, Figure CCP5.4, CCP6.1, CCP6.2, CCP7.2, CCP7.3, CCB EXTREMES, CCB ILLNESS, CCB MOVING PLATE, CCB NATURAL, CCB PALEO, CCB SLR, SROCC 2.3}

B.1.3 Climate change including increases in frequency and intensity of extremes have reduced food and water security, hindering efforts to meet Sustainable Development Goals (*high confidence*). Although overall agricultural productivity has increased, climate change has slowed this growth over the past 50 years globally (*medium confidence*), related negative impacts were mainly in mid- and low latitude regions but positive impacts occurred in some high latitude regions (*high confidence*). Ocean warming and ocean acidification have adversely affected food production from shellfish aquaculture and fisheries in some oceanic regions (*high confidence*). Increasing weather and climate extreme events have exposed millions of people to acute food insecurity[30] and reduced water security, with the largest impacts observed in many locations and/or communities in Africa, Asia, Central and South America, Small Islands and the Arctic (*high confidence*). Jointly, sudden losses of food production and access to food compounded by decreased diet diversity have increased malnutrition in many communities (*high confidence*), especially for Indigenous Peoples, small-scale food producers and low-income households (*high confidence*), with children, elderly people and pregnant women particularly impacted (*high confidence*). Roughly half of the world's population currently experience severe water scarcity for at least some part of the year due to climatic and non-climatic drivers (*medium confidence*). (Figure SPM.2b) {3.5, 4.3, 4.4, Box 4.1, 5.2, 5.4, 5.8, 5.9, 5.12, 7.1, 7.2, 9.8, 10.4, 11.3, 12.3, 13.5, 14.4, 14.5, 15.3, 16.2, CCP5.2, CCP6.2}

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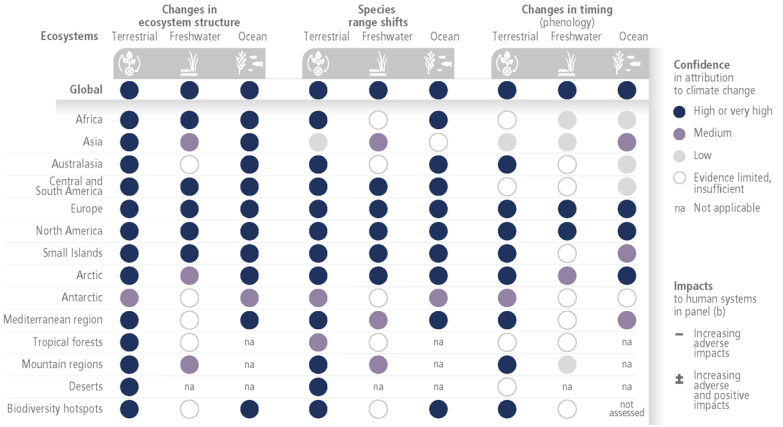
28 Attribution is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with an assessment of confidence. {Annex II Glossary, CWGB ATTRIB}

29 Impacts of climate change are caused by slow onset and extreme events. Slow onset events are described among the climatic-impact drivers of the WGI AR6 and refer to the risks and impacts associated with e.g., increasing temperature means, desertification, decreasing precipitation, loss of biodiversity, land and forest degradation, glacial retreat and related impacts, ocean acidification, sea level rise and salinization (https://interactive-atlas.ipcc.ch).

30 Acute food insecurity can occur at any time with a severity that threatens lives, livelihoods or both, regardless of the causes, context or duration, as a result of shocks risking determinants of food security and nutrition, and used to assess the need for humanitarian action.

Impacts of climate change are observed in many ecosystems and human systems worldwide

(a) Observed impacts of climate change on ecosystems



(b) Observed impacts of climate change on human systems

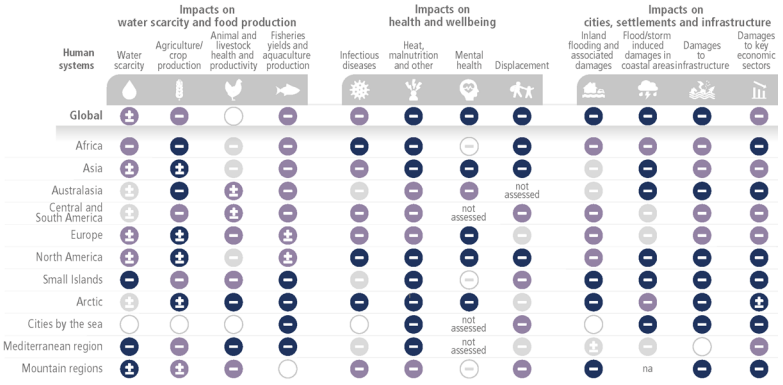


Figure SPM.2 | Observed global and regional impacts on ecosystems and human systems attributed to climate change. Confidence levels reflect uncertainty in attribution of the observed impact to climate change. Global assessments focus on large studies, multi-species, meta-analyses and large reviews. For that reason they can be assessed with higher confidence than regional studies, which may often rely on smaller studies that have more limited data. Regional assessments consider evidence on impacts across an entire region and do not focus on any country in particular.

(a) Climate change has already altered terrestrial, freshwater and ocean ecosystems at global scale, with multiple impacts evident at regional and local scales where there is sufficient literature to make an assessment. Impacts are evident on ecosystem structure, species geographic ranges and timing of seasonal life cycles (phenology) (for methodology and detailed references to chapters and cross-chapter papers see SMTS.1 and SMTS.1.1).

(b) Climate change has already had diverse adverse impacts on human systems, including on water security and food production, health and well-being, and cities, settlements and infrastructure. The + and – symbols indicate the direction of observed impacts, with a – denoting an increasing adverse impact and a ± denoting that, within a region or globally, both adverse and positive impacts have been observed (e.g., adverse impacts in one area or food item may occur with positive impacts in another area or food item). Globally, '–' denotes an overall adverse impact; 'Water scarcity' considers, e.g., water availability in general, groundwater, water quality, demand for water, drought in cities. Impacts on food production were assessed by excluding non-climatic drivers of production increases; Global assessment for agricultural production is based on the impacts on global aggregated production; 'Reduced animal and livestock health and productivity' considers, e.g., heat stress, diseases, productivity, mortality; 'Reduced fisheries yields and aquaculture production' includes marine and freshwater fisheries/production; 'Infectious diseases' include, e.g., water-borne and vector-borne diseases; 'Heat, malnutrition and other' considers, e.g., human heat-related morbidity and mortality, labour productivity, harm from wildfire, nutritional deficiencies; 'Mental health' includes impacts from extreme weather events, cumulative events, and vicarious or anticipatory events; 'Displacement' assessments refer to evidence of displacement attributable to climate and weather extremes; 'Inland flooding and associated damages' considers, e.g., river overflows, heavy rain, glacier outbursts, urban flooding; 'Flood/storm induced damages in coastal areas' include damages due to, e.g., cyclones, sea level rise, storm surges. Damages by key economic sectors are observed impacts related to an attributable mean or extreme climate hazard or directly attributed. Key economic sectors include standard classifications and sectors of importance to regions (for methodology and detailed references to chapters and cross-chapter papers see SMTS.1 and SMTS.1.2).

B.1.4 Climate change has adversely affected physical health of people globally (*very high confidence)* and mental health of people in the assessed regions (*very high confidence*). Climate change impacts on health are mediated through natural and human systems, including economic and social conditions and disruptions (*high confidence*). In all regions extreme heat events have resulted in human mortality and morbidity (*very high confidence*). The occurrence of climate-related food-borne and water-borne diseases has increased (*very high confidence*). The incidence of vector-borne diseases has increased from range expansion and/or increased reproduction of disease vectors (*high confidence*). Animal and human diseases, including zoonoses, are emerging in new areas (*high confidence*). Water and food-borne disease risks have increased regionally from climate-sensitive aquatic pathogens, including *Vibrio* spp. (*high confidence*), and from toxic substances from harmful freshwater cyanobacteria (*medium confidence*). Although diarrheal diseases have decreased globally, higher temperatures, increased rain and flooding have increased the occurrence of diarrheal diseases, including cholera (*very high confidence*) and other gastrointestinal infections (*high confidence*). In assessed regions, some mental health challenges are associated with increasing temperatures (*high confidence*), trauma from weather and climate extreme events (*very high confidence*), and loss of livelihoods and culture (*high confidence*). Increased exposure to wildfire smoke, atmospheric dust, and aeroallergens have been associated with climate-sensitive cardiovascular and respiratory distress (*high confidence*). Health services have been disrupted by extreme events such as floods (*high confidence*). {4.3, 5.12, 7.2, Box 7.3, 8.2, 8.3, Box 8.6, Figure 8.10, 9.10, Figure 9.33, Figure 9.34, 10.4, 11.3, 12.3, 13.7, 14.4, 14.5, Figure 14.8, 15.3, 16.2, CCP5.2, Table CCP5.1, CCP6.2, Figure CCP6.3, Table CCB ILLNESS.1}

B.1.5 In urban settings, observed climate change has caused impacts on human health, livelihoods and key infrastructure (*high confidence*). Multiple climate and non-climate hazards impact cities, settlements and infrastructure and sometimes coincide, magnifying damage (*high confidence*). Hot extremes including heatwaves have intensified in cities (*high confidence*), where they have also aggravated air pollution events (*medium confidence*) and limited functioning of key infrastructure (*high confidence*). Observed impacts are concentrated amongst the economically and socially marginalized urban residents, e.g., in informal settlements (*high confidence*). Infrastructure, including transportation, water, sanitation and energy systems have been compromised by extreme and slow-onset events, with resulting economic losses, disruptions of services and impacts to well-being (*high confidence*). {4.3, 6.2, 7.1, 7.2, 9.9, 10.4, 11.3, 12.3, 13.6, 14.5, 15.3, CCP2.2, CCP4.2, CCP5.2}

B.1.6 Overall adverse economic impacts attributable to climate change, including slow-onset and extreme weather events, have been increasingly identified (*medium confidence*). Some positive economic effects have been identified in regions that have benefited from lower energy demand as well as comparative advantages in agricultural markets and tourism (*high confidence*). Economic damages from climate change have been detected in climate-exposed sectors, with regional effects to agriculture, forestry, fishery, energy, and tourism (*high confidence*), and through outdoor labour productivity (*high confidence*). Some extreme weather events, such as tropical cyclones, have reduced economic growth in the short-term (*high confidence*). Non-climatic factors including some patterns of settlement, and siting of infrastructure have contributed to the exposure of more assets to extreme climate hazards increasing the magnitude of the losses (*high confidence*). Individual livelihoods have been affected through changes in agricultural productivity, impacts on human health and food security, destruction of homes and infrastructure, and loss of property and income, with adverse effects on gender and social equity (*high confidence*). {3.5, 4.2, 5.12, 6.2, 7.2, 8.2, 9.6, 10.4, 13.10, 14.5, Box 14.6, 16.2, Table 16.5, 18.3, CCP6.2, CCB GENDER, CWGB ECONOMICS}

B.1.7 Climate change is contributing to humanitarian crises where climate hazards interact with high vulnerability (*high confidence*). Climate and weather extremes are increasingly driving displacement in all regions (*high confidence*), with Small Island States disproportionately affected (*high confidence*). Flood and drought-related acute food insecurity and malnutrition have increased in Africa (*high confidence*) and Central and South America (*high confidence*). While non-climatic factors are the dominant drivers of existing intrastate violent conflicts, in some assessed regions extreme weather and climate events have had a small, adverse impact on their length, severity or frequency, but the statistical association is weak (*medium confidence*). Through displacement and involuntary migration from extreme weather and climate events, climate change has generated and perpetuated vulnerability (*medium confidence*). {4.2, 4.3, 5.4, 7.2, 9.8, Box 9.9, Box 10.4, 12.3, 12.5, 16.2, CCB DISASTER, CCB MIGRATE}

Vulnerability and Exposure of Ecosystems and People

B.2 Vulnerability of ecosystems and people to climate change differs substantially among and within regions (*very high confidence*), driven by patterns of intersecting socioeconomic development, unsustainable ocean and land use, inequity, marginalization, historical and ongoing patterns of inequity such as colonialism, and governance[31] (*high confidence*). Approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change (*high confidence*). A high proportion of species is vulnerable to climate change (*high confidence*). Human and ecosystem vulnerability are interdependent (*high confidence*). Current unsustainable development patterns are increasing exposure of ecosystems and people to climate hazards (*high confidence*). {2.3, 2.4, 3.5, 4.3, 6.2, 8.2, 8.3, 9.4, 9.7, 10.4, 12.3, 14.5, 15.3, CCP5.2, CCP6.2, CCP7.3, CCP7.4, CCB GENDER}

B.2.1 Since AR5 there is increasing evidence that degradation and destruction of ecosystems by humans increases the vulnerability of people (*high confidence*). Unsustainable land-use and land cover change, unsustainable use of natural resources, deforestation, loss of biodiversity, pollution, and their interactions, adversely affect the capacities of ecosystems, societies, communities and individuals to adapt to climate change (*high confidence*). Loss of ecosystems and their services has cascading and long-term impacts on people globally, especially for Indigenous Peoples and local communities who are directly dependent on ecosystems, to meet basic needs (*high confidence*). {2.3, 2.5, 2.6, 3.5, 3.6, 4.2, 4.3, 4.6, 5.1, 5.4, 5.5, 5.7, 5.8, 7.2, 8.1, 8.2, 8.3, 8.4, 8.5, 9.6, 10.4, 11.3, 12.2, 12.5, 13.8, 14.4, 14.5, 15.3, CCP1.2, CCP1.3, CCP2.2, CCP3, CCP4.3, CCP5.2, CCP6.2, CCP7.2, CCP7.3, CCP7.4, CCB ILLNESS, CCB MOVING PLATE, CCB SLR}

B.2.2 Non-climatic human-induced factors exacerbate current ecosystem vulnerability to climate change (*very high confidence*). Globally, and even within protected areas, unsustainable use of natural resources, habitat fragmentation, and ecosystem damage by pollutants increase ecosystem vulnerability to climate change (*high confidence*). Globally, less than 15% of the land, 21% of the freshwater and 8% of the ocean are protected areas. In most protected areas, there is insufficient stewardship to contribute to reducing damage from, or increasing resilience to, climate change (*high confidence*). {2.4, 2.5, 2.6, 3.4, 3.6, 4.2, 4.3, 5.8, 9.6, 11.3, 12.3, 13.3, 13.4, 14.5, 15.3, CCP1.2, Figure CCP1.15, CCP2.1, CCP2.2, CCP4.2, CCP5.2, CCP6.2, CCP7.2, CCP7.3, CCB NATURAL}

B.2.3 Future vulnerability of ecosystems to climate change will be strongly influenced by the past, present and future development of human society, including from overall unsustainable consumption and production, and increasing demographic pressures, as well as persistent unsustainable use and management of land, ocean, and water (*high confidence*). Projected climate change, combined with non-climatic drivers, will cause loss and degradation of much of the world's forests (*high confidence*), coral reefs and low-lying coastal wetlands (*very high confidence*). While agricultural development contributes to food security, unsustainable agricultural expansion, driven in part by unbalanced diets[32], increases ecosystem and human vulnerability and leads to competition for land and/or water resources (*high confidence*). {2.2, 2.3, 2.4, 2.6, 3.4, 3.5, 3.6, 4.3, 4.5, 5.6, 5.12, 5.13, 7.2, 12.3, 13.3, 13.4, 13.10, 14.5, CCP1.2, CCP2.2, CCP5.2, CCP6.2, CCP7.2, CCP7.3, CCB HEALTH, CCB NATURAL}

B.2.4 Regions and people with considerable development constraints have high vulnerability to climatic hazards (*high confidence*). Global hotspots of high human vulnerability are found particularly in West-, Central- and East Africa, South Asia, Central and South America, Small Island Developing States and the Arctic (*high confidence*). Vulnerability is higher in locations with poverty, governance challenges and limited access to basic services and resources, violent conflict and high levels of climate-sensitive livelihoods (e.g., smallholder farmers, pastoralists, fishing communities) (*high confidence*). Between 2010–2020, human mortality from floods, droughts and storms was 15 times higher in highly vulnerable regions, compared to regions with very low vulnerability (*high confidence*). Vulnerability at different spatial levels is exacerbated by inequity and marginalization linked to gender, ethnicity, low income or combinations thereof (*high confidence*), especially for many Indigenous Peoples and local communities (*high confidence*). Present development challenges causing high vulnerability are influenced by historical and ongoing patterns of inequity such as colonialism, especially for many Indigenous Peoples and local communities (*high confidence*). {4.2, 5.12, 6.2, 6.4, 7.1, 7.2, Box 7.1, 8.2, 8.3, Box 8.4, Figure 8.6, Box 9.1, 9.4, 9.7, 9.9, 10.3, 10.4, 10.6, 12.3, 12.5, Box 13.2, 14.4, 15.3, 15.6, 16.2, CCP6.2, CCP7.4}

B.2.5 Future human vulnerability will continue to concentrate where the capacities of local, municipal and national governments, communities and the private sector are least able to provide infrastructures and basic services (*high confidence*). Under the global trend of urbanization, human vulnerability will also concentrate in informal settlements and rapidly growing smaller settlements (*high*

31 Governance: The structures, processes and actions through which private and public actors interact to address societal goals. This includes formal and informal institutions and the associated norms, rules, laws and procedures for deciding, managing, implementing and monitoring policies and measures at any geographic or political scale, from global to local.

32 Balanced diets feature plant-based foods, such as those based on coarse grains, legumes fruits and vegetables, nuts and seeds, and animal-source foods produced in resilient, sustainable and low-greenhouse gas emissions systems, as described in SRCCL.

confidence). In rural areas vulnerability will be heightened by compounding processes including high emigration, reduced habitability and high reliance on climate-sensitive livelihoods (*high confidence*). Key infrastructure systems including sanitation, water, health, transport, communications and energy will be increasingly vulnerable if design standards do not account for changing climate conditions (*high confidence*). Vulnerability will also rapidly rise in low-lying Small Island Developing States and atolls in the context of sea level rise and in some mountain regions, already characterised by high vulnerability due to high dependence on climate-sensitive livelihoods, rising population displacement, the accelerating loss of ecosystem services and limited adaptive capacities (*high confidence*). Future exposure to climatic hazards is also increasing globally due to socioeconomic development trends including migration, growing inequality and urbanization *(high confidence*). {4.5, 5.5, 6.2, 7.2, 8.3, 9.9, 9.11, 10.3, 10.4, 12.3, 12.5, 13.6, 14.5, 15.3, 15.4, 16.5, CCP2.3, CCP4.3, CCP5.2, CCP5.3, CCP5.4, CCP6.2, CCB MIGRATE}

Risks in the near term (2021–2040)

B.3 **Global warming, reaching 1.5°C in the near-term, would cause unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans (*very high confidence*). The level of risk will depend on concurrent near-term trends in vulnerability, exposure, level of socioeconomic development and adaptation (*high confidence*). Near-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all (*very high confidence*). (Figure SPM.3, Box SPM.1) {16.4, 16.5, 16.6, CCP1.2, CCP5.3, CCB SLR, WGI AR6 SPM B1.3, WGI AR6 Table SPM.1}**

B.3.1 Near-term warming and increased frequency, severity and duration of extreme events will place many terrestrial, freshwater, coastal and marine ecosystems at high or very high risks of biodiversity loss (*medium to very high confidence*, depending on ecosystem). Near-term risks for biodiversity loss are moderate to high in forest ecosystems (*medium confidence*), kelp and seagrass ecosystems (*high* to *very high confidence*), and high to very high in Arctic sea-ice and terrestrial ecosystems (*high confidence*) and warm-water coral reefs (*very high confidence*). Continued and accelerating sea level rise will encroach on coastal settlements and infrastructure (*high confidence*) and commit low-lying coastal ecosystems to submergence and loss (*medium confidence*). If trends in urbanisation in exposed areas continue, this will exacerbate the impacts, with more challenges where energy, water and other services are constrained (*medium confidence*). The number of people at risk from climate change and associated loss of biodiversity will progressively increase (*medium confidence*). Violent conflict and, separately, migration patterns, in the near-term will be driven by socioeconomic conditions and governance more than by climate change (*medium confidence*). (Figure SPM.3) {2.5, 3.4, 4.6, 6.2, 7.3, 8.7, 9.2, 9.9, 11.6, 12.5, 13.6, 13.10, 14.6, 15.3, 16.5, 16.6, CCP1.2, CCP2.1, CCP2.2, CCP5.3, CCP6.2, CCP6.3, CCB MIGRATE, CCB SLR}

B.3.2 In the near term, climate-associated risks to natural and human systems depend more strongly on changes in their vulnerability and exposure than on differences in climate hazards between emissions scenarios (*high confidence*). Regional differences exist, and risks are highest where species and people exist close to their upper thermal limits, along coastlines, in close association with ice or seasonal rivers (*high confidence*). Risks are also high where multiple non-climate drivers persist or where vulnerability is otherwise elevated (*high confidence*). Many of these risks are unavoidable in the near-term, irrespective of emissions scenario (*high confidence*). Several risks can be moderated with adaptation (*high confidence*). (Figure SPM.3, Section C) {2.5, 3.3, 3.4, 4.5, 6.2, 7.1, 7.3, 8.2, 11.6, 12.4, 13.6, 13.7, 13.10, 14.5, 16.4, 16.5, CCP2.2, CCP4.3, CCP5.3, CCB SLR, WGI AR6 Table SPM.1}

B.3.3 Levels of risk for all Reasons for Concern (RFC) are assessed to become high to very high at lower global warming levels than in AR5 (*high confidence*). Between 1.2°C and 4.5°C global warming level very high risks emerge in all five RFCs compared to just two RFCs in AR5 (*high confidence*). Two of these transitions from high to very high risk are associated with near-term warming: risks to unique and threatened systems at a median value of 1.5 [1.2 to 2.0] °C (*high confidence*) and risks associated with extreme weather events at a median value of 2.0 [1.8 to 2.5] °C (*medium confidence*). Some key risks contributing to the RFCs are projected to lead to widespread, pervasive, and potentially irreversible impacts at global warming levels of 1.5–2°C if exposure and vulnerability are high and adaptation is low (*medium confidence*). Near-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all (*very high confidence*). (Figure SPM.3b) {16.5, 16.6, CCB SLR}

Mid to Long-term Risks (2041–2100)

B.4 Beyond 2040 and depending on the level of global warming, climate change will lead to numerous risks to natural and human systems (*high confidence*). For 127 identified key risks, assessed mid- and long-term impacts are up to multiple times higher than currently observed (*high confidence*). The magnitude and rate of climate change and associated risks depend strongly on near-term mitigation and adaptation actions, and projected adverse impacts and related losses and damages escalate with every increment of global warming (*very high confidence*). (Figure SPM.3) {2.5, 3.4, 4.4, 5.2, 6.2, 7.3, 8.4, 9.2, 10.2, 11.6, 12.4, 13.2, 13.3, 13.4, 13.5, 13.6, 13.7, 13.8, 14.6, 15.3, 16.5, 16.6, CCP1.2, CCP2.2, CCP3.3, CCP4.3, CCP5.3, CCP6.3, CCP7.3}

B.4.1 Biodiversity loss and degradation, damages to and transformation of ecosystems are already key risks for every region due to past global warming and will continue to escalate with every increment of global warming (*very high confidence*). In terrestrial ecosystems, 3 to 14% of species assessed[33] will *likely* face very high risk of extinction[34] at global warming levels of 1.5°C, increasing up to 3 to 18% at 2°C, 3 to 29% at 3°C, 3 to 39% at 4°C, and 3 to 48% at 5°C. In ocean and coastal ecosystems, risk of biodiversity loss ranges between moderate and very high by 1.5°C global warming level and is moderate to very high by 2°C but with more ecosystems at high and very high risk (*high confidence*), and increases to high to very high across most ocean and coastal ecosystems by 3°C (*medium* to *high confidence*, depending on ecosystem). Very high extinction risk for endemic species in biodiversity hotspots is projected to at least double from 2% between 1.5°C and 2°C global warming levels and to increase at least tenfold if warming rises from 1.5°C to 3°C (*medium confidence*). (Figure SPM.3c, d, f) {2.4, 2.5, 3.4, 3.5,12.3, 12.5, Table 12.6, 13.4, 13.10, 16.4, 16.6, CCP1.2, Figure CCP1.6, Figure CCP1.7, CCP5.3, CCP6.3, CCB PALEO}

B.4.2 Risks in physical water availability and water-related hazards will continue to increase by the mid- to long-term in all assessed regions, with greater risk at higher global warming levels (*high confidence*). At approximately 2°C global warming, snowmelt water availability for irrigation is projected to decline in some snowmelt dependent river basins by up to 20%, and global glacier mass loss of 18 ± 13% is projected to diminish water availability for agriculture, hydropower, and human settlements in the mid- to long-term, with these changes projected to double with 4°C global warming (*medium confidence*). In Small Islands, groundwater availability is threatened by climate change (*high confidence*). Changes to streamflow magnitude, timing and associated extremes are projected to adversely impact freshwater ecosystems in many watersheds by the mid- to long-term across all assessed scenarios (*medium confidence*). Projected increases in direct flood damages are higher by 1.4 to 2 times at 2°C and 2.5 to 3.9 times at 3°C compared to 1.5°C global warming without adaptation (*medium confidence*). At global warming of 4°C, approximately 10% of the global land area is projected to face increases in both extreme high and low river flows in the same location, with implications for planning for all water use sectors (*medium confidence*). Challenges for water management will be exacerbated in the near, mid and long term, depending on the magnitude, rate and regional details of future climate change and will be particularly challenging for regions with constrained resources for water management (*high confidence*). {2.3, 4.4, 4.5, Box 4.2, Figure 4.20, 15.3, CCP5.3, CCB DISASTER, SROCC 2.3}

B.4.3 Climate change will increasingly put pressure on food production and access, especially in vulnerable regions, undermining food security and nutrition (*high confidence*). Increases in frequency, intensity and severity of droughts, floods and heatwaves, and continued sea level rise will increase risks to food security (*high confidence*) in vulnerable regions from moderate to high between 1.5°C and 2°C global warming level, with no or low levels of adaptation (*medium confidence*). At 2°C or higher global warming level in the mid-term, food security risks due to climate change will be more severe, leading to malnutrition and micro-nutrient deficiencies, concentrated in Sub-Saharan Africa, South Asia, Central and South America and Small Islands (*high confidence).* Global warming will progressively weaken soil health and ecosystem services such as pollination, increase pressure from pests and diseases, and reduce marine animal biomass, undermining food productivity in many regions on land and in the ocean (*medium confidence*). At 3°C or higher global warming level in the long term, areas exposed to climate-related hazards will expand substantially compared with 2°C or lower global warming level (*high confidence*), exacerbating regional disparity in food security risks (*high confidence*). (Figure SPM.3) {1.1, 3.3, 4.5, 5.2, 5.4, 5.5, 5.8, 5.9, 5.12, 7.3, 8.3, 9.11, 13.5, 15.3, 16.5, 16.6, CCB MOVING PLATE, CCB SLR}

33 Numbers of species assessed are in the tens of thousands globally.

34 The term 'very high risks of extinction' is used here consistently with the IUCN categories and criteria and equates with 'critically endangered'.

B.4.4 Climate change and related extreme events will significantly increase ill health and premature deaths from the near- to long-term (*high confidence*). Globally, population exposure to heatwaves will continue to increase with additional warming, with strong geographical differences in heat-related mortality without additional adaptation (*very high confidence*). Climate-sensitive food-borne, water-borne, and vector-borne disease risks are projected to increase under all levels of warming without additional adaptation (*high confidence*). In particular, dengue risk will increase with longer seasons and a wider geographic distribution in Asia, Europe, Central and South America and sub-Saharan Africa, potentially putting additional billions of people at risk by the end of the century (*high confidence*). Mental health challenges, including anxiety and stress, are expected to increase under further global warming in all assessed regions, particularly for children, adolescents, elderly, and those with underlying health conditions (*very high confidence*). {4.5, 5.12, Box 5.10, 7.3, Figure 7.9, 8.4, 9.10, Figure 9.32, Figure 9.35, 10.4, Figure 10.11, 11.3, 12.3, Figure 12.5, Figure 12.6, 13.7, Figure 13.23, Figure 13.24, 14.5, 15.3, CCP6.2}

B.4.5 Climate change risks to cities, settlements and key infrastructure will rise rapidly in the mid- and long-term with further global warming, especially in places already exposed to high temperatures, along coastlines, or with high vulnerabilities (*high confidence*). Globally, population change in low-lying cities and settlements will lead to approximately a billion people projected to be at risk from coastal-specific climate hazards in the mid-term under all scenarios, including in Small Islands (*high confidence*). The population potentially exposed to a 100-year coastal flood is projected to increase by about 20% if global mean sea level rises by 0.15 m relative to 2020 levels; this exposed population doubles at a 0.75 m rise in mean sea level and triples at 1.4 m without population change and additional adaptation (*medium confidence*). Sea level rise poses an existential threat for some Small Islands and some low-lying coasts (*medium confidence*). By 2100 the value of global assets within the future 1-in-100 year coastal floodplains is projected to be between US$7.9 and US$12.7 trillion (2011 value) under RCP4.5, rising to between US$8.8 and US$14.2 trillion under RCP8.5 (*medium confidence*). Costs for maintenance and reconstruction of urban infrastructure, including building, transportation, and energy will increase with global warming level (*medium confidence*), the associated functional disruptions are projected to be substantial particularly for cities, settlements and infrastructure located on permafrost in cold regions and on coasts (*high confidence*). {6.2, 9.9, 10.4, 13.6, 13.10, 15.3, 16.5, CCP2.1, CCP2.2, CCP5.3, CCP6.2, CCB SLR, SROCC 2.3, SROCC CCB9}

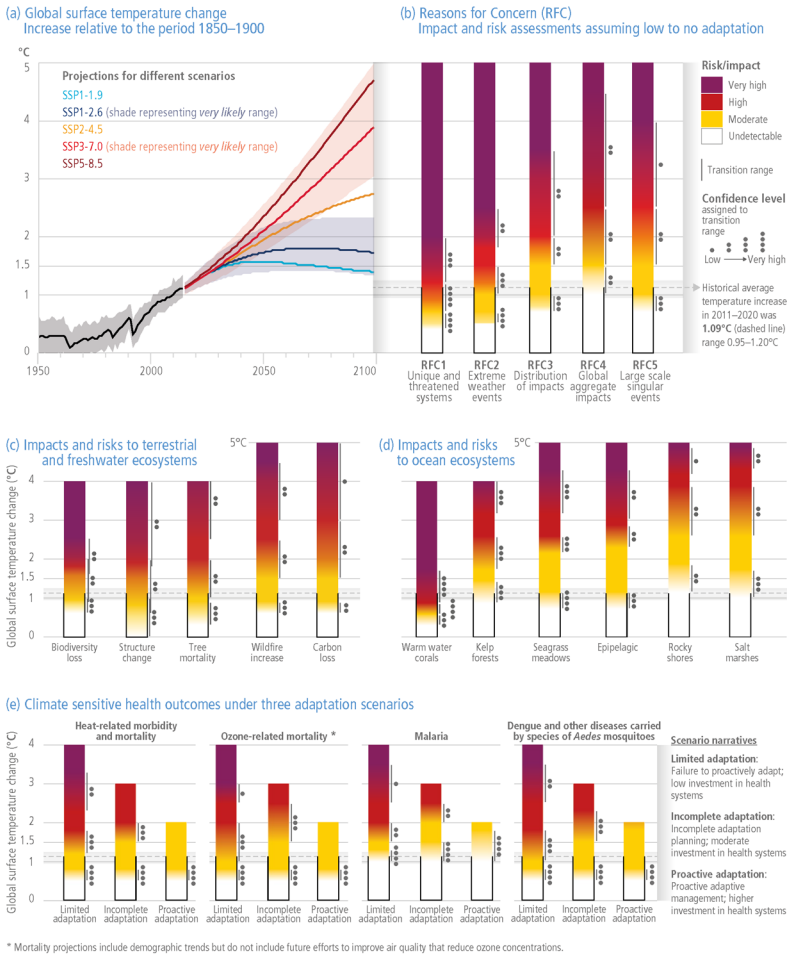
B.4.6 Projected estimates of global aggregate net economic damages generally increase non-linearly with global warming levels (*high confidence*).[35] The wide range of global estimates, and the lack of comparability between methodologies, does not allow for identification of a robust range of estimates (*high confidence*). The existence of higher estimates than assessed in AR5 indicates that global aggregate economic impacts could be higher than previous estimates (*low confidence*).[36] Significant regional variation in aggregate economic damages from climate change is projected (*high confidence*) with estimated economic damages per capita for developing countries often higher as a fraction of income (*high confidence*). Economic damages, including both those represented and those not represented in economic markets, are projected to be lower at 1.5°C than at 3°C or higher global warming levels (*high confidence*). {4.4, 9.11, 11.5, 13.10, Box 14.6, 16.5, CWGB ECONOMIC}

B.4.7 In the mid- to long-term, displacement will increase with intensification of heavy precipitation and associated flooding, tropical cyclones, drought and, increasingly, sea level rise (*high confidence*). At progressive levels of warming, involuntary migration from regions with high exposure and low adaptive capacity would occur (*medium confidence*). Compared to other socioeconomic factors the influence of climate on conflict is assessed as relatively weak (*high confidence*). Along long-term socioeconomic pathways that reduce non-climatic drivers, risk of violent conflict would decline (*medium confidence*). At higher global warming levels, impacts of weather and climate extremes, particularly drought, by increasing vulnerability will increasingly affect violent intrastate conflict (*medium confidence*). {TS B.7.4, 7.3, 16.5, CCB MIGRATE }

35 The assessment found estimated rates of increase in projected global economic damages that were both greater than linear and less than linear as global warming level increases. There is evidence that some regions could benefit from low levels of warming (*high confidence*). [CWGB ECONOMIC]

36 *Low confidence* assigned due to the assessed lack of comparability and robustness of global aggregate economic damage estimates. [CWGB ECONOMIC]

Global and regional risks for increasing levels of global warming



* Mortality projections include demographic trends but do not include future efforts to improve air quality that reduce ozone concentrations.

(f) Examples of regional key risks

Absence of risk diagrams does not imply absence of risks within a region. The development of synthetic diagrams for Small Islands, Asia and Central and South America was limited due to the paucity of adequately downscaled climate projections, with uncertainty in the direction of change, the diversity of climatologies and socioeconomic contexts across countries within a region, and the resulting few numbers of impact and risk projections for different warming levels.

The risks listed are of at least *medium confidence* level:

Small Islands
- Loss of terrestrial, marine and coastal biodiversity and ecosystem services
- Loss of lives and assets, risk to food security and economic disruption due to destruction of settlements and infrastructure
- Economic decline and livelihood failure of fisheries, agriculture, tourism and from biodiversity loss from traditional agroecosystems
- Reduced habitability of reef and non-reef islands leading to increased displacement
- Risk to water security in almost every small island

North America
- Climate-sensitive mental health outcomes, human mortality and morbidity due to increasing average temperature, weather and climate extremes, and compound climate hazards
- Risk of degradation of marine, coastal and terrestrial ecosystems, including loss of biodiversity, function, and protective services
- Risk to freshwater resources with consequences for ecosystems, reduced surface water availability for irrigated agriculture, other human uses, and degraded water quality
- Risk to food and nutritional security through changes in agriculture, livestock, hunting, fisheries, and aquaculture productivity and access
- Risks to well-being, livelihoods and economic activities from cascading and compounding climate hazards, including risks to coastal cities, settlements and infrastructure from sea level rise

Europe
- Risks to people, economies and infrastructures due to coastal and inland flooding
- Stress and mortality to people due to increasing temperatures and heat extremes
- Marine and terrestrial ecosystems disruptions
- Water scarcity to multiple interconnected sectors
- Losses in crop production, due to compound heat and dry conditions, and extreme weather

Central and South America
- Risk to water security
- Severe health effects due to increasing epidemics, in particular vector-borne diseases
- Coral reef ecosystems degradation due to coral bleaching
- Risk to food security due to frequent/extreme droughts
- Damages to life and infrastructure due to floods, landslides, sea level rise, storm surges and coastal erosion

Australasia
- Degradation of tropical shallow coral reefs and associated biodiversity and ecosystem service values
- Loss of human and natural systems in low-lying coastal areas due to sea level rise
- Impact on livelihoods and incomes due to decline in agricultural production
- Increase in heat-related mortality and morbidity for people and wildlife
- Loss of alpine biodiversity in Australia due to less snow

Asia
- Urban infrastructure damage and impacts on human well-being and health due to flooding, especially in coastal cities and settlements
- Biodiversity loss and habitat shifts as well as associated disruptions in dependent human systems across freshwater, land, and ocean ecosystems
- More frequent, extensive coral bleaching and subsequent coral mortality induced by ocean warming and acidification, sea level rise, marine heat waves and resource extraction
- Decline in coastal fishery resources due to sea level rise, decrease in precipitation in some parts and increase in temperature
- Risk to food and water security due to increased temperature extremes, rainfall variability and drought

Africa
- Species extinction and reduction or irreversible loss of ecosystems and their services, including freshwater, land and ocean ecosystems
- Risk to food security, risk of malnutrition (micronutrient deficiency), and loss of livelihood due to reduced food production from crops, livestock and fisheries
- Risks to marine ecosystem health and to livelihoods in coastal communities
- Increased human mortality and morbidity due to increased heat and infectious diseases (including vector-borne and diarrhoeal diseases)
- Reduced economic output and growth, and increased inequality and poverty rates
- Increased risk to water and energy security due to drought and heat

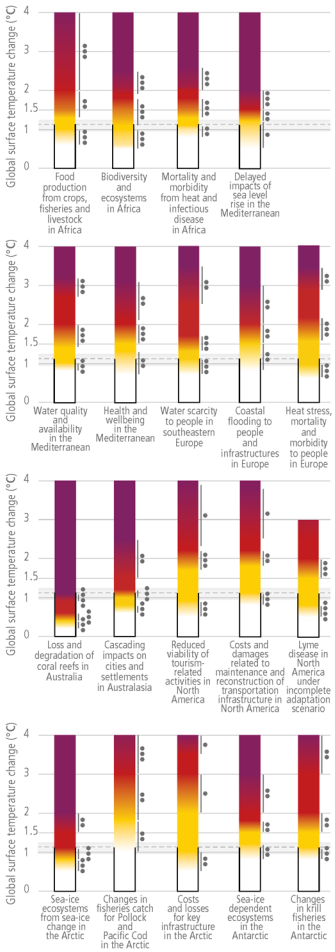


Figure SPM.3 | Synthetic diagrams of global and sectoral assessments and examples of regional key risks. Diagrams show the change in the levels of impacts and risks assessed for global warming of 0–5°C global surface temperature change relative to pre-industrial period (1850–1900) over the range.

(a) Global surface temperature changes in °C relative to 1850–1900. These changes were obtained by combining CMIP6 model simulations with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity (Box SPM.1). Changes relative to 1850–1900 based on 20-year averaging periods are calculated by adding 0.85°C (the observed global surface temperature increase from 1850–1900 to 1995–2014) to simulated changes relative to 1995–2014. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0 (WGI AR6 Figure SPM.8). Assessments were carried out at the global scale for (b), (c), (d) and (e).

(b) The Reasons for Concern (RFC) framework communicates scientific understanding about accrual of risk for five broad categories. Diagrams are shown for each RFC, assuming low to no adaptation (i.e., adaptation is fragmented, localized and comprises incremental adjustments to existing practices). However, the transition to a very high risk level has an emphasis on irreversibility and adaptation limits. Undetectable risk level (white) indicates no associated impacts are detectable and attributable to climate change; moderate risk (yellow) indicates associated impacts are both detectable and attributable to climate change with at least *medium confidence*, also accounting for the other specific criteria for key risks; high risk (red) indicates severe and widespread impacts that are judged to be high on one or more criteria for assessing key risks; and very high risk level (purple) indicates very high risk of severe impacts and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks. The horizontal line denotes the present global warming of 1.09°C which is used to separate the observed, past impacts below the line from the future projected risks above it. RFC1: Unique and threatened systems: ecological and human systems that have restricted geographic ranges constrained by climate-related conditions and have high endemism or other distinctive properties. Examples include coral reefs, the Arctic and its Indigenous Peoples, mountain glaciers and biodiversity hotspots. RFC2: Extreme weather events: risks/impacts to human health, livelihoods, assets and ecosystems from extreme weather events such as heatwaves, heavy rain, drought and associated wildfires, and coastal flooding. RFC3: Distribution of impacts: risks/impacts that disproportionately affect particular groups due to uneven distribution of physical climate change hazards, exposure or vulnerability. RFC4: Global aggregate impacts: impacts to socio-ecological systems that can be aggregated globally into a single metric, such as monetary damages, lives affected, species lost or ecosystem degradation at a global scale. RFC5: Large-scale singular events: relatively large, abrupt and sometimes irreversible changes in systems caused by global warming, such as ice sheet disintegration or thermohaline circulation slowing. Assessment methods are described in SM16.6 and are identical to AR5, but are enhanced by a structured approach to improve robustness and facilitate comparison between AR5 and AR6.

Risks for **(c)** terrestrial and freshwater ecosystems and **(d)** ocean ecosystems. For c) and d), diagrams shown for each risk assume low to no adaptation. The transition to a very high risk level has an emphasis on irreversibility and adaptation limits.

(e) Climate-sensitive human health outcomes under three scenarios of adaptation effectiveness. The assessed projections were based on a range of scenarios, including SRES, CMIP5, and ISIMIP, and, in some cases, demographic trends. The diagrams are truncated at the nearest whole °C within the range of temperature change in 2100 under three SSP scenarios in panel (a).

(f) Examples of regional key risks. Risks identified are of at least *medium confidence* level. Key risks are identified based on the magnitude of adverse consequences (pervasiveness of the consequences, degree of change, irreversibility of consequences, potential for impact thresholds or tipping points, potential for cascading effects beyond system boundaries); likelihood of adverse consequences; temporal characteristics of the risk; and ability to respond to the risk, e.g., by adaptation. The full set of 127 assessed global and regional key risks is given in SM16.7. Diagrams are provided for some risks. The development of synthetic diagrams for Small Islands, Asia and Central and South America were limited by the availability of adequately downscaled climate projections, with uncertainty in the direction of change, the diversity of climatologies and socioeconomic contexts across countries within a region, and the resulting low number of impact and risk projections for different warming levels. Absence of risks diagrams does not imply absence of risks within a region. (Box SPM.1) {Figure TS.4, Figure 2.11, Figure SM3.1, Figure 7.9, Figure 9.6, Figure 11.6, Figure 13.28, 16.5, 16.6, Figure 16.15, SM16.3, SM16.4, SM16.5, SM16.6 (methodologies), SM16.7, Figure CCP4.8, Figure CCP4.10, Figure CCP6.5, WGI AR6 2, WGI AR6 SPM A.1.2, WGI AR6 Figure SPM.8}

Complex, Compound and Cascading Risks

B.5 **Climate change impacts and risks are becoming increasingly complex and more difficult to manage. Multiple climate hazards will occur simultaneously, and multiple climatic and non-climatic risks will interact, resulting in compounding overall risk and risks cascading across sectors and regions. Some responses to climate change result in new impacts and risks. (*high confidence*) {1.3, 2.4, Box 2.2, Box 9.5, 11.5, 13.5, 14.6, Box 15.1, CCP1.2, CCP2.2, CCB COVID, CCB DISASTER, CCB INTEREG, CCB SRM, }**

B.5.1 Concurrent and repeated climate hazards occur in all regions, increasing impacts and risks to health, ecosystems, infrastructure, livelihoods and food (*high confidence*). Multiple risks interact, generating new sources of vulnerability to climate hazards, and compounding overall risk (*high confidence*). Increasing concurrence of heat and drought events are causing crop production losses and tree mortality (*high confidence*). Above 1.5°C global warming increasing concurrent climate extremes will increase risk of simultaneous crop losses of maize in major food-producing regions, with this risk increasing further with higher global warming levels (*medium confidence*). Future sea level rise combined with storm surge and heavy rainfall will increase compound flood risks (*high confidence*). Risks to health and food production will be made more severe from the interaction of sudden food production losses from heat and drought, exacerbated by heat-induced labour productivity losses (*high confidence*). These interacting impacts will increase food prices, reduce household incomes, and lead to health risks of malnutrition and climate-related mortality with no or low levels of adaptation, especially in tropical regions (*high confidence*). Risks to food safety from climate change will further compound the risks to health by increasing food contamination of crops from mycotoxins and contamination of seafood from harmful algal blooms, mycotoxins, and chemical contaminants (*high confidence*). {Figure TS.10c, 5.2, 5.4, 5.8, 5.9, 5.11, 5.12, 7.2, 7.3, 9.8, 9.11, 10.4, 11.3, 11.5, 12.3, 13.5, 14.5, 15.3, Box 15.1, 16.6, CCP1.2, CCP6.2, , WGI AR6 SPM A.3.1, WGI AR6 SPM A.3.2, WGI AR6 SPM C.2.7}

B.5.2 Adverse impacts from climate hazards and resulting risks are cascading across sectors and regions (*high confidence*), propagating impacts along coasts and urban centres (*medium confidence*) and in mountain regions (*high confidence*). These hazards and cascading risks also trigger tipping points in sensitive ecosystems and in significantly and rapidly changing social-ecological systems impacted by ice melt, permafrost thaw and changing hydrology in polar regions (*high confidence*). Wildfires, in many regions, have affected ecosystems and species, people and their built assets, economic activity, and health (*medium to high confidence*). In cities and

settlements, climate impacts to key infrastructure are leading to losses and damages across water and food systems, and affect economic activity, with impacts extending beyond the area directly impacted by the climate hazard (*high confidence*). In Amazonia, and in some mountain regions, cascading impacts from climatic (e.g., heat) and non-climatic stressors (e.g., land use change) will result in irreversible and severe losses of ecosystem services and biodiversity at 2°C global warming level and beyond (*medium confidence*). Unavoidable sea level rise will bring cascading and compounding impacts resulting in losses of coastal ecosystems and ecosystem services, groundwater salinisation, flooding and damages to coastal infrastructure that cascade into risks to livelihoods, settlements, health, well-being, food and water security, and cultural values in the near to long-term (*high confidence*). (Figure SPM.3) {Figure TS.10, 2.5, 3.4, 3.5, Box 7.3, Box 8.7, Box 9.4, 11.5, Box 11.1, 12.3, 13.9, 14.6, 15.3, 16.5, 16.6, CCP1.2, CCP2.2, CCP5.2, CCP5.3, CCP6.2, CCP6.3, Box CCP6.1, Box CCP6.2, CCB EXTREMES, WGI AR6 Figure SPM.8d}

B.5.3 Weather and climate extremes are causing economic and societal impacts across national boundaries through supply-chains, markets, and natural resource flows, with increasing transboundary risks projected across the water, energy and food sectors (*high confidence*). Supply chains that rely on specialized commodities and key infrastructure can be disrupted by weather and climate extreme events. Climate change causes the redistribution of marine fish stocks, increasing risk of transboundary management conflicts among fisheries users, and negatively affecting equitable distribution of food provisioning services as fish stocks shift from lower to higher latitude regions, thereby increasing the need for climate-informed transboundary management and cooperation (*high confidence*). Precipitation and water availability changes increases the risk of planned infrastructure projects, such as hydropower in some regions, having reduced productivity for food and energy sectors including across countries that share river basins (*medium confidence*). {Figure TS.10e-f, 3.4, 3.5, 4.5, 5.8, 5.13, 6.2, 9.4, Box 9.5,14.5, Box 14.5, Box 14.6, CCP5.3, CCB DISASTER, CCB EXTREMES, CCB INTEREG, CCB MOVING PLATE}

B.5.4 Risks arise from some responses that are intended to reduce the risks of climate change, including risks from maladaptation and adverse side effects of some emissions reduction and carbon dioxide removal measures (*high confidence*). Deployment of afforestation of naturally unforested land, or poorly implemented bioenergy, with or without carbon capture and storage, can compound climate-related risks to biodiversity, water and food security, and livelihoods, especially if implemented at large scales, especially in regions with insecure land tenure (*high confidence*). {Box 2.2, 4.1, 4.7, 5.13, Table 5.18, Box 9.3, Box 13.2, CCB NATURAL, CWGB BIOECONOMY}

B.5.5 Solar radiation modification approaches, if they were to be implemented, introduce a widespread range of new risks to people and ecosystems, which are not well understood (*high confidence*). Solar radiation modification approaches have potential to offset warming and ameliorate some climate hazards, but substantial residual climate change or overcompensating change would occur at regional scales and seasonal timescales (*high confidence*). Large uncertainties and knowledge gaps are associated with the potential of solar radiation modification approaches to reduce climate change risks. Solar radiation modification would not stop atmospheric CO_2 concentrations from increasing or reduce resulting ocean acidification under continued anthropogenic emissions (*high confidence*). {CWGB SRM}

Impacts of Temporary Overshoot

B.6 If global warming transiently exceeds 1.5°C in the coming decades or later (overshoot)[37], then many human and natural systems will face additional severe risks, compared to remaining below 1.5°C (*high confidence*). Depending on the magnitude and duration of overshoot, some impacts will cause release of additional greenhouse gases (*medium confidence*) and some will be irreversible, even if global warming is reduced (*high confidence*). (Box SPM.1, Figure SPM.3) {2.5, 3.4, 12.3, 16.6, CCB DEEP, CCB SLR}

B.6.1 While model-based assessments of the impacts of overshoot pathways are limited, observations and current understanding of processes permit assessment of impacts from overshoot. Additional warming, e.g., above 1.5°C during an overshoot period this century, will result in irreversible impacts on certain ecosystems with low resilience, such as polar, mountain, and coastal ecosystems, impacted by ice-sheet, glacier melt, or by accelerating and higher committed sea level rise (*high confidence*).[38] Risks to human systems will increase, including those to infrastructure, low-lying coastal settlements, some ecosystem-based adaptation measures, and associated livelihoods (*high confidence*), cultural and spiritual values (*medium confidence*). Projected impacts are less severe with shorter duration and lower levels of overshoot (*medium confidence*). {2.5, 3.4, 12.3, 13.2, 16.5, 16.6, CCP1.2, CCP2.2, CCP5.3, CCP6.1, CCP6.2, CCB SLR, WGI AR6 SPM B.5, WGI AR6 SPM C.3, SROCC 2.3, SROCC 5.4}

37 In this report, overshoot pathways exceed 1.5°C global warming and then return to that level, or below, after several decades.

38 Despite limited evidence specifically on the impacts of a temporary overshoot of 1.5°C, a much broader evidence base from process understanding and the impacts of higher global warming levels allows a high confidence statement on the irreversibility of some impacts that would be incurred following such an overshoot.

B.6.2 Risk of severe impacts increase with every additional increment of global warming during overshoot (*high confidence*). In high-carbon ecosystems (currently storing 3,000 to 4,000 GtC)[39] such impacts are already observed and are projected to increase with every additional increment of global warming, such as increased wildfires, mass mortality of trees, drying of peatlands, and thawing of permafrost, weakening natural land carbon sinks and increasing releases of greenhouse gases (*medium confidence*). The resulting contribution to a potential amplification of global warming indicates that a return to a given global warming level or below would be more challenging (*medium confidence*). {2.4, 2.5, CCP4.2, WGI AR6 SPM B.4.3, SROCC 5.4}

C: Adaptation Measures and Enabling Conditions

Adaptation, in response to current climate change, is reducing climate risks and vulnerability mostly via adjustment of existing systems. Many adaptation options exist and are used to help manage projected climate change impacts, but their implementation depends upon the capacity and effectiveness of governance and decision-making processes. These and other enabling conditions can also support climate resilient development (Section D).

Current Adaptation and its Benefits

C.1 **Progress in adaptation planning and implementation has been observed across all sectors and regions, generating multiple benefits (*very high confidence*). However, adaptation progress is unevenly distributed with observed adaptation gaps[40] (*high confidence*). Many initiatives prioritize immediate and near-term climate risk reduction which reduces the opportunity for transformational adaptation (*high confidence*). {2.6, 5.14, 7.4, 10.4, 12.5, 13.11, 14.7, 16.3, 17.3, CCP5.2, CCP5.4}**

C.1.1 Adaptation planning and implementation have continued to increase across all regions (*very high confidence*). Growing public and political awareness of climate impacts and risks has resulted in at least 170 countries and many cities including adaptation in their climate policies and planning processes (*high confidence*). Decision support tools and climate services are increasingly being used (*very high confidence*). Pilot projects and local experiments are being implemented in different sectors (*high confidence*). Adaptation can generate multiple additional benefits such as improving agricultural productivity, innovation, health and well-being, food security, livelihood, and biodiversity conservation as well as reduction of risks and damages (*very high confidence*). {1.4, 2.6, 3.5, 3.6, 4.7, 4.8, 5.4, 5.6, 5.10, 6.4, 7.4, 8.5, 9.3, 9.6, 10.4, 12.5, 13.11, 15.5, 16.3, 17.2, 17.3, 17.5, CCP5.4, CCB ADAPT, CCB NATURAL}

C.1.2 Despite progress, adaptation gaps exist between current levels of adaptation and levels needed to respond to impacts and reduce climate risks (*high confidence*). Most observed adaptation is fragmented, small in scale, incremental, sector-specific, designed to respond to current impacts or near-term risks, and focused more on planning rather than implementation (*high confidence*). Observed adaptation is unequally distributed across regions *(high confidence)*, and gaps are partially driven by widening disparities between the estimated costs of adaptation and documented finance allocated to adaptation (*high confidence*). The largest adaptation gaps exist among lower income population groups (*high confidence*). At current rates of adaptation planning and implementation the adaptation gap will continue to grow (*high confidence*). As adaptation options often have long implementation times, long-term planning and accelerated implementation, particularly in the next decade, is important to close adaptation gaps, recognising that constraints remain for some regions (*high confidence*). {1.1, 1.4, 5.6, 6.3, Figure 6.4, 7.4, 8.3, 10.4, 11.3, 11.7, 13.11, Box 13.1, 15.2, 15.5, 16.3, 16.5, Box 16.1, Figure 16.4, Figure 16.5, 17.4, 18.2, CCP2.4, CCP5.4, CCB FINANCE, CCB SLR}

39 At the global scale, terrestrial ecosystems currently remove more carbon from the atmosphere (-3.4 ± 0.9 Gt yr^{-1}) than they emit (+1.6 ± 0.7 Gt yr^{-1}), a net sink of -1.9 ± 1.1 Gt yr^{-1}. However, recent climate change has shifted some systems in some regions from being net carbon sinks to net carbon sources.

40 Adaptation gaps are defined as the difference between actually implemented adaptation and a societally set goal, determined largely by preferences related to tolerated climate change impacts and reflecting resource limitations and competing priorities.

Future Adaptation Options and their Feasibility

C.2 There are feasible[41] and effective[42] adaptation options which can reduce risks to people and nature. The feasibility of implementing adaptation options in the near-term differs across sectors and regions (*very high confidence*). The effectiveness of adaptation to reduce climate risk is documented for specific contexts, sectors and regions (*high confidence*) and will decrease with increasing warming (*high confidence*). Integrated, multi-sectoral solutions that address social inequities, differentiate responses based on climate risk and cut across systems, increase the feasibility and effectiveness of adaptation in multiple sectors (*high confidence*). (Figure SPM.4) {Figure TS.6e, 1.4, 3.6, 4.7, 5.12, 6.3, 7.4, 11.3, 11.7, 13.2, 15.5, 17.6, CCP2.3, CCB FEASIB}

Land, Ocean and Ecosystems Transition

C.2.1 Adaptation to water-related risks and impacts make up the majority of all documented adaptation (*high confidence*). For inland flooding, combinations of non-structural measures like early warning systems and structural measures like levees have reduced loss of lives (*medium confidence*). Enhancing natural water retention such as by restoring wetlands and rivers, land use planning such as no build zones or upstream forest management, can further reduce flood risk (*medium confidence*). On-farm water management, water storage, soil moisture conservation and irrigation are some of the most common adaptation responses and provide economic, institutional or ecological benefits and reduce vulnerability (*high confidence*). Irrigation is effective in reducing drought risk and climate impacts in many regions and has several livelihood benefits, but needs appropriate management to avoid potential adverse outcomes, which can include accelerated depletion of groundwater and other water sources and increased soil salinization (*medium confidence*). Large scale irrigation can also alter local to regional temperature and precipitation patterns (*high confidence*), including both alleviating and exacerbating temperature extremes (*medium confidence*). The effectiveness of most water-related adaptation options to reduce projected risks declines with increasing warming (*high confidence*). {4.1, 4.6, 4.7, Box 4.3, Box 4.6, Box 4.7, Figure 4.22, Figure 4.28, Figure 4.29, Table 4.9, 9.3, 9.7, 11.3, 12.5, 13.1, 13.2, 16.3, CCP5.4}

C.2.2 Effective adaptation options, together with supportive public policies enhance food availability and stability and reduce climate risk for food systems while increasing their sustainability (*medium confidence*). Effective options include cultivar improvements, agroforestry, community-based adaptation, farm and landscape diversification, and urban agriculture (*high confidence*). Institutional feasibility, adaptation limits of crops and cost effectiveness also influence the effectiveness of the adaptation options (*limited evidence*, *medium agreement*). Agroecological principles and practices, ecosystem-based management in fisheries and aquaculture, and other approaches that work with natural processes support food security, nutrition, health and well-being, livelihoods and biodiversity, sustainability and ecosystem services (*high confidence*). These services include pest control, pollination, buffering of temperature extremes, and carbon sequestration and storage (*high confidence*). Trade-offs and barriers associated with such approaches include costs of establishment, access to inputs and viable markets, new knowledge and management (*high confidence*) and their potential effectiveness varies by socioeconomic context, ecosystem zone, species combinations and institutional support (*medium confidence*). Integrated, multi-sectoral solutions that address social inequities and differentiate responses based on climate risk and local situation will enhance food security and nutrition (*high confidence*). Adaptation strategies which reduce food loss and waste or support balanced diets[33] (as described in the IPCC Special Report on Climate Change and Land) contribute to nutrition, health, biodiversity and other environmental benefits (*high confidence*). {3.2, 4.7, 4.6, Box 4.3, 5.4, 5.5, 5.6, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, Box 5.10, Box 5.13, 6.3, 7.4, 10.4, 12.5, 13.5, 13.10, 14.5, CCP5.4, CCB FEASIB, CCB HEALTH, CCB MOVING PLATE, CCB NATURAL, CWGB BIOECONOMY}

C.2.3 Adaptation for natural forests[43] includes conservation, protection and restoration measures. In managed forests[43], adaptation options include sustainable forest management, diversifying and adjusting tree species compositions to build resilience, and managing increased risks from pests and diseases and wildfires. Restoring natural forests and drained peatlands and improving sustainability of managed forests, generally enhances the resilience of carbon stocks and sinks. Cooperation, and inclusive decision making, with local communities and Indigenous Peoples, as well as recognition of inherent rights of Indigenous Peoples, is integral to successful forest adaptation in many areas. (*high confidence*) {2.6, Box 2.2, 5.6, 5.13, Table 5.23, 11.4, 12.5, 13.5, Box 14.1, Box 14.2, CCP7.5, Box CCP7.1, CCB FEASIB, CCB INDIG, CCB NATURAL}

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41 In this report, feasibility refers to the potential for a mitigation or adaptation option to be implemented. Factors influencing feasibility are context-dependent, temporally dynamic, and may vary between different groups and actors. Feasibility depends on geophysical, environmental-ecological, technological, economic, socio-cultural and institutional factors that enable or constrain the implementation of an option. The feasibility of options may change when different options are combined and increase when enabling conditions are strengthened.

42 Effectiveness refers to the extent to which an adaptation option is anticipated or observed to reduce climate-related risk.

43 In this report, the term natural forests describes those which are subject to little or no direct human intervention, whereas the term managed forests describes those where planting or other management activities take place, including those managed for commodity production.

(a) Diverse feasible climate responses and adaptation options exist to respond to Representative Key Risks of climate change, with varying synergies with mitigation

Multidimensional feasibility and synergies with mitigation of climate responses and adaptation options relevant in the near-term, at global scale and up to 1.5°C of global warming

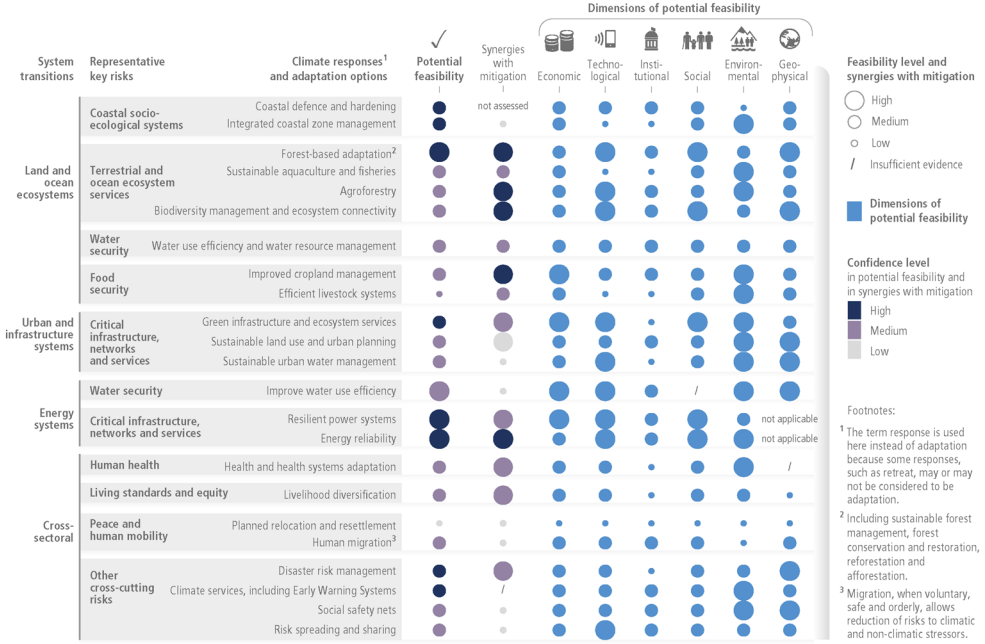
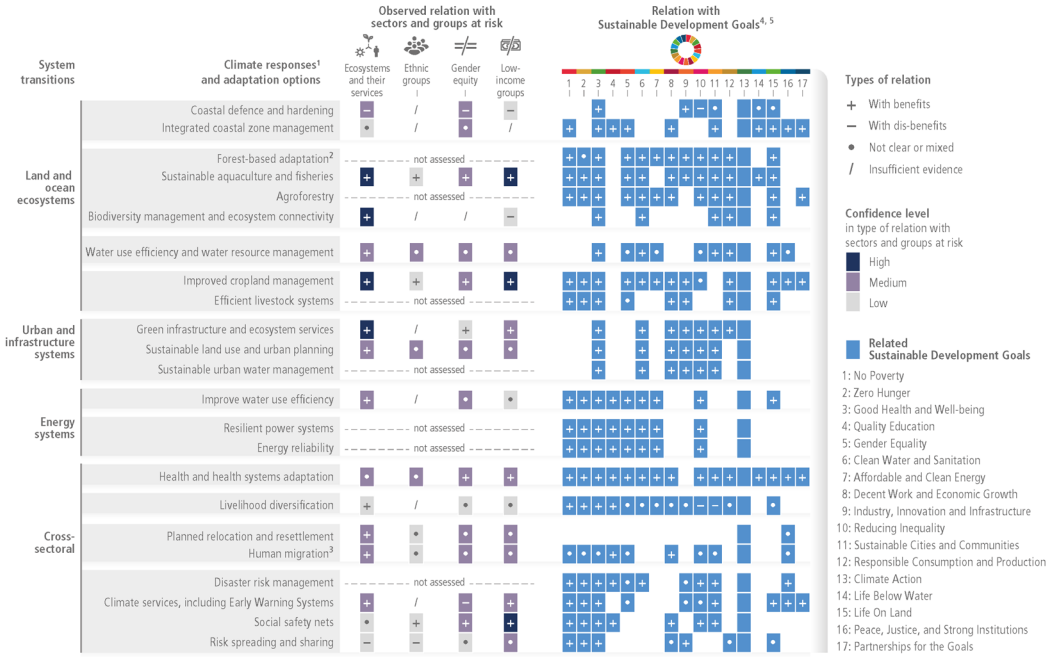


Figure SPM.4 | (a) Climate responses and adaptation options, organized by System Transitions and Representative Key Risks (RKRs), are assessed for their multidimensional feasibility at global scale, in the near term and up to 1.5°C global warming. As literature above 1.5°C is limited, feasibility at higher levels of warming may change, which is currently not possible to assess robustly. Climate responses and adaptation options at global scale are drawn from a set of options assessed in AR6 that have robust evidence across the feasibility dimensions. This figure shows the six feasibility dimensions (economic, technological, institutional, social, environmental and geophysical) that are used to calculate the potential feasibility of climate responses and adaptation options, along with their synergies with mitigation. For potential feasibility and feasibility dimensions, the figure shows high, medium, or low feasibility. Synergies with mitigation are identified as high, medium, and low. Insufficient evidence is denoted by a dash. {CCB FEASIB, Table SMCCB FEASIB.1.1, SR1.5 4.SM.4.3}

(b) Climate responses and adaptation options have benefits for ecosystems, ethnic groups, gender equity, low-income groups and the Sustainable Development Goals

Relations of sectors and groups at risk (as observed) and the SDGs (relevant in the near-term, at global scale and up to 1.5°C of global warming) with climate responses and adaptation options



Footnotes: [1] The term response is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation. [2] Including sustainable forest management, forest conservation and restoration, reforestation and afforestation. [3] Migration, when voluntary, safe and orderly, allows reduction of risks to climatic and non-climatic stressors. [4] The Sustainable Development Goals (SDGs) are integrated and indivisible, and efforts to achieve any goal in isolation may trigger synergies or trade-offs with other SDGs. [5] Relevant in the near-term, at global scale and up to 1.5°C of global warming.

Figure SPM.4 | (b) Climate responses and adaptation options, organized by System Transitions and Representative Key Risks, are assessed at global scale for their likely ability to reduce risks for ecosystems and social groups at risk, as well as their relation with the 17 Sustainable Development Goals (SDGs). Climate responses and adaptation options are assessed for observed benefits (+) to ecosystems and their services, ethnic groups, gender equity, and low-income groups, or observed dis-benefits (-) for these systems and groups. Where there is highly diverging evidence of benefits/ dis-benefits across the scientific literature, e.g., based on differences between regions, it is shown as not clear or mixed (•). Insufficient evidence is shown by a dash. The relation with the SDGs is assessed as having benefits (+), dis-benefits (-) or not clear or mixed (•) based on the impacts of the climate response and adaptation option on each SDG. Areas not coloured indicate there is no evidence of a relation or no interaction with the respective SDG. The climate responses and adaptation options are drawn from two assessments. For comparability of climate responses and adaptation options see Table SM17.5. {17.2, 17.5, CCB FEASIB}

C.2.4 Conservation, protection and restoration of terrestrial, freshwater, coastal and ocean ecosystems, together with targeted management to adapt to unavoidable impacts of climate change, reduces the vulnerability of biodiversity to climate change (*high confidence*). The resilience of species, biological communities and ecosystem processes increases with size of natural area, by restoration of degraded areas and by reducing non-climatic stressors (*high confidence*). To be effective, conservation and restoration actions will increasingly need to be responsive, as appropriate, to ongoing changes at various scales, and plan for future changes in ecosystem structure, community composition and species' distributions, especially as 1.5°C global warming is approached and even more so if it is exceeded (*high confidence*). Adaptation options, where circumstances allow, include facilitating the movement of species to new ecologically appropriate locations, particularly through increasing connectivity between conserved or protected areas, targeted intensive management for vulnerable species and protecting refugial areas where species can survive locally (*medium confidence*). {2.3, 2,6, Figure 2.1, Table 2.6, 3.3, 3.6, Box 3.4, 4.6, Box 4.6, Box 11.2, 12.3, 12.5, 13.4, 14.7, CCP5.4, CCB FEASIB}

C.2.5 Effective Ecosystem-based Adaptation[44] reduces a range of climate change risks to people, biodiversity and ecosystem services with multiple co-benefits (*high confidence*). Ecosystem-based Adaptation is vulnerable to climate change impacts, with effectiveness declining with increasing global warming (*high confidence*). Urban greening using trees and other vegetation can provide local cooling (*very high confidence*). Natural river systems, wetlands and upstream forest ecosystems reduce flood risk by storing water and slowing water flow, in most circumstances (*high confidence*). Coastal wetlands protect against coastal erosion and flooding associated with storms and sea level rise where sufficient space and adequate habitats are available until rates of sea level rise exceeds natural adaptive capacity to build sediment (*very high confidence*). {2.4, 2.5, 2.6, Table 2.7, 3.4, 3.5, 3.6, Figure 3.26, 4.6, Box 4.6, Box 4.7, 5.5, 5.14, Box 5.11, 6.3, 6.4, Figure 6.6, 7.4, 8.5, 8.6, 9.6, 9.8, 9.9, 10.2, 11.3, 12.5, 13.3, 13.4, 13.5, 14.5, Box 14.7, 16.3, 18.3, CCP5.4, CCB FEASIB.3, CCB HEALTH, CCB MOVING PLATE, CCB NATURAL, CWGB BIOECONOMY}

Urban, Rural and Infrastructure Transition

C.2.6 Considering climate change impacts and risks in the design and planning of urban and rural settlements and infrastructure is critical for resilience and enhancing human well-being (*high confidence*). The urgent provision of basic services, infrastructure, livelihood diversification and employment, strengthening of local and regional food systems and community-based adaptation enhance lives and livelihoods, particularly of low-income and marginalised groups (*high confidence*). Inclusive, integrated and long-term planning at local, municipal, sub-national and national scales, together with effective regulation and monitoring systems and financial and technological resources and capabilities foster urban and rural system transition (*high confidence*). Effective partnerships between governments, civil society, and private sector organizations, across scales provide infrastructure and services in ways that enhance the adaptive capacity of vulnerable people (*medium* to *high confidence*). {5.12, 5.13, 5.14, 6.3, 6.4, Box 6.3, Box 6.6, Table 6.6, 7.4, 12.5, 13.6, 14.5, Box 14.4, Box 17.4, CCP2.3, CCP2.4, CCP5.4, CCB FEASIB}

C.2.7 An increasing number of adaptation responses exist for urban systems, but their feasibility and effectiveness is constrained by institutional, financial, and technological access and capacity, and depends on coordinated and contextually appropriate responses across physical, natural and social infrastructure (*high confidence*). Globally, more financing is directed at physical infrastructure than natural and social infrastructure (*medium confidence*) and there is *limited evidence* of investment in the informal settlements hosting the most vulnerable urban residents (*medium* to *high confidence*). Ecosystem-based adaptation (e.g., urban agriculture and forestry, river restoration) has increasingly been applied in urban areas (*high confidence*). Combined ecosystem-based and structural adaptation responses are being developed, and there is growing evidence of their potential to reduce adaptation costs and contribute to flood control, sanitation, water resources management, landslide prevention and coastal protection (*medium confidence*). {3.6, Box 4.6, 5.12, 6.3, 6.4, Table 6.8, 7.4, 9.7, 9.9, 10.4, Table 10.3, 11.3, 11.7, Box 11.6, 12.5, 13.2, 13.3, 13.6, 14.5, 15.5, 17.2, Box 17.4, CCP2.3, CCP 3.2, CCP5.4, CCB FEASIB, CCB SLR, SROCC SPM}

44 Ecosystem based Adaptation (EbA) is recognised internationally under the Convention on Biological Diversity (CBD14/5). A related concept is Nature-based Solutions (NbS), which includes a broader range of approaches with safeguards, including those that contribute to adaptation and mitigation. The term 'Nature-based Solutions' is widely but not universally used in the scientific literature. The term is the subject of ongoing debate, with concerns that it may lead to the misunderstanding that NbS on its own can provide a global solution to climate change.

C.2.8 Sea level rise poses a distinctive and severe adaptation challenge as it implies dealing with slow onset changes and increased frequency and magnitude of extreme sea level events which will escalate in the coming decades (*high confidence*). Such adaptation challenges would occur much earlier under high rates of sea level rise, in particular if low-likelihood, high impact outcomes associated with collapsing ice sheets occur (*high confidence*). Responses to ongoing sea level rise and land subsidence in low-lying coastal cities and settlements and small islands include protection, accommodation, advance and planned relocation (*high confidence*)[45]. These responses are more effective if combined and/or sequenced, planned well ahead, aligned with sociocultural values and development priorities, and underpinned by inclusive community engagement processes (*high confidence*). { 6.2, 10.4, 11.7, Box 11.6, 13.2, 14.5, 15.5, CCP2.3, CCB SLR, WGI AR6 SPM B.5, WGI AR6 SPM C.3, SROCC SPM C3.2}

C.2.9 Approximately 3.4 billion people globally live in rural areas around the world, and many are highly vulnerable to climate change. Integrating climate adaptation into social protection programs, including cash transfers and public works programmes, is highly feasible and increases resilience to climate change, especially when supported by basic services and infrastructure. Social safety nets are increasingly being reconfigured to build adaptive capacities of the most vulnerable in rural and also urban communities. Social safety nets that support climate change adaptation have strong co-benefits with development goals such as education, poverty alleviation, gender inclusion and food security. (*high confidence*) {5.14, 9.4, 9.10, 9.11, 12.5, 14.5, CCP5.4, CCB FEASIB, CCB GENDER}

Energy System Transition

C.2.10 Within energy system transitions, the most feasible adaptation options support infrastructure resilience, reliable power systems and efficient water use for existing and new energy generation systems (*very high confidence*). Energy generation diversification, including with renewable energy resources and generation that can be decentralised depending on context (e.g., wind, solar, small scale hydroelectric) and demand side management (e.g., storage, and energy efficiency improvements) can reduce vulnerabilities to climate change, especially in rural populations (*high confidence*). Adaptations for hydropower and thermo-electric power generation are effective in most regions up to 1.5°C to 2°C, with decreasing effectiveness at higher levels of warming (*medium confidence*). Climate responsive energy markets, updated design standards on energy assets according to current and projected climate change, smart-grid technologies, robust transmission systems and improved capacity to respond to supply deficits have high feasibility in the medium- to long-term, with mitigation co-benefits (*very high confidence*). {4.6, 4.7, Figure 4.28, Figure 4.29, 10.4, Table 11.8, 13.6, Figure 13.16, Figure 13.19, 18.3,CCP5.2, CCP5.4, CCB FEASIB, CWGB BIOECONOMY}

Cross-cutting Options

C.2.11 Strengthening the climate resiliency of health systems will protect and promote human health and well-being (*high confidence*). There are multiple opportunities for targeted investments and finance to protect against exposure to climate hazards, particularly for those at highest risk. Heat Health Action Plans that include early warning and response systems are effective adaptation options for extreme heat (*high confidence*). Effective adaptation options for water-borne and food-borne diseases include improving access to potable water, reducing exposure of water and sanitation systems to flooding and extreme weather events, and improved early warning systems (*very high confidence*). For vector-borne diseases, effective adaptation options include surveillance, early warning systems, and vaccine development (*very high confidence*). Effective adaptation options for reducing mental health risks under climate change include improving surveillance, access to mental health care, and monitoring of psychosocial impacts from extreme weather events (*high confidence*). Health and well-being would benefit from integrated adaptation approaches that mainstream health into food, livelihoods, social protection, infrastructure, water and sanitation policies requiring collaboration and coordination at all scales of governance (*very high confidence*). {5.12, 6.3, 7.4, 9.10, Box 9.7, 11.3, 12.5, 13.7, 14.5, CCB COVID, CCB FEASIB, CCB ILLNESS }

C.2.12 Increasing adaptive capacities minimises the negative impacts of climate-related displacement and involuntary migration for migrants and sending and receiving areas (*high confidence*). This improves the degree of choice under which migration decisions are made, ensuring safe and orderly movements of people within and between countries (*high confidence*). Some development reduces underlying vulnerabilities associated with conflict, and adaptation contributes by reducing the impacts of climate change on climate sensitive drivers of conflict (*high confidence*). Risks to peace are reduced, for example, by supporting people in climate-sensitive economic activities (*medium confidence*) and advancing women's empowerment (*high confidence*). {7.4, Box 9.8, Box 10.2, 12.5, CCB FEASIB, CCB MIGRATE}

45 The term 'response' is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation.

C.2.13 There are a range of adaptation options, such as disaster risk management, early warning systems, climate services and risk spreading and sharing that have broad applicability across sectors and provide greater benefits to other adaptation options when combined (*high confidence*). For example, climate services that are inclusive of different users and providers can improve agricultural practices, inform better water use and efficiency, and enable resilient infrastructure planning (*high confidence*). {2.6, 3.6, 4.7, 5.4, 5.5, 5.6, 5.8, 5.9, 5.12, 5.14, 9.4, 9.8, 10.4, 12.5, 13.11, CCP5.4, CCB FEASIB, CCB MOVING PLATE}

Limits to Adaptation

C.3 Soft limits to some human adaptation have been reached, but can be overcome by addressing a range of constraints, primarily financial, governance, institutional and policy constraints (*high confidence*). Hard limits to adaptation have been reached in some ecosystems (*high confidence*). With increasing global warming, losses and damages will increase and additional human and natural systems will reach adaptation limits (*high confidence*). {Figure TS.7, 1.4, 2.4, 2.5, 2.6, 3.4, 3.6, 4.7, Figure 4.30, 5.5, Table 8.6, Box 10.7, 11.7, Table 11.16, 12.5, 13.2, 13.5, 13.6, 13.10, 13.11, Figure 13.21, 14.5, 15.6, 16.4, Figure 16.8, Table 16.3, Table 16.4, CCP1.2, CCP1.3, CCP2.3, CCP3.3, CCP5.2, CCP5.4, CCP6.3, CCP7.3, CCB SLR}

C.3.1 Soft limits to some human adaptation have been reached, but can be overcome by addressing a range of constraints, which primarily consist of financial, governance, institutional and policy constraints (*high confidence*). For example, individuals and households in low-lying coastal areas in Australasia and Small Islands and smallholder farmers in Central and South America, Africa, Europe and Asia have reached soft limits (*medium confidence*). Inequity and poverty also constrain adaptation, leading to soft limits and resulting in disproportionate exposure and impacts for most vulnerable groups (*high confidence*). Lack of climate literacy[46] at all levels and limited availability of information and data pose further constraints to adaptation planning and implementation (*medium confidence*). {1.4, 4.7, 5.4, 8.4, Table 8.6, 9.1, 9.4, 9.5, 9.8, 11.7, 12.5 13.5, 15.3, 15.5, 15.6, 16.4, Box 16.1, Figure 16.8, CCP5.2, CCP5.4, CCP6.3}

C.3.2 Financial constraints are important determinants of soft limits to adaptation across sectors and all regions (*high confidence*). Although global tracked climate finance has shown an upward trend since AR5, current global financial flows for adaptation, including from public and private finance sources, are insufficient for and constrain implementation of adaptation options especially in developing countries (*high confidence*). The overwhelming majority of global tracked climate finance was targeted to mitigation while a small proportion was targeted to adaptation (*very high confidence*). Adaptation finance has come predominantly from public sources (*very high confidence*). Adverse climate impacts can reduce the availability of financial resources by incurring losses and damages and through impeding national economic growth, thereby further increasing financial constraints for adaptation, particularly for developing and least developed countries (*medium confidence*). {Figure TS.7, 1.4, 2.6, 3.6, 4.7, Figure 4.30, 5.14, 7.4, 8.4, Table 8.6, 9.4, 9.9, 9.11, 10.5, 12.5, 13.3, 13.11, Box 14.4, 15.6, 16.2, 16.4, Figure 16.8, Table 16.4, 17.4, 18.1, CCP2.4, CCP5.4, CCP6.3, CCB FINANCE}

C.3.3 Many natural systems are near the hard limits of their natural adaptation capacity and additional systems will reach limits with increasing global warming (*high confidence*). Ecosystems already reaching or surpassing hard adaptation limits include some warm-water coral reefs, some coastal wetlands, some rainforests, and some polar and mountain ecosystems (*high confidence*). Above 1.5°C global warming level, some Ecosystem-based Adaptation measures will lose their effectiveness in providing benefits to people as these ecosystems will reach hard adaptation limits (*high confidence*). (Figure SPM.4) {1.4, 2.4, 2.6, 3.4, 3.6, 9.6, Box 11.2, 13.4, 14.5, 15.5, 16.4, 16.6, 17.2, CCP1.2, CCP5.2, CCP6.3, CCP7.3, CCB SLR}

C.3.4 In human systems, some coastal settlements face soft adaptation limits due to technical and financial difficulties of implementing coastal protection (*high confidence*). Above 1.5°C global warming level, limited freshwater resources pose potential hard limits for Small Islands and for regions dependent on glacier and snow-melt (*medium confidence*). By 2°C global warming level, soft limits are projected for multiple staple crops in many growing areas, particularly in tropical regions (*high confidence*). By 3°C global warming level, soft limits are projected for some water management measures for many regions, with hard limits projected for parts of Europe (*medium confidence*). {1.4, 4.7, 5.4, 5.8, 7.2, 7.3, 8.4, Table 8.6, 9.8, 10.4, 12.5, 13.2, 13.6, 16.4, 17.2, CCP1.3. Box CCP1.1, CCP2.3, CCP3.3, CCP4.4, CCP5.3, CCB SLR}

C.3.5 Adaptation does not prevent all losses and damages, even with effective adaptation and before reaching soft and hard limits. Losses and damages are unequally distributed across systems, regions and sectors and are not comprehensively addressed by current financial, governance and institutional arrangements, particularly in vulnerable developing countries. With increasing global warming, losses and damages increase and become increasingly difficult to avoid, while strongly concentrated among the poorest vulnerable populations. (*high confidence*) {1.4, 2.6, 3.4, 3.6, 6.3, Figure 6.4, 8.4, 13.2, 13.7, 13.10, 17.2, CCP2.3, CCP4.4, CCB LOSS, CCB SLR, CWGB ECONOMIC}

46 Climate literacy encompasses being aware of climate change, its anthropogenic causes and implications.

Avoiding Maladaptation

C.4 There is increased evidence of maladaptation[15] across many sectors and regions since the AR5. Maladaptive responses to climate change can create lock-ins of vulnerability, exposure and risks that are difficult and expensive to change and exacerbate existing inequalities. Maladaptation can be avoided by flexible, multi-sectoral, inclusive and long-term planning and implementation of adaptation actions with benefits to many sectors and systems. (*high confidence*) {1.3, 1.4, 2.6, Box 2.2, 3.2, 3.6, 4.6, 4.7, Box 4.3, Box 4.5, Figure 4.29, 5.6, 5.13, 8.2, 8.3, 8.4, 8.6, 9.6, 9.7, 9.8, 9.9, 9.10, 9.11, Box 9.5, Box 9.8, Box 9.9, Box 11.6, 13.11, 13.3, 13.4, 13.5, 14.5, 15.5, 15.6, 16.3, 17.2, 17.3, 17.4, 17.5, 17.6, CCP2.3, CCP2.3, CCP5.4, CCB DEEP, CCB NATURAL, CCB SLR, CWGB BIOECONOMY}

C.4.1 Actions that focus on sectors and risks in isolation and on short-term gains often lead to maladaptation if long-term impacts of the adaptation option and long-term adaptation commitment are not taken into account (*high confidence*). The implementation of these maladaptive actions can result in infrastructure and institutions that are inflexible and/or expensive to change (*high confidence*). For example, seawalls effectively reduce impacts to people and assets in the short-term but can also result in lock-ins and increase exposure to climate risks in the long-term unless they are integrated into a long-term adaptive plan (*high confidence*). Adaptation integrated with development reduces lock-ins and creates opportunities (e.g., infrastructure upgrading) (*medium confidence*). {1.4, 3.4, 3.6, 10.4, 11.7, Box 11.6, 13.2, 17.2, 17.5, 17.6, CCP 2.3, CCB DEEP, CCB SLR}

C.4.2 Biodiversity and ecosystem resilience to climate change are decreased by maladaptive actions, which also constrain ecosystem services. Examples of these maladaptive actions for ecosystems include fire suppression in naturally fire-adapted ecosystems or hard defences against flooding. These actions reduce space for natural processes and represent a severe form of maladaptation for the ecosystems they degrade, replace or fragment, thereby reducing their resilience to climate change and the ability to provide ecosystem services for adaptation. Considering biodiversity and autonomous adaptation in long-term planning processes reduces the risk of maladaptation. (*high confidence*) {2.4, 2.6, Table 2.7, 3.4, 3.6, 4.7, 5.6, 5.13, Table 5.21, Table 5.23, Box 11.2, 13.2, Box 13.2, 17.2, 17.5, CCP5.4}

C.4.3 Maladaptation especially affects marginalised and vulnerable groups adversely (e.g., Indigenous Peoples, ethnic minorities, low-income households, informal settlements), reinforcing and entrenching existing inequities. Adaptation planning and implementation that do not consider adverse outcomes for different groups can lead to maladaptation, increasing exposure to risks, marginalising people from certain socioeconomic or livelihood groups, and exacerbating inequity. Inclusive planning initiatives informed by cultural values, Indigenous knowledge, local knowledge, and scientific knowledge can help prevent maladaptation. (*high confidence*) (Figure SPM.4) {2.6, 3.6, 4.3, 4.6, 4.8, 5.12, 5.13, 5.14, 6.1, Box 7.1, 8.4, 11.4, 12.5, Box 13.2, 14.4, Box 14.1, 17.2, 17.5, 18.2, 17.2, CCP2.4}

C.4.4 To minimize maladaptation, multi-sectoral, multi-actor and inclusive planning with flexible pathways encourages low-regret[47] and timely actions that keep options open, ensure benefits in multiple sectors and systems and indicate the available solution space for adapting to long-term climate change (*very high confidence*). Maladaptation is also minimized by planning that accounts for the time it takes to adapt (*high confidence*), the uncertainty about the rate and magnitude of climate risk (*medium confidence*) and a wide range of potentially adverse consequences of adaptation actions (*high confidence*). {1.4, 3.6, 5.12, 5.13, 5.14, 11.6, 11.7, 17.3, 17.6, CCP2.3, CCP2.4, CCP5.4, CCB DEEP, CCB SLR}

Enabling Conditions

C.5 Enabling conditions are key for implementing, accelerating and sustaining adaptation in human systems and ecosystems. These include political commitment and follow-through, institutional frameworks, policies and instruments with clear goals and priorities, enhanced knowledge on impacts and solutions, mobilization of and access to adequate financial resources, monitoring and evaluation, and inclusive governance processes. (*high confidence*) {1.4, 2.6, 3.6, 4.8, 6.4, 7.4, 8.5, 9.4, 10.5, 11.4, 11.7, 12.5, 13.11, 14.7, 15.6, 17.4, 18.4, CCP2.4, CCP5.4, CCB FINANCE, CCB INDIG}

C.5.1 Political commitment and follow-through across all levels of government accelerate the implementation of adaptation actions (*high confidence*). Implementing actions can require large upfront investments of human, financial and technological resources (*high confidence*), whilst some benefits could only become visible in the next decade or beyond (*medium confidence*). Accelerating commitment and follow-through is promoted by rising public awareness, building business cases for adaptation, accountability and transparency mechanisms, monitoring and evaluation of adaptation progress, social movements, and climate-related litigation in some regions (*medium confidence*). {3.6, 4.8, 5.8, 6.4, 8.5, 9.4, 11.7, 12.5, 13.11, 17.4, 17.5, 18.4, CCP2.4, CCB COVID}

47 From AR5, an option *that would generate net social and/or economic benefits under current climate change and a range of future climate change scenarios*, and represent one example of robust strategies.

C.5.2 Institutional frameworks, policies and instruments that set clear adaptation goals and define responsibilities and commitments and that are coordinated amongst actors and governance levels, strengthen and sustain adaptation actions (*very high confidence*). Sustained adaptation actions are strengthened by mainstreaming adaptation into institutional budget and policy planning cycles, statutory planning, monitoring and evaluation frameworks and into recovery efforts from disaster events (*high confidence*). Instruments that incorporate adaptation such as policy and legal frameworks, behavioural incentives, and economic instruments that address market failures, such as climate risk disclosure, inclusive and deliberative processes strengthen adaptation actions by public and private actors (*medium confidence*). {1.4, 3.6, 4.8, 5.14, 6.3, 6.4, 7.4, 9.4, 10.4, 11.7, Box 11.6, Table 11.17, 13.10, 13.11, 14.7, 15.6, 17.3, 17.4, 17.5, 17.6, 18.4, CCP2.4, CCP5.4, CCP6.3, CCB DEEP}

C.5.3 Enhancing knowledge on risks, impacts, and their consequences, and available adaptation options promotes societal and policy responses (*high confidence*). A wide range of top-down, bottom-up and co-produced processes and sources can deepen climate knowledge and sharing, including capacity building at all scales, educational and information programmes, using the arts, participatory modelling and climate services, Indigenous knowledge and local knowledge and citizen science (*high confidence*). These measures can facilitate awareness, heighten risk perception and influence behaviours (*high confidence*). {1.3, 3.6, 4.8, 5.9, 5.14, 6.4, Table 6.8, 7.4, 9.4, 10.5, 11.1, 11.7, 12.5, 13.9, 13.11, 14.3, 15.6, 15.6, 17.4, 18.4, CCP2.4.1, CCB INDIG}

C.5.4 With adaptation finance needs estimated to be higher than those presented in AR5, enhanced mobilization of and access to financial resources are essential for implementation of adaptation and to reduce adaptation gaps (*high confidence*). Building capacity and removing some barriers to accessing finance is fundamental to accelerate adaptation, especially for vulnerable groups, regions and sectors (*high confidence*). Public and private finance instruments include inter alia grants, guarantee, equity, concessional debt, market debt, and internal budget allocation as well as savings in households and insurance. Public finance is an important enabler of adaptation (*high confidence*). Public mechanisms and finance can leverage private sector finance for adaptation by addressing real and perceived regulatory, cost and market barriers, for example via public-private partnerships (*high confidence*). Financial and technological resources enable effective and ongoing implementation of adaptation, especially when supported by institutions with a strong understanding of adaptation needs and capacity (*high confidence*). {4.8, 5.14, 6.4, Table 6.10, 7.4, 9.4, Table 11.17, 12.5, 13.11, 15.6, 17.4, 18.4, Box 18.9, CCP5.4, CCB FINANCE}

C.5.5 Monitoring and evaluation (M&E) of adaptation are critical for tracking progress and enabling effective adaptation (*high confidence*). M&E implementation is currently limited (*high confidence*) but has increased since AR5 at local and national levels. Although most of the monitoring of adaptation is focused towards planning and implementation, the monitoring of outcomes is critical for tracking the effectiveness and progress of adaptation *(high confidence).* M&E facilitates learning on successful and effective adaptation measures, and signals when and where additional action may be needed. M&E systems are most effective when supported by capacities and resources and embedded in enabling governance systems (*high confidence*). {1.4, 2.6, 6.4, 7.4, 11.7, 11.8, 13.2, 13.11, 17.5, 18.4, CCP2.4, CCB DEEP, CCB ILLNESS, CCB NATURAL, CCB PROGRESS}

C.5.6 Inclusive governance that prioritises equity and justice in adaptation planning and implementation leads to more effective and sustainable adaptation outcomes (*high confidence*). Vulnerabilities and climate risks are often reduced through carefully designed and implemented laws, policies, processes, and interventions that address context specific inequities such as based on gender, ethnicity, disability, age, location and income (*high confidence*). These approaches, which include multi-stakeholder co-learning platforms, transboundary collaborations, community-based adaptation and participatory scenario planning, focus on capacity-building, and meaningful participation of the most vulnerable and marginalised groups, and their access to key resources to adapt (*high confidence*). {1.4, 2.6, 3.6, 4.8, 5.4, 5.8, 5.9, 5.13, 6.4, 7.4, 8.5, 11.8, 12.5, 13.11, 14.7, 15.5, 15.7, 17.3, 17.5, 18.4, CCP2.4, CCP5.4, CCP6.4, CCB GENDER, CCB HEALTH, CCB INDIG}

D: Climate Resilient Development

Climate resilient development integrates adaptation measures and their enabling conditions (Section C) with mitigation to advance sustainable development for all. Climate resilient development involves questions of equity and system transitions in land, ocean and ecosystems; urban and infrastructure; energy; industry; and society and includes adaptations for human, ecosystem and planetary health. Pursuing climate resilient development focuses on both where people and ecosystems are co-located as well as the protection and maintenance of ecosystem function at the planetary scale. Pathways for advancing climate resilient development are development trajectories that successfully integrate mitigation and adaptation actions to advance sustainable development. Climate resilient development pathways may be temporarily coincident with any RCP and SSP scenario used throughout AR6, but do not follow any particular scenario in all places and over all time.

Conditions for Climate Resilient Development

D.1 **Evidence of observed impacts, projected risks, levels and trends in vulnerability, and adaptation limits, demonstrate that worldwide climate resilient development action is more urgent than previously assessed in AR5. Comprehensive, effective, and innovative responses can harness synergies and reduce trade-offs between adaptation and mitigation to advance sustainable development. (*very high confidence*) {2.6, 3.4, 3.6, 4.2, 4.6, 7.2, 7.4, 8.3, 8.4, 9.3, 10.6, 13.3, 13.8, 13.10, 14.7, 17.2, 18.3, Box 18.1, Figure 18.1, Table 18.5}**

D.1.1 There is a rapidly narrowing window of opportunity to enable climate resilient development. Multiple climate resilient development pathways are still possible by which communities, the private sector, governments, nations and the world can pursue climate resilient development – each involving and resulting from different societal choices influenced by different contexts and opportunities and constraints on system transitions. Climate resilient development pathways are progressively constrained by every increment of warming, in particular beyond 1.5°C, social and economic inequalities, the balance between adaptation and mitigation varying by national, regional and local circumstances and geographies, according to capabilities including resources, vulnerability, culture and values, past development choices leading to past emissions and future warming scenarios, bounding the climate resilient development pathways remaining, and the ways in which development trajectories are shaped by equity, and social and climate justice. (*very high confidence*) {Figure TS.14d, 2.6, 4.7, 4.8, 5.14, 6.4, 7.4, 8.3, 9.4, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 14.7, 15.3, 18.5, CCP2.3, CCP3.4, CCP4.4, CCP5.3, CCP5.4, Table CCP5.2, CCP6.3, CCP7.5}

D.1.2 Opportunities for climate resilient development are not equitably distributed around the world (*very high confidence*). Climate impacts and risks exacerbate vulnerability and social and economic inequities and consequently increase persistent and acute development challenges, especially in developing regions and sub-regions, and in particularly exposed sites, including coasts, small islands, deserts, mountains and polar regions. This in turn undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities (*very high confidence*). {2.5, 4.4, 4.7, 6.3, Box 6.4, Figure 6.5, 9.4, Table 18.5, CCP2.2, CCP3.2, CCP3.3, CCP5.4, CCP6.2, CCB HEALTH, CWGB URBAN}

D.1.3 Embedding effective and equitable adaptation and mitigation in development planning can reduce vulnerability, conserve and restore ecosystems, and enable climate resilient development. This is especially challenging in localities with persistent development gaps and limited resources (*high confidence*). Dynamic trade-offs and competing priorities exist between mitigation, adaptation, and development. Integrated and inclusive system-oriented solutions based on equity and social and climate justice reduce risks and enable climate resilient development (*high confidence*). {1.4, 2.6, Box 2.2, 3.6, 4.7, 4.8, Box 4.5, Box 4.8, 5.13, 7.4, 8.5, 9.4, Box 9.3, 10.6, 12.5, 12.6, 13.3, 13.4, 13.10, 13.11, 14.7, 18.4, CCB DEEP, CCP2, CCP5.4, CCB HEALTH, SRCCL}

Enabling Climate Resilient Development

D.2 **Climate resilient development is enabled when governments, civil society and the private sector make inclusive development choices that prioritise risk reduction, equity and justice, and when decision-making processes, finance and actions are integrated across governance levels, sectors and timeframes (*very high confidence*). Climate resilient development is facilitated by international cooperation and by governments at all levels working with communities, civil society, educational bodies, scientific and other institutions, media, investors and businesses; and by developing partnerships with traditionally marginalised groups, including women, youth, Indigenous Peoples, local communities and ethnic minorities (*high confidence*). These partnerships are most effective when supported by enabling political leadership, institutions, resources, including finance, as well as climate services, information and decision support tools (*high confidence*). (Figure SPM.5) {1.3, 1.4, 1.5, 2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.4, 17.6, 18.4, 18.5, CCP2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB DEEP, CCB GENDER, CCB HEALTH, CCB INDIG, CCB NATURAL, CCB SLR}**

D.2.1 Climate resilient development is advanced when actors work in equitable, just and enabling ways to reconcile divergent interests, values and worldviews, toward equitable and just outcomes (*high confidence*). These practices build on diverse knowledges about climate risk and chosen development pathways account for local, regional and global climate impacts, risks, barriers and opportunities (*high confidence*). Structural vulnerabilities to climate change can be reduced through carefully designed and implemented legal, policy, and process interventions from the local to global that address inequities based on gender, ethnicity, disability, age, location and income (*very high confidence*). This includes rights-based approaches that focus on capacity-building, meaningful participation of the most vulnerable groups, and their access to key resources, including financing, to reduce risk and adapt (*high confidence*). Evidence shows that climate resilient development processes link scientific, Indigenous, local, practitioner and other forms of knowledge, and are more effective and sustainable because they are locally appropriate and lead to more legitimate, relevant and effective actions (*high confidence*).

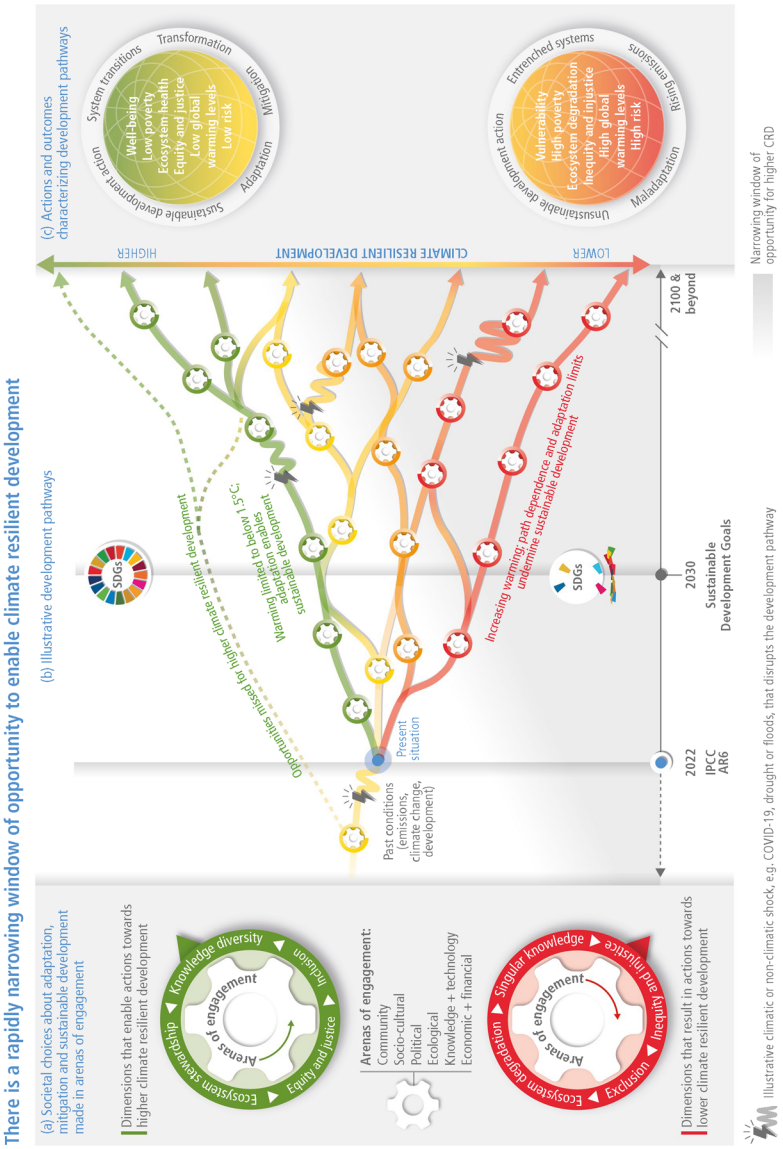

There is a rapidly narrowing window of opportunity to enable climate resilient development
(a) Societal choices about adaptation, mitigation and sustainable development made in arenas of engagement
Dimensions that enable actions towards higher climate resilient development
Ecosystem stewardship
Knowledge diversity
Inclusion
Equity and justice
Arenas of engagement
Arenas of engagement:
Community
Socio-cultural
Political
Ecological
Knowledge + technology
Economic + financial
Ecosystem degradation
Singular knowledge
Inequity and injustice
Exclusion
Arenas of engagement
Dimensions that result in actions towards lower climate resilient development
(b) Illustrative development pathways
Past conditions (emissions, climate change, development)
Present situation
2022 IPCC AR6
2030 Sustainable Development Goals
2100 & beyond
SDGs
SDGs
Opportunities missed for higher climate resilient development
Warming limited to below 1.5°C; adaptation to tackle sustainable development challenges
Increasing warming; path dependence and adaptation limits undermine sustainable development
CLIMATE RESILIENT DEVELOPMENT
HIGHER
LOWER
(c) Actions and outcomes characterizing development pathways
Sustainable development action
System transitions
Transformation
Mitigation
Adaptation
Well-being
Low poverty
Ecosystem health
Equity and justice
Low global warming levels
Low risk
Unsustainable development action
Entrenched systems
Rising emissions
Maladaptation
Vulnerability
High poverty
Ecosystem degradation
Inequity and injustice
High global warming levels
High risk
Illustrative climatic or non-climatic shock, e.g. COVID-19, drought or floods, that disrupts the development pathway
Narrowing window of opportunity for higher CRD

Figure SPM.5 | Climate resilient development (CRD) is the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development. This figure builds on Figure SPM.9 in AR5 WGII (depicting climate resilient pathways) by describing how CRD pathways are the result of cumulative societal choices and actions within multiple arenas.

Panel (a) Societal choices towards higher CRD **(green cog)** or lower CRD **(red cog)** result from interacting decisions and actions by diverse government, private sector and civil society actors, in the context of climate risks, adaptation limits and development gaps. These actors engage with adaptation, mitigation and development actions in political, economic and financial, ecological, socio-cultural, knowledge and technology, and community arenas from local to international levels. Opportunities for climate resilient development are not equitably distributed around the world.

Panel (b) Cumulatively, societal choices, which are made continuously, shift global development pathways towards higher **(green)** or lower **(red)** climate resilient development. Past conditions (past emissions, climate change and development) have already eliminated some development pathways towards higher CRD **(dashed green line)**.

Panel (c) Higher CRD is characterised by outcomes that advance sustainable development for all. Climate resilient development is progressively harder to achieve with global warming levels beyond 1.5°C. Inadequate progress towards the Sustainable Development Goals (SDGs) by 2030 reduces climate resilient development prospects. There is a narrowing window of opportunity to shift pathways towards more climate resilient development futures as reflected by the adaptation limits and increasing climate risks, considering the remaining carbon budgets. (Figure SPM.2, Figure SPM.3) {Figure TS.14b, 2.6, 3.6, 7.2, 7.3, 7.4, 8.3, 8.4, 8.5, 16.4, 16.5, 17.3, 17.4, 17.5, 18.1, 18.2, 18.3, 18.4, Box 18.1, Figure 18.1, Figure 18.2, Figure 18.3, CCB COVID, CCB GENDER, CCB HEALTH, CCB INDIG, CCB SLR, WGI AR6 Table SPM.1, WGI AR6 Table SPM.2, SR1.5 Figure SPM.1}

Pathways towards climate resilient development overcome jurisdictional and organizational barriers, and are founded on societal choices that accelerate and deepen key system transitions (*very high confidence*). Planning processes and decision analysis tools can help identify 'low regrets' options[47] that enable mitigation and adaptation in the face of change, complexity, deep uncertainty and divergent views (*medium confidence*). {1.3, 1.4, 1.5, 2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, Box 8.7, 9.4, Box 9.2, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2–17.6, 18.2–18.4, CCP2.3–2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB DEEP, CCB HEALTH, CCB INDIG, CCB NATURAL, CCB SLR}

D.2.2 Inclusive governance contributes to more effective and enduring adaptation outcomes and enables climate resilient development (*high confidence*). Inclusive processes strengthen the ability of governments and other stakeholders to jointly consider factors such as the rate and magnitude of change and uncertainties, associated impacts, and timescales of different climate resilient development pathways given past development choices leading to past emissions and scenarios of future global warming (*high confidence*). Associated societal choices are made continuously through interactions in arenas of engagement from local to international levels. The quality and outcome of these interactions helps determine whether development pathways shift towards or away from climate resilient development (*medium confidence*). (Figure SPM.5) {2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2–17.6, 18.2, 18.4, CCP2.3–2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB GENDER, CCB HEALTH, CCB INDIG}

D.2.3 Governance for climate resilient development is most effective when supported by formal and informal institutions and practices that are well-aligned across scales, sectors, policy domains and timeframes. Governance efforts that advance climate resilient development account for the dynamic, uncertain and context-specific nature of climate-related risk, and its interconnections with non-climate risks. Institutions[48] that enable climate resilient development are flexible and responsive to emergent risks and facilitate sustained and timely action. Governance for climate resilient development is enabled by adequate and appropriate human and technological resources, information, capacities and finance. (*high confidence*) {2.7, 3.6, 4.8, 5.14, 6.3, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2-17.6, 18.2, 18.4, CCP2.3–2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB DEEP, CCB GENDER, CCB HEALTH, CCB INDIG, CCB NATURAL, CCB SLR}

Climate Resilient Development for Natural and Human Systems

D.3 Interactions between changing urban form, exposure and vulnerability can create climate change-induced risks and losses for cities and settlements. However, the global trend of urbanisation also offers a critical opportunity in the near-term, to advance climate resilient development (*high confidence*). Integrated, inclusive planning and investment in everyday decision-making about urban infrastructure, including social, ecological and grey/physical infrastructures, can significantly increase the adaptive capacity of urban and rural settlements. Equitable outcomes contributes to multiple benefits for health and well-being and ecosystem services, including for Indigenous Peoples, marginalised and vulnerable communities (*high confidence*). Climate resilient development in urban areas also supports adaptive capacity in more rural places through maintaining peri-urban supply chains of goods and services and financial flows (*medium confidence*). Coastal cities and settlements play an especially important role in advancing climate resilient development (*high confidence*). {6.2, 6.3, Table 6.6, 7.4, 8.6, Box 9.8, 18.3, CCP2.1. CCP2.2, CCP6.2, CWGB URBAN}

48 Institutions: Rules, norms and conventions that guide, constrain or enable human behaviours and practices. Institutions can be formally established, for instance through laws and regulations, or informally established, for instance by traditions or customs. Institutions may spur, hinder, strengthen, weaken or distort the emergence, adoption and implementation of climate action and climate governance.

D.3.1 Taking integrated action for climate resilience to avoid climate risk requires urgent decision making for the new built environment and retrofitting existing urban design, infrastructure and land use. Based on socioeconomic circumstances, adaptation and sustainable development actions will provide multiple benefits including for health and well-being, particularly when supported by national governments, non-governmental organisations and international agencies that work across sectors in partnerships with local communities. Equitable partnerships between local and municipal governments, the private sector, Indigenous Peoples, local communities, and civil society can, including through international cooperation, advance climate resilient development by addressing structural inequalities, insufficient financial resources, cross-city risks and the integration of Indigenous knowledge and local knowledge. (*high confidence*) {6.2, 6.3, 6.4, Table 6.6, 7.4, 8.5, 9.4, 10.5. 12.5, 17.4, Table 17.8, 18.2, Box 18.1, CCP2.4, CCB FINANCE, CCB GENDER, CCB INDIG, CWGB URBAN}

D.3.2 Rapid global urbanisation offers opportunities for climate resilient development in diverse contexts from rural and informal settlements to large metropolitan areas (*high confidence*). Dominant models of energy intensive and market-led urbanisation, insufficient and misaligned finance and a predominant focus on grey infrastructure in the absence of integration with ecological and social approaches, risks missing opportunities for adaptation and locking in maladaptation (*high confidence*). Poor land use planning and siloed approaches to health, ecological and social planning also exacerbates, vulnerability in already marginalised communities (*medium confidence*). Urban climate resilient development is observed to be more effective if it is responsive to regional and local land use development and adaptation gaps, and addresses the underlying drivers of vulnerability (*high confidence*). The greatest gains in well-being can be achieved by prioritizing finance to reduce climate risk for low-income and marginalized residents including people living in informal settlements (*high confidence*). {5.14, 6.1, 6.2, 6.3, 6.4, 6.5, Figure 6.5, Table 6.6, 7.4, 8.5, 8.6, 9.8, 9.9, 10.4, Table 17.8, 18.2, CCP2.2, CCP5.4, CCB HEALTH, CWGB URBAN}

D.3.3 Urban systems are critical, interconnected sites for enabling climate resilient development, especially at the coast. Coastal cities and settlements play a key role in moving toward higher climate resilient development given firstly, almost 11% of the global population – 896 million people – lived within the Low Elevation Coastal Zone[49] in 2020, potentially increasing to beyond 1 billion people by 2050, and these people, and associated development and coastal ecosystems, face escalating climate compounded risks, including sea level rise. Secondly, these coastal cities and settlements make key contributions to climate resilient development through their vital role in national economies and inland communities, global trade supply chains, cultural exchange, and centres of innovation. (*high confidence*) {6.1, 6.2, 6.4, Table 6.6, Box 15.2, SMCCP Table 2.1, CCP2.2, CCP2.4, CCB SLR, XWGB URBAN, SROCC Chapter 4}

D.4 Safeguarding biodiversity and ecosystems is fundamental to climate resilient development, in light of the threats climate change poses to them and their roles in adaptation and mitigation (*very high confidence*). Recent analyses, drawing on a range of lines of evidence, suggest that maintaining the resilience of biodiversity and ecosystem services at a global scale depends on effective and equitable conservation of approximately 30% to 50% of Earth's land, freshwater and ocean areas, including currently near-natural ecosystems (*high confidence*). {2.4, 2.5, 2.6, 3.4, 3.5, 3.6, Box 3.4, 12.5, 13.3, 13.4, 13.5, 13.10, CCB INDIG, CCB NATURAL}

D.4.1 Building the resilience of biodiversity and supporting ecosystem integrity[50] can maintain benefits for people, including livelihoods, human health and well-being and the provision of food, fibre and water, as well as contributing to disaster risk reduction and climate change adaptation and mitigation. {2.2, 2.5, 2.6, Table 2.6, Table 2.7, 3.5, 3.6, 5.8, 5.13, 5.14, Box 5.11, 12.5, CCP5.4, CCB COVID, CCB GENDER, CCB ILLNESS, CCB INDIG, CCB MIGRATE, CCB NATURAL}

D.4.2 Protecting and restoring ecosystems is essential for maintaining and enhancing the resilience of the biosphere (*very high confidence*). Degradation and loss of ecosystems is also a cause of greenhouse gas emissions and is at increasing risk of being exacerbated by climate change impacts, including droughts and wildfire *(high confidence).* Climate resilient development avoids adaptation and mitigation measures that damage ecosystems (*high confidence*). Documented examples of adverse impacts of land-based measures intended as mitigation, when poorly implemented, include afforestation of grasslands, savannas and peatlands, and risks from bioenergy crops at large scale to water supply, food security and biodiversity (*high confidence*). {2.4, 2.5, Box 2.2, 3.4, 3.5, Box 3.4, Box 9.3, CCP7.3, CCB NATURAL, CWGB BIOECONOMY}

49 LECZ, coastal areas below 10 m of elevation above sea level that are hydrologically connected to the sea.

50 Ecosystem integrity refers to the ability of ecosystems to maintain key ecological processes, recover from disturbance, and adapt to new conditions.

D.4.3 Biodiversity and ecosystem services have limited capacity to adapt to increasing global warming levels, which will make climate resilient development progressively harder to achieve beyond 1.5°C warming (*very high confidence*). Consequences of current and future global warming for climate resilient development include reduced effectiveness of Ecosystem-based Adaptation and approaches to climate change mitigation based on ecosystems and amplifying feedbacks to the climate system (*high confidence*). {Figure TS.14d, 2.4, 2.5, 2.6, 3.4, Box 3.4, 3.5, 3.6, Table 5.2, 12.5, 13.2, 13.3, 13.10, 14.5, 14.5, Box 14.3, 15.3, 17.3, 17.6, CCP5.3, CCP5.4, CCB EXTREMES, CCB ILLNESS, CCB NATURAL, CCB SLR, SR1.5, SRCCL, SROCC}

Achieving Climate Resilient Development

D.5 **It is unequivocal that climate change has already disrupted human and natural systems. Past and current development trends (past emissions, development and climate change) have not advanced global climate resilient development (*very high confidence*). Societal choices and actions implemented in the next decade determine the extent to which medium- and long-term pathways will deliver higher or lower climate resilient development (*high confidence*). Importantly climate resilient development prospects are increasingly limited if current greenhouse gas emissions do not rapidly decline, especially if 1.5°C global warming is exceeded in the near-term (*high confidence*). These prospects are constrained by past development, emissions and climate change, and enabled by inclusive governance, adequate and appropriate human and technological resources, information, capacities and finance (*high confidence*). {Figure TS.14d, 1.2, 1.4, 1.5, 2.6, 2.7, 3.6, 4.7, 4.8, 5.14, 6.4, 7.4, 8.3, 8.5, 8.6, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 13.11, 14.7, 15.3, 15.6, 15.7, 16.2, 16.4, 16.5, 16.6, 17.2–17.6, 18.2–18.5, CCP2.3–2.4, CCP3.4, CCP4.4, CCP5.3, CCP5.4, Table CCP5.2, CCP6.3, CCP6.4, CCP7.5, CCP7.6, CCB DEEP, CCB HEALTH, CCB INDIG, CCB NATURAL, CCB SLR}**

D.5.1 Climate resilient development is already challenging at current global warming levels (*high confidence*). The prospects for climate resilient development will be further limited if global warming levels exceeds 1.5°C (*high confidence*) and not be possible in some regions and sub-regions if the global warming level exceeds 2°C (*medium confidence*). Climate resilient development is most constrained in regions/subregions in which climate impacts and risks are already advanced, including low-lying coastal cities and settlements, small islands, deserts, mountains and polar regions (*high confidence*). Regions and subregions with high levels of poverty, water, food and energy insecurity, vulnerable urban environments, degraded ecosystems and rural environments, and/or few enabling conditions, face many non-climate challenges that inhibit climate resilient development which are further exacerbated by climate change (*high confidence*). {Figure TS.14d, 1.2, Box 6.6, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 14.7, 15.3, CCP2.3, CCP3.4, CCP4.4, CCP5.3, Table CCP5.2, CCP6.3, CCP7.5}

D.5.2 Inclusive governance, investment aligned with climate resilient development, access to appropriate technology and rapidly scaled-up finance, and capacity building of governments at all levels, the private sector and civil society enable climate resilient development. Experience shows that climate resilient development processes are timely, anticipatory, integrative, flexible and action focused. Common goals and social learning build adaptive capacity for climate resilient development. When implementing adaptation and mitigation together, and taking trade-offs into account, multiple benefits and synergies for human well-being as well as ecosystem and planetary health can be realised. Prospects for climate resilient development are increased by inclusive processes involving local knowledge and Indigenous Knowledge as well as processes that coordinate across risks and institutions. Climate resilient development is enabled by increased international cooperation including mobilising and enhancing access to finance, particularly for vulnerable regions, sectors and groups. (*high confidence*) (Figure SPM.5) {2.7, 3.6, 4.8, 5.14, 6.4, 7.4, 8.5, 8.6, 9.4, 10.6, 11.8, 12.5, 13.11, 14.7, 15.6, 15.7, 17.2–17.6, 18.2–18.5, CCP2.3–2.4, CCP3.4, CCP4.4, CCP5.4, CCP6.4, CCP7.6, CCB DEEP, CCB HEALTH, CCB INDIG, CCB NATURAL, CCB SLR}

D.5.3 The cumulative scientific evidence is unequivocal: Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all. (*very high confidence*) {1.2, 1.4, 1.5, 16.2, Table SM16.24, 16.4, 16.5, 16.6, 17.4, 17.5, 17.6, 18.3, 18.4, 18.5, CCB DEEP, CWGB URBAN, WGI AR6 SPM, SROCC SPM, SRCCL SPM}



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King Cove-Cold Bay: Assessment of Non-Road Alternatives

Aleutians East Borough, Alaska

FINAL

June 18, 2015

Prepared for:

U.S. Army Corps of Engineers, Alaska District

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King Cove-Cold Bay
Assessment of Non-Road Alternatives

June 2015

Executive Summary

King Cove, Alaska, population 800, is located in the Aleutians East Borough (AEB) in southwest Alaska. The area is remote and located where the North Pacific Ocean meets the Bering Sea. The area is known for harsh weather; high winds, rough seas, and fog or persistent clouds occur frequently. These conditions are not necessarily unusual for other small, rural communities in Alaska, but King Cove is different in one key respect: it lies 18 miles from the Cold Bay Airport, which has a 10,000-foot jet-capable runway originally built by the military and now maintained as an emergency landing location on the great circle routes between North America and Asia. Several plane crashes, many harrowing tales, and near misses trying to get patients evacuated to Anchorage for medical emergencies by small plane or by boat from King Cove to Cold Bay have highlighted the difficulty of travel in the area, particularly under emergency circumstances. The Cold Bay Airport is close, but sometimes inaccessible. King Cove, the borough, and Alaska's Congressional delegation have pushed Congress for a road connection through the Izembek National Wildlife Refuge and Izembek Wilderness along a narrow isthmus that separates the rich tidal marshes of the Bering Sea and Pacific Ocean water. It is an area that is critical habitat for wildlife, including almost the entire global population of black brant. The U.S. Department of the Interior (DOI) has decided against the road option. This document reviewed past studies and the latest thinking on potential non-road alternatives. It is designed to filter past work on non-road-access alternatives and present the most promising in each of three non-road transportation modes: marine vessel, fixed-wing aircraft, and helicopter.

This *Assessment of Non-Road Alternatives* for medical evacuation (medevac) from King Cove to Cold Bay and on to Anchorage examines three modes of transportation as selected by DOI: (1) ice-capable marine vessel, (2) fixed-wing aircraft/new airport, and (3) helicopter/heliport. Variations within each alternative address the location of the facilities and, to a lesser extent, type of equipment and facilities. This assessment provides a high-level overview of the three non-road-access options and does not provide a recommendation, but presents conceptual information on the locations, costs, risks, and dependability of each. This report does not identify the actual steps needed for implementing a selected alternative such as additional analysis under the National Environmental Policy Act or similar regulation.

The proposed marine vessel is a 150-foot ferry capable of carrying vehicles and passengers year-round in expected seas (based on wave records over a 5-year time period), including capability of moving through bay ice 12 inches thick (OASIS Environmental, Inc. 2003). The vessel would require modifications at the Cold Bay dock and a new dock on the King Cove side, where it would reside. The vessel port could include a rock breakwater, depending on the location chosen. It is assumed the ferry would operate for general use, not just medevac use, and would transport passengers, cargo, and vehicles to and from Cold Bay but would be available for medevac trips to Cold Bay,

where patients would transfer to a medevac flight or commercial flight to Anchorage. This would be necessary when flights were not possible in and out of the King Cove Airport.

The identified airport location is north of King Cove and north of mountainous terrain in an area with few obstructions, at the end of the existing King Cove road system. It could be designed for service by small jet (longer, paved runway) or turbo-prop aircraft (shorter, gravel runway). Implementation of this alternative is assumed to mean closure of the existing King Cove Airport, which is located in mountainous area where turbulence is common and terrain hazards compound weather issues. Medevac flights would respond when called from Unalaska (190 miles away) or Anchorage (620 miles), and take patients from the new airport directly to Anchorage.

The helicopter option assumes a helicopter would be leased by a government entity and based at a new heliport, with hangar and lighting, located at King Cove, on the King Cove road system, or at a new location on the southern edge of Cold Bay (the water body). The helicopter would transport patients to the Cold Bay Airport, where they would transfer to a medevac flight or commercial flight to Anchorage.

The table below summarizes life-cycle costs and operating factors, such as medevac time, risks to the project, and dependability, for the alternatives addressed in this document. Capital and operations and maintenance costs assume a 75-year life cycle. The net present value (NPV) for each alternative incorporated conceptual-level construction cost estimates and 75-year operating costs in 2015 dollars. The document provides greater detail.

Table ES-1. Summary of Costs and Operating Factors

	Marine *150-ft ice-capable monohull ferry*			**Airport** *New airport located NW of Mt. Dutton*		**Helicopter** *Leased helicopter and crew with dedicated heliport*			
	1a NE Cold Bay Ferry	**1b** Lenard Harbor Ferry	**1c** Direct Ferry (KC-CB)	**2a** 5,000-ft Runway (Learjet)	**2b** 3,500-ft Runway (King Air)	**3a** NE Cold Bay Heliport	**3b** Lenard Harbor Heliport	**3c** Peninsula Heliport	**3d** King Cove Heliport
Life-cycle Costs *(75 years)*									
Capital Cost *($ millions)*	41.8	29.9	39.0	84.0	47.0	2.8	2.8	28.3	2.8
Operations and Maintenance Cost ($)	872,300	925,600	1.14 M	674,700	223,300	2.34 M	2.25 M	2.28 M	2.19 M
Net Present Value *($ millions)*	65.7	56.7	71.9	97.0	49.3	78.3	75.3	99.1	73.6
Operating Factors									
Medevac Time *(hrs)*	3.5	3.7	5.0	2.4	3.0	3.1	2.6	2.7	2.1
Risk Score	2.4	2.4	2.5	2.5	2.6	2.5	2.5	2.5	2.2
Annual Dependability	99.9%	99.9%	99.6%	94.9%	94.9%	82.6%	67.5%	67.5%	70%

Notes:
All costs are shown in 2015 dollars. See main document for explanation of cost estimates.
Medevac time is the elapsed travel time between the City of King Cove and Ted Stevens Anchorage International Airport. See main document for further explanation.
Risk score compiles multiple risk factors on a 1–4 scale (1=low, 2=moderate, 3=serious, 4=high) and averages them. Risk assessment is qualitative. Scoring allows for deriving the average and is not meant to imply precision in quantifying risk. See main document for explanation of methods.
Dependability shown is based largely on wind data thresholds. Other factors affect dependability and may differ between modes of travel. See main document for explanation.

Table of Contents

Executive Summary ..... **i**

1 Introduction **1**
1.1 Background 1
1.2 Transportation Challenges 5

2 Objectives, Scope of Work, and Methods **7**
2.1 Method Used to Assess Costs 7
2.2 Method Used to Assess Risk 8
2.3 Method Used to Assess Dependability 8
2.4 Method Used to Assess Medevac Travel Time 9

3 Existing Information and Past Studies **11**

4 Marine Alternative **13**
4.1 Introduction to Ferry Concept 13
4.2 Detailed Descriptions—Marine Alternatives 17
4.2.1 Facilities Common to all Marine Alternatives 17
4.2.2 Northeast Ferry (Alternative 1a) 21
4.2.3 Lenard Harbor Ferry (Alternative 1b) 25
4.2.4 Direct Ferry (Alternative 1c) 29
4.2.5 Comparison of Mode Options 29
4.3 Construction and 75-Year Life-Cycle Costs 33
4.4 Risks 34
4.5 Dependability 34
4.6 Other Marine Considerations 36

5 Airport Alternatives **37**
5.1 Introduction to Airport Concept 37
5.2 Detailed Descriptions—Airport Alternatives 41
5.2.1 Alternative 2a (5,000-foot runway/Learjet 35) 45
5.2.2 Alternative 2b (3,500-foot runway/King Air) 45
5.2.3 Comparison of Airport Options 45
5.3 Construction and 75-Year Life-Cycle Cost 46
5.4 Risks 47
5.5 Dependability 48

6 Helicopter Alternative **51**
6.1 Introduction to Helicopter Concept and Common Design Features 51
6.2 Detailed Descriptions—Helicopter Alternatives 55
6.2.1 Alternative 3a (Northeast Heliport) 59
6.2.2 Alternative 3b (Lenard Harbor Heliport) 59
6.2.3 Alternative 3c (Peninsula Heliport) 59
6.2.4 Alternative 3d (King Cove Heliport) 60
6.2.5 Comparison of Heliport Options 60
6.3 Construction Cost and 75-Year Life-Cycle Cost 61

6.4 Risks 62
6.5 Dependability 63
6.6 Other Considerations 64
6.6.1 Helicopter Hangar on the King Cove Side of the Bay 65
6.6.2 Helicopter Hangar at Cold Bay Airport 65
7 Annotated Bibliography 67

List of Tables

Table 1. Summary Comparison of Marine Alternatives 29
Table 2. Costs of the Marine Alternatives 33
Table 3. Marine Alternatives, Dependability by Month (%) 35
Table 4. Summary Comparison of Airport Alternatives 46
Table 5. Costs of the Airport Alternatives 47
Table 6. Alternatives 2a and 2b, Dependability by Month (%) 49
Table 7. Summary Comparison of Heliport Alternatives 61
Table 8. Costs of the Heliport Alternatives (millions) 61
Table 9. Heliport Alternatives, Dependability by Month (%) 64
Table 10. Pros and Cons of Hangar Locations 65

List of Figures

Figure 1. Vicinity Map 3
Figure 2. Ferry Alternative Routes 15
Figure 3. Cold Bay Dock Modifications 19
Figure 4. Proposed Northeast Cold Bay Dock 23
Figure 5. Proposed Lenard Harbor Dock 27
Figure 6. Proposed King Cove Dock 31
Figure 7. Proposed King Cove Airport 39
Figure 8. Airports Concept 43
Figure 9. Heliport Alternative Locations 53
Figure 10. Heliport Dimensions 57

List of Appendices

Appendix A: Risk Matrix and Risk Assessment Tables
Appendix B: Wind Data
Appendix C: Medevac Elapsed-Time Tables

Acronyms and Abbreviations

AEB	Aleutians East Borough
AIP	Airport Improvement Program
ANC	Ted Stevens Anchorage International Airport
DOT&PF	Alaska Department of Transportation and Public Facilities
EIS	Environmental impact statement
FAA	Federal Aviation Administration
IFR	Instrument Flight Rules
ILS	Instrument Landing System
KUCB	Unalaska Community Broadcasting
NPV	Net present value
NWR	National Wildlife Refuge
O&M	Operations and maintenance
RNAV	Area Navigation
SRE	Snow removal equipment
USCG	U.S. Coast Guard
VFR	Visual Flight Rules

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1 Introduction

1.1 Background

The cities of King Cove and Cold Bay in southwestern Alaska lie 18 miles apart; see Figure 1. King Cove's population is about 800 year-round and expands to approximately 1,300 when the Peter Pan Seafoods processing plant is operating at full capacity.[1] While King Cove has the larger population, Cold Bay has the larger airport—an instrument-capable airport with a paved runway more than 10,000 feet long (one of the longest in the state) and a crosswind runway. It is a former military airport kept in service primarily as an emergency landing location on the long-haul great circle route between North American airport hubs and Asian airport hubs.

The communities of King Cove and Cold Bay are separated not only by miles. They are also separated:

- By the water body of Cold Bay, which is more protected than the open ocean, but still known for severe winds and waves, and infrequently for ice.
- By mountainous terrain, particularly near the City of King Cove and its small airport.
- By an isthmus 3 miles wide separating the head of Cold Bay, which opens to the Pacific Ocean, from the Bering Sea.
- By protected lands of the Izembek National Wildlife Refuge (NWR) and Izembek Wilderness on the isthmus and by the Alaska Peninsula NWR along the shoreline, as established by Congress.

King Cove, the Aleutians East Borough (AEB), and Alaska's Congressional delegation have worked since the 1980s to convince Congress, the U.S. Department of the Interior, and USFWS to allow and fund a road between the communities, principally for medical evacuation (medevac).

Congress, in the Omnibus Land Management Act of 2009, directed that the Department of the Interior should examine a road in an Environmental Impact Statement (EIS) and use the EIS to determine whether a land exchange to allow road access would be in the public interest of the people of the United States. A December 23, 2013, Record of Decision signed by Secretary of the Interior Sally Jewell found it would not be in the overall public interest because "construction of a road through the Izembek National Wildlife Refuge would lead to significant degradation of irreplaceable ecological resources that would not be offset by the protection of other land to be received under an exchange…(and)… because reasonable and viable transportation alternatives exist to meet the important health and safety needs of the people of King Cove."[2] Secretary Jewell received a request for reconsideration of the decision. After further consultation and visiting the site, Secretary Jewell signed a letter dated August 13, 2014, stating the Department of Interior would stand by its decision and would not re-open the record of decision. At the same time, she reiterated commitment to continuing to work with Alaskans "to evaluate and develop other

[1] The Peter Pan Seafoods processing plant in King Cove is the largest capacity salmon processor in the state, and it processes Bering Sea crab catches and multiple other species.
[2] Record of Decision, December 23, 2013.

transportation improvements for the residents of King Cove and Cold Bay." This document is a result of that request.

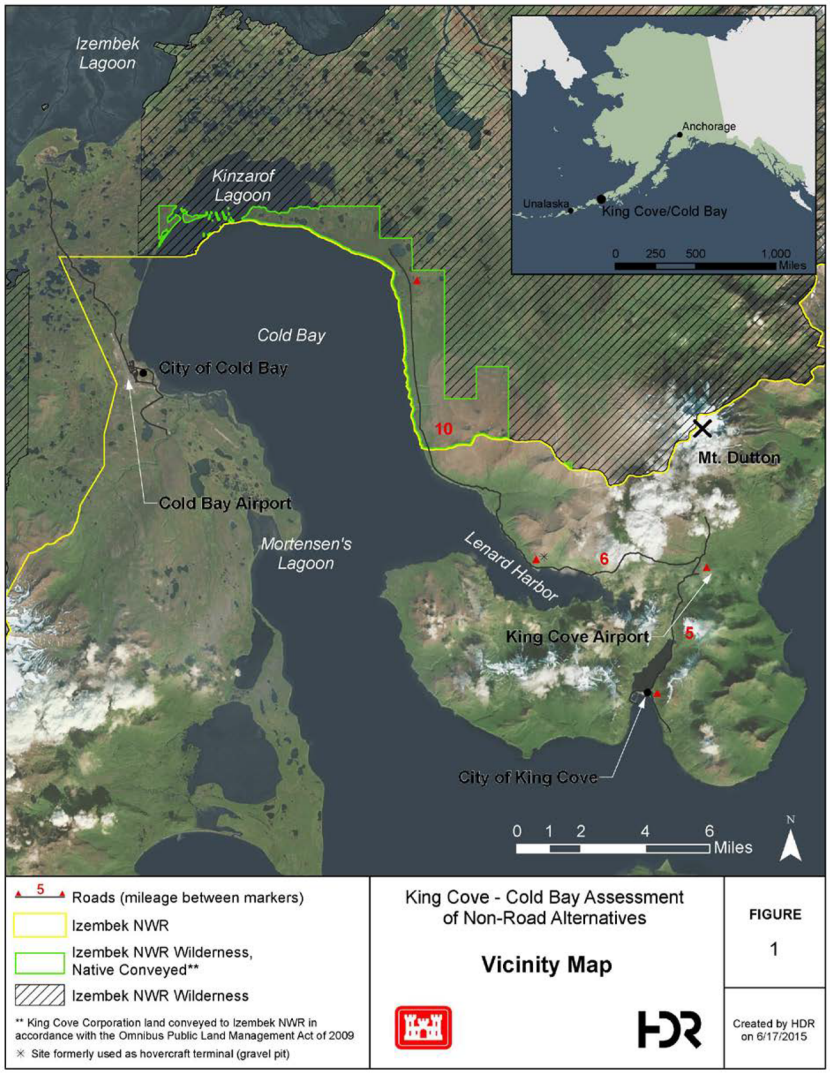


Figure 1. Vicinity Map

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Secretary Jewell requested assistance from the United States Army Corps of Engineers, Alaska District, to examine three non-road access alternatives in 2015. This document is the result of that request. It is designed to filter past work on non-road access alternatives and present the most promising in each of three non-road transportation modes:

- Marine vessel
- Fixed-wing aircraft
- Helicopter

1.2 Transportation Challenges

King Cove is an ocean-oriented community. However, there is no dependable and publicly available marine connection between King Cove and Cold Bay. The state-operated Alaska Marine Highway System ferry stops twice a month at King Cove and Cold Bay, May to October, with the only other marine connection consisting of fishing vessels that can sometimes be chartered between King Cove and Cold Bay. Fishing vessels can make the trip in most weather conditions but are not equipped to handle passengers, especially medevac passengers. Fishing vessels often are out of port on the fishing grounds or undergoing maintenance while in port. They must travel approximately 27 nautical miles from King Cove to Cold Bay, with roughly half that distance in open seas.

Another shortcoming in the marine connection between King Cove and Cold Bay is the inadequate infrastructure in place for passengers to disembark from vessels at the existing Cold Bay Dock. Passengers or medical evacuees must travel up a 20-foot ladder from the boat to reach the wharf deck. This can be dangerous, particularly for those who are not in good physical shape, especially when sea conditions cause the vessel to move with respect to the ladder used for disembarking. The state ferry that occasionally uses the dock during the summer has provisions for a ramp to allow vehicle and passenger transfer between the ferry and the dock. Sea and wind conditions at any time of year could preclude safe operation without a ramp similar to the state ferry at the Cold Bay Dock in its current configuration.

Regarding air transportation, the existing King Cove Airport lies north of town in a mountainous area. It has a single gravel runway 3,500 feet long. Terrain limits the available approaches and, in many wind conditions, creates turbulence that can cause unsafe flying conditions. Clouds also may form over or adjacent to the mountains, obscuring the runway. Scheduled air service to and from Cold Bay and other communities exists, but because of delays and cancellations due to wind, cloud cover, or snow and icing conditions compounded by winter darkness and mountainous terrain, scheduled air service is not considered to be as reliable as most air service elsewhere in the Lower 48. The scope of this assessment did not allow for analysis of other Alaska airports that have constraints similar to those attributed to King Cove.

Regarding the safety, reliability, and convenience of air travel, the Alaska Department of Transportation and Public Facilities (DOT&PF) published the 1994 *Alaska Intermodal Transportation Plan*, which noted:

1. A significant portion of the scheduled flights in and out of King Cove were cancelled due to unsafe flying conditions.
2. In addition to documented air crashes in King Cove, numerous incidents and near-misses occurred during operations around the airport, associated principally with weather.
3. Canceled flights due to unsafe flying conditions caused medical complications and fatalities for patients awaiting evacuation from King Cove.

Improvements to navigation aids installed at the airport or to the configuration of the existing airport would not adequately address these problems.

The AEB was the recipient of a $37.5 million federal appropriation for improving transportation between King Cove and Cold Bay and for improving medical care in King Cove. AEB purchased a $9 million hovercraft and constructed a landing for the hovercraft along the northeastern shore of Cold Bay. The vessel, the 93-foot *Suna-X*, operated from a landing site in Lenard Harbor while a road was under construction to the intended northeast landing site, and it had a landing site across the bay just south of the existing Cold Bay Dock. This allowed for a 14-mile hovercraft trip that could be completed in 17 minutes under favorable conditions. The hovercraft functioned as the primary marine connection between King Cove and Cold Bay and successfully evacuated 30 medical patients out of King Cove to the Cold Bay Airport from 2007 to 2010. Ultimately, however, local officials determined it was too costly to operate and could not operate in waves above 6 feet or winds above 30 miles per hour. The hovercraft was inoperable 30 percent of the time due to a combination of maintenance down-time and weather conditions beyond its operational capabilities.

The AEB moved the hovercraft to Akutan Island, where it ferried mail and seafood processing workers to a new airport on Akun Island about 6 miles away; however, the operation still required a large annual subsidy and was shut down in February 2014 to be replaced with helicopter service. In an April 2, 2014, article published by KUCB (Unalaska Community Broadcasting), AEB Administrator Rick Gifford was quoted as saying that the hovercraft service was unsustainable, costing about $3 million per year to operate. Further, he said that the helicopter service was cheaper, costing about $2 million per year, but not cheap enough. Gifford indicated that the AEB continues to look for access to the Akutan/Akun airport that it can support for the long term—perhaps via a ferry—but the capital costs of such an alternative are a major obstacle.

This document examines options for using the new road for access to a new marine terminal, a new airport, or a new heliport north of Mount Dutton, at the end of the road. Variations on these alternatives also are considered as ways to solve the long-standing problem of unreliable access across the bay or to Anchorage, primarily for medevac purposes.

2 Objectives, Scope of Work, and Methods

The U.S. Department of the Interior, through the U.S. Fish and Wildlife Service, has requested the U.S. Army Corps of Engineers, Alaska District, to assess three transportation modes that would not include a road through Izembek NWR. For each alternative, the assessment includes:

- **Description:** A narrative description of each alternative assessed, built off of multiple past studies but configured uniquely based on current conditions and understanding of the need, including a road that has been extended northward to a favorable airport and vessel launching area on the northeast side of the bay near the southern boundary of Izembek NWR.
- **Costs:** Costs of construction in projected 2015 dollars, and costs of maintaining the alternative over 75 years (standard annual operations and maintenance [O&M]). Replacement costs including major overhauls and replacement of system components are not included.
- **Risks:** Risks related to permitting, funding, and operating each alternative. Although each is given a numerical score, this is considered a qualitative risk assessment, a tool to help examine risks but not a determinant of which alternative is best overall.
- **Dependability:** The dependability of each alternative, defined as "the average percentage of time a minimum of four King Cove residents can successfully be transported to Cold Bay on a monthly basis for a one-year period." The document presents the amount of time in each month of a typical year that each alternative would be expected to operate as required, based primarily on monthly weather records.

Methods for assessing costs, risks, and dependability are further described below.

This document provides up-to-date information about marine, fixed- wing, and helicopter aircraft transportation modes. It specifically makes no recommendation regarding which mode might be most favorable, but presents high-level data to further the discussion.

2.1 Method Used to Assess Costs

Estimates of probable cost were developed for each alternative discussed in this document, assuming a 75-year life. These costs are considered Class 4 as defined by ASTM International (E2516-11), an organization that sets technical standards used globally. Class 4 costs, by definition, typically use stochastic methods and are used for projects that are in the conceptual phase of development. The alternatives herein fit into this conceptual category.

Many of the alternatives presented in this document use concepts (e.g., boats, helicopters) that have been evaluated in previous reports for transportation alternatives between King Cove and Cold Bay or in the region (e.g., Akutan). These earlier reports are more fully discussed below in Section 3. This report uses an analogous approach, which provides high-level estimates—not detailed estimates—by comparing costs for historical projects with similar features (e.g., Akutan Airport) to the project being estimated. Historical costs were brought forward to 2015 dollars using standard

cost indices. This technique, which is also known as top-down estimating, is often used to estimate costs when only conceptual details about the project are available.

Capital and operations (including maintenance) costs are provided. For purposes of this document, construction of any alternative is assumed to occur in 2020, although some alternatives likely would take more than one construction season to complete. To allow comparison between alternatives, net present values for capital and operating costs are provided using a discount rate of 5 percent and an inflation rate of 2.7 percent. All costs are reported as 2015 dollars.

2.2 Method Used to Assess Risk

Risks for marine and aviation alternatives were assessed qualitatively using a risk assessment method developed by the Federal Aviation Administration (FAA) and incorporated into a risk assessment workbook published by the U.S. Forest Service and Department of the Interior, Bureau of Land Management. This method uses a matrix to relate the likelihood of an outcome with its consequences to determine the level of risk it represents. The matrix, along with definitions, appears in Appendix A.

The matrix combines the likelihood of an event (frequent, probable, occasional, remote, improbable) with the anticipated severity of the outcome or event (catastrophic, critical, marginal, negligible). These result in a combined level of risk, each assigned a score:

1. Low
2. Medium
3. Serious
4. High

Scoring multiple risks for each alternative this way enables the calculation of an average score, allowing for easy comparison among alternatives. However, the process is necessarily subjective, and the risks are not weighted for relative importance. This can be misleading if the exercise is viewed as being more than mostly qualitative. The exercise is meant as a tool for evaluating alternatives but is not meant to produce a final, definitive answer about which alternative is best. Further, the scope of this assessment did not allow for additional evaluations of risk, such as weighting various risks, assessing risk by season, or creating separate risk assessments for different types of risk. Appendix A presents lists of key risks associated with the alternatives—both the risks of implementing each alternative and the risks of operating them once the project is complete.

2.3 Method Used to Assess Dependability

The definition of dependability presented near the beginning of this section calls for an assessment by month. Dependability of any of the alternatives was determined to be primarily a function of wind and weather in any given month. Wind speed and direction were identified as most critical to the dependability of both the marine and fixed-wing aviation alternatives. Wind and other weather information drove dependability for the helicopter alternative.

The alternatives presented were conceptually designed with the area's weather in mind, so dependability of many of the alternatives is relatively high, based primarily on weather. The following sections on each alternative indicate annual dependability ranging from about 70 percent to virtually 100 percent. Many other factors may contribute to dependability, including maintenance issues with the equipment used, human factors such as illness of a pilot or how quickly a vessel operator can reach the vessel, and snow and ice on the road between the clinic in King Cove and the vessel port, airport, or heliport.

Several of the marine and aviation alternatives make use of the existing road between King Cove and the northeast shore of Cold Bay. Anecdotal evidence suggests that there are snow and avalanche hazards that could make portions of the road impassable at times. While this has been identified as a potential risk and could impact dependability, further investigation would be necessary to more accurately quantify the impacts on road travel. This study assumes that regular maintenance of the road, together with an appropriate level of staffing and equipment, would reduce the risk of an impassable road on dependability of medevac access. Thus, these hazards, when compared to wind, are not assumed to be a primary driver of the dependability of the alternatives considered.

Appendix B presents wind data used for all of the marine, airport, and helicopter alternatives.

2.4 Method Used to Assess Medevac Travel Time

The calculation of travel time was based solely on travel for medevac purposes. It was assumed that most medical evacuations would start from the King Cove clinic or from the population center at King Cove. However, the alternatives would operate differently from each other. The marine and helicopter alternatives would cross the water body of Cold Bay to meet a medevac aircraft at the Cold Bay Airport, and the airport alternatives would provide for the medevac aircraft to meet a vehicle on the eastern shore of Cold Bay, without a need to cross the bay. Because the alternatives would operate in different ways, the travel time was calculated for all from the City of King Cove to Ted Stevens Anchorage International Airport (ANC). From ANC, a patient could be delivered to any of three hospitals, all approximately equidistant from the airport. This analysis did not try to determine travel time from ANC to an Anchorage hospital.

Travel time was calculated by adding together each leg of the journey. The calculations assumed average speeds for automobile, ferry, aircraft, and helicopter transportation, and multiplied those speeds by the distance to be traveled under each mode. No time was included for transfers; the calculations are based solely on the times needed for each mode once underway. For the airport alternatives, it is assumed that the time on the road (estimated at 1 hour) would be equal to or greater than the time required for the medevac aircraft to arrive from its home base.

Appendix C presents the estimated medevac times from the City of King Cove to ANC for each alternative.

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3 Existing Information and Past Studies

This document is built upon existing information and past studies, and presents updates to previous studies. Most of the critical engineering research regarding airport and docking locations, marine vessel types, and weather issues was completed previously.

The annotated bibliography at the end of this document (see Section 7) is a list of past studies completed on the topic of transportation alternatives between King Cove and Cold Bay. Most of these were examined in preparation of the current document, but a few studies provided key information. The primary documents referenced were the following:

- "King Cove-Cold Bay Transportation Improvement Assessment: Available Marine Technologies Technical Memorandum" (Glosten Associates 1998) provided important background for the marine ferry alternative.
- "Technical Memorandum, King Cove-Cold Bay Transportation Improvement Assessment: Two Selected Marine Options" (Glosten Associates 1998) provided important design information about the marine ferry alternative.
- "Cold Bay Ferry Study" (Glosten Associates 1999) provided additional information specific to the ferry alternative.
- "King Cove-Cold Bay Transportation Improvement Assessment: Facilities Concept Report" (HDR and Parson Brinckerhoff 2000) provided extensive information on air and marine alternatives, including five appendices listed separately in the bibliography for this *Assessment of Non-Road Alternatives*.
- *King Cove Access Project Final Environmental Impact Statement* (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service 2003) provided extensive information regarding both air and marine alternatives.

Existing planning studies also inform the current effort. According to the 1994 *Alaska Intermodal Transportation Plan*, DOT&PF, the AEB, and the Cities of King Cove and Cold Bay identified the need for improved access between King Cove and Cold Bay to increase the safety, reliability, and convenience of travel to and from King Cove by eliminating dependence on the city's inadequate air facilities; to reduce redundant infrastructure and associated costs; and to strengthen the regional economy. Since that time, the focus has narrowed somewhat to safety and medevac capabilities for King Cove. The Omnibus Public Land Management Act of 2009 (Public Law 111-11), as well as the 2003 EIS related to this issue, focused on a road to be "used primarily for health and safety purposes… and only for noncommercial purposes."

Past Marine Vessel Work. Some of the critical selection criteria established by the AEB for the marine route alternative were identified in the *Project Description for the King Cove Access Project, 7th Revision* (OASIS Environmental, Inc. 2003), and are summarized as follows:

- Reliability 95 percent of the year
- Capability of travel year-round, during all anticipated weather conditions. This includes significant wind and wave heights.

- Ability to travel through up to 12 inches of solid bay ice.
- Suitable for carrying passengers, as well as vehicles with "roll-on/roll-off" capability.
- Cost-effective and sustainable acquisition, operation, and maintenance.

Previous studies identified several potential marine vessel alternatives, including hydrofoils, high-speed catamarans, and ground-effect-type crafts. Many of them offered advantages and quick traverse times in fair weather and calm, ice-free seas. However, the ability to operate year-round and under adverse weather conditions common in this area eliminated many of the marine alternatives under consideration. The studies provided to the AEB identified two viable marine alternatives based on the above criteria:

1. Large purpose-built hovercraft capable of transporting passengers and vehicles
2. Ice-capable monohull ferry suitable for all expected weather and sea conditions

As discussed in Section 1.2, the AEB purchased a purpose-built hovercraft. It operated successfully for approximately 3 years between Lenard Harbor, near King Cove (see Figure 1), and the City of Cold Bay. But ultimately it was taken out of operation because it was too costly to maintain and, in part, because it could not operate about 30 percent of the time. This document reexamines primarily Option 2, the ice-capable monohull ferry.

An ice-capable monohull ferry of sufficient size has been identified as a viable alternative that could meet the marine transportation criteria developed by the AEB. The "Cold Bay Ferry Study" (Glosten Associates 1999) identified a concept vessel that could meet these criteria with a stated 100 percent operability in the weather and ocean conditions of Cold Bay. It is further described in Section 4.

Past Aviation Work. DOT&PF's *King Cove – Cold Bay Facilities Concept Report and Assessment of Transportation Need*, published in 2000, found that flight operations by Pen Air, the only commercial air carrier serving King Cove at that time, were restricted to operating in daylight hours under Visual Flight Rules (VFR). Due to the frequency of bad weather (i.e., non-VFR conditions), flights in and out of King Cove were often delayed or canceled. The report cited a letter written by Pen Air President Orin Seybert which stated that "Due to terrain there will never be other than VFR daylight-only operations possible, with better than average weather necessary."

The 2000 DOT&PF report determined that the best available alternative site for a new airport was located on the northeastern shore of Cold Bay, northwest of Mount Dutton.

4 Marine Alternative

4.1 Introduction to Ferry Concept

The ferry concept includes a vessel capable of transporting people and vehicles in virtually all weather conditions and the terminal (dock) facilities needed on both ends of its route. Although the ferry has a longer traverse time than the hovercraft, it appears to be more reliable based on anecdotal information about the approximate 30 percent downtime experienced by the hovercraft during its operation in Cold Bay. Ferries are used widely as a primary means of marine transportation in Alaska, as evidenced by the 3,500 miles of ferry routes and more than 30 communities serviced that make up the Alaska Marine Highway System. Three alternative ferry routes have been identified as viable for marine travel between King Cove and Cold Bay:

- Alternative 1a, Northeast Ferry (with a terminal on the northeast shore of Cold Bay)
- Alternative 1b, Lenard Harbor Ferry (with a terminal on the northern shore of Lenard Harbor)
- Alternative 1c, Direct Ferry (with a terminal in the City of King Cove)

See Figure 2 for the locations of the ferry terminals.

Each alternative would have a dedicated terminal built onto the existing Cold Bay Dock. Each would include a similar ferry terminal, built new, on the King Cove side of the bay. It is assumed that the ferry would be typically moored at the ferry landing on the King Cove side, as this would be most expedient in the event of a medevac situation. These alternatives are described further below.

The three routes provide different combinations of ferry travel time versus driving time to reach the ferry, and exposure to different risks. For example, Alternative 1c has a longer overall travel time and higher exposure to rough sea conditions, but eliminates the risks associated with impassable roads due to heavy snow or avalanches.

All alternatives use the existing Cold Bay Dock. Based on preliminary analysis, there does not appear to be a site within practical distance of the Cold Bay Airport that provides significant advantages or more protection from wind and wave action than the existing dock location. Further investigation is warranted to validate the preliminary assumptions used in this document.

While the primary purpose of the ferry under consideration is medevac, the vessel likely would be used to establish a regular, year-round ferry service between King Cove and Cold Bay. While it is unlikely that the ferry would be used to its full capability, it could make up to three daily round trips between King Cove and Cold Bay. The fares collected from an established ferry schedule would help offset the annual operating expenses associated with the ferry transportation alternative. It is also worth noting that the King Cove Airport is assumed to continue to function under this alternative. This means that, under many conditions, a medevac flight could occur from the King Cove Airport. The ferry would be particularly useful in conditions that were too turbulent, too cloudy, or at night, when use of the King Cove Airport would not be recommended.

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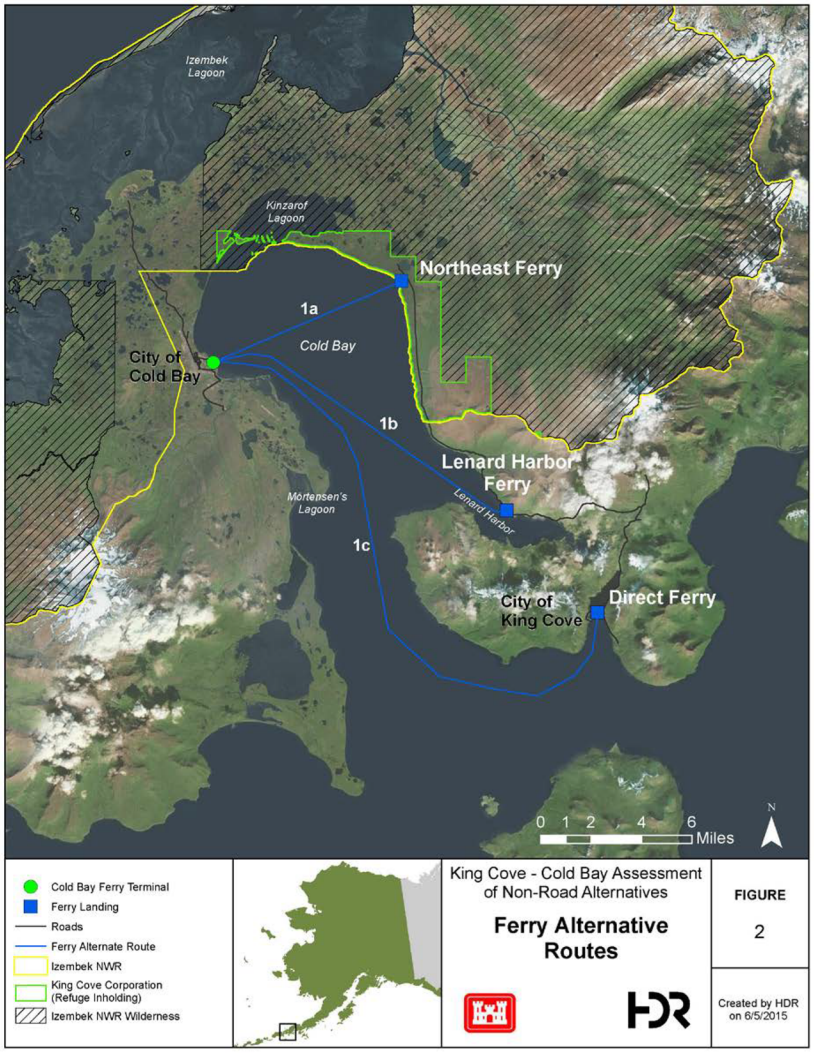


Figure 2. Ferry Alternative Routes

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4.2 Detailed Descriptions—Marine Alternatives

4.2.1 Facilities Common to all Marine Alternatives

The three alternative ferry routes are summarized in the following sections. Most components, including the vessel itself, Cold Bay dock modifications, and the basic mooring and terminal facilities on the King Cove side, would be the same.

The Vessel. The ferry vessel under consideration would have an approximate length of 150 feet, a beam of roughly 42 feet, and a draft of 12 to 14 feet. Sea conditions are the main driver in specifying a vessel of this size. The beam and length of the vessel were optimized based on the wave characteristics in Cold Bay to provide year-round capability and minimize passenger discomfort. The ferry could carry up to 150 passengers, in addition to 19 passenger vehicles and two large trucks. The hull would be strengthened to American Bureau of Shipping ice class A0 classification, capable of travelling through first-year sea ice up to 12 inches thick, and would be capable of operating in virtually all anticipated weather conditions within the waters of Cold Bay. It would likely have a dual-rudder/twin-screw configuration with engines producing approximately 1,200 horsepower. It would be an open deck design with a centrally located island to accommodate passengers and the pilothouse, as opposed to an enclosed ferry with overhead pilothouse. This would allow for ferrying over-height vehicles. Freeboard and bulwark height would be large to maintain the vessel's safe seakeeping capability in the expected sea conditions throughout the year, as well as to minimize shipping of green water and spray ice accumulation on the deck. This is the vessel described in the "Cold Bay Ferry Study" (Glosten Associates 1999).

Cold Bay Ferry Terminal. Figure 3 illustrates a concept for the Cold Bay ferry terminal. The Cold Bay terminal would make use of the first 1,200 feet of the existing Cold Bay Dock to access a new transfer ramp that would branch off the existing trestle and provide access to a floating barge (transfer platform). The barge would function as the landing area for the ferry ramp. The ferry would breast against new dolphins (piling structures bedded in the sea floor, either monopole dolphins with floating donut fenders or five-pile breasting dolphins), and would power in to wingwalls near the moored transfer barge during loading and offloading operations. The mooring site would be located far enough offshore to take advantage of existing bathymetry and eliminate the need for dredging. A breakwater would be required to minimize wave exposure, and would be approximately 900 feet long with a crest elevation +15 feet. The side slopes of the breakwater would range between 1.5H:1V and 2H:1V. The ferry would have ramps off both the bow and stern that could be set down on the transfer platform to allow for vehicle and passenger transfer. This configuration would allow for forward drive-on and drive-off of transported vehicles. Although not currently the case, this analysis assumes that the Cold Bay terminal would have vessel refueling capabilities for the ferry. This would most likely consist of a mobile tanker truck that could drive aboard the ferry to fill the tanks. It is assumed that a tanker truck with refueling capabilities can be made available in Cold Bay.

Ferry Terminal near King Cove. A configuration similar to the one described above for Cold Bay would be used for all three marine alternatives for the ferry terminal providing access from King Cove, although a new trestle would also be required at these locations. In all cases, power would be

required for navigation and facility lights. It is assumed that power would be provided at outlying sites using a battery with light-emitting diode lights and provisions for small-scale solar and/or wind charging. Specifications and photographs of these systems are available online; see, for example, www.sealite.com.

It is also possible that a power line could be buried along the road from the existing King Cove Airport, but it is not included in the cost estimate due to the relatively high cost. For Alternative 1c, located at the City of King Cove, power is assumed to be readily available.

The following sections provide more detail on the terminal locations near King Cove, including figures showing conceptual layouts of marine terminal configurations.

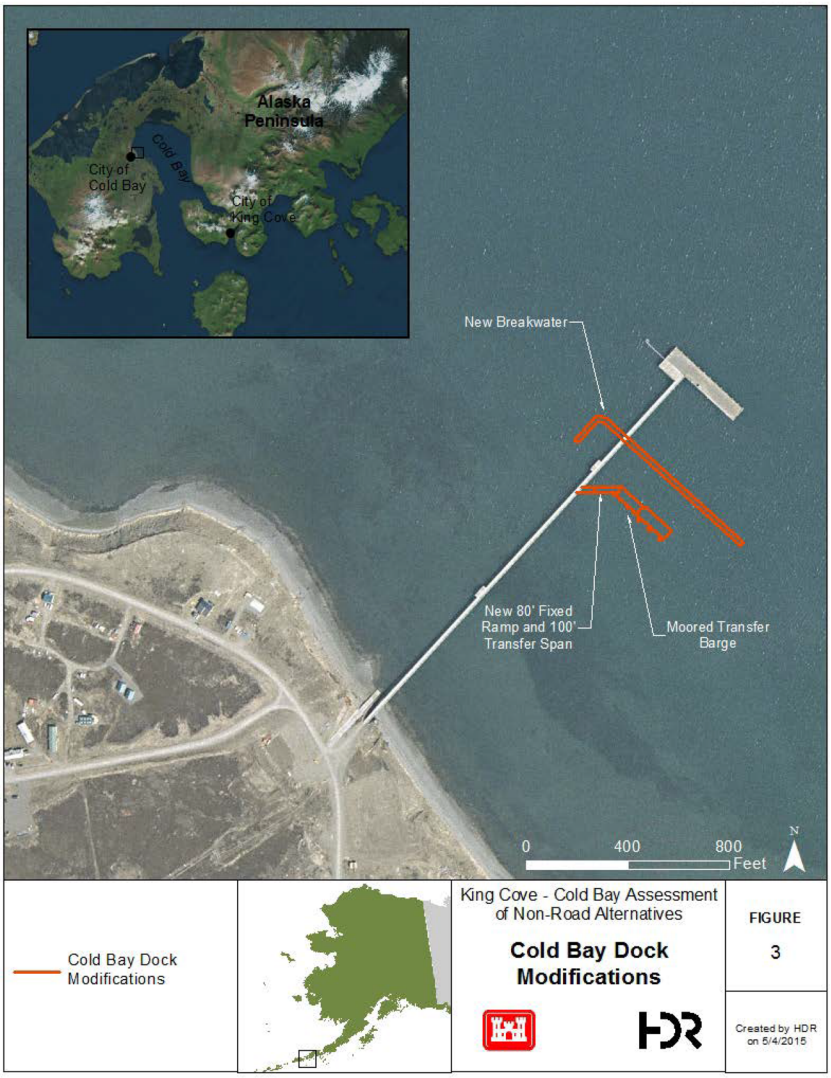


Figure 3. Cold Bay Dock Modifications

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4.2.2 Northeast Ferry (Alternative 1a)

The Northeast Ferry alternative would include a ferry terminal on the northeast shore of Cold Bay, just south of the Izembek NWR boundary, and would include modifications to the existing dock at Cold Bay. The new dock/trestle is anticipated to be about 1,000 feet long to suit existing bathymetry and prevent the need for dredging. A breakwater would be required to minimize wave exposure, and would be approximately 850 feet long with a crest elevation +15 feet. The side slopes of the breakwater would range between 1.5H:1V and 2H:1V. See Figure 4.

Access to the Northeast Ferry terminal would be via the recently constructed road that provides access to the unused hovercraft landing site on the northeast shore of Cold Bay. The route would consist of approximately 21 miles of travel by road, followed by 6 miles of ferry travel to the Cold Bay ferry terminal.

This alternative has a longer road and more exposure to avalanche hazards and hazardous road conditions than the Lenard Harbor Ferry alternative, but it provides the shortest ferry travel time and slightly less severe wind and wave exposure than the other ferry alternatives.

Total travel time from King Cove to ANC Airport for medevac purposes is estimated to be 3.5 hours. Appendix C provides a complete look at medevac travel times for the marine, airport, and helicopter alternatives.

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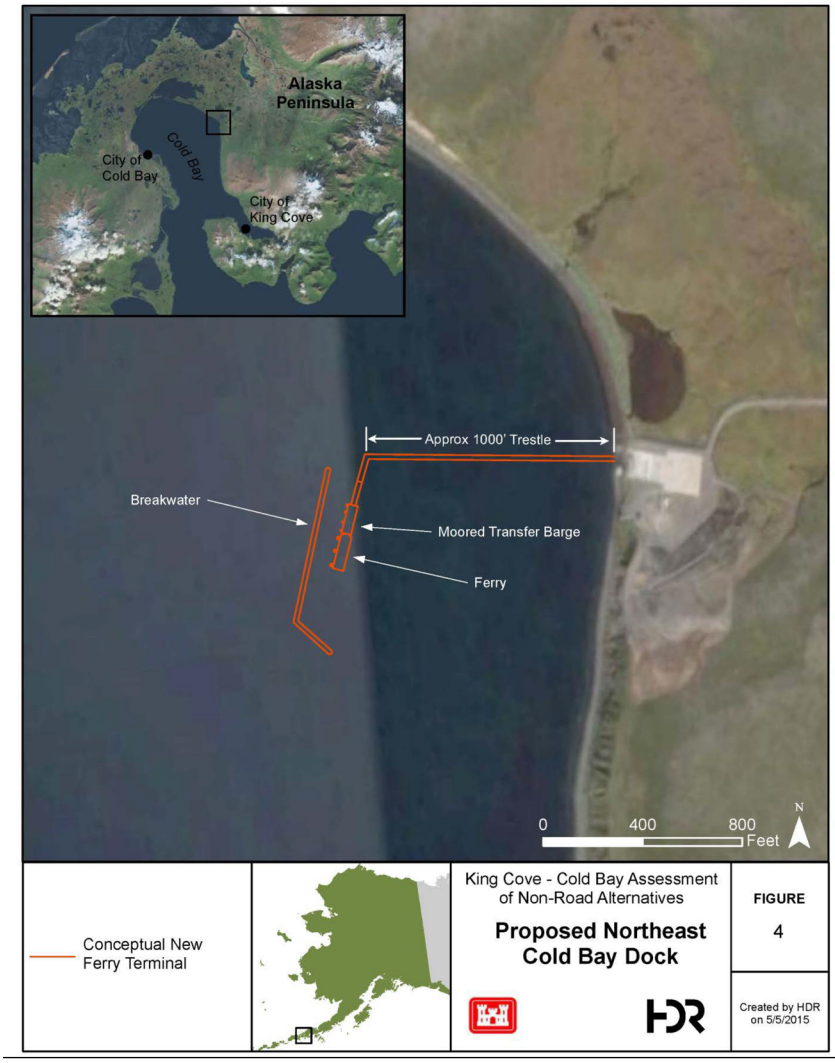


Figure 4. Proposed Northeast Cold Bay Dock

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4.2.3 Lenard Harbor Ferry (Alternative 1b)

The Lenard Harbor alternative would include a ferry terminal at Lenard Harbor and modifications to the dock at Cold Bay. The terminal at Lenard Harbor would be relatively protected from wind and wave exposure, and it is assumed it would not require a breakwater. The existing bathymetry is such that the new trestle would need to be approximately 300 feet long to eliminate the need for dredging. See Figure 5.

Access to the Lenard Harbor ferry terminal would be via the existing road between King Cove and Lenard Harbor. Travel from King Cove would include 11 miles on the road and a 14-mile ferry trip to Cold Bay.

Avalanche hazards and the potential for snow-covered roads exist along the road route between King Cove and Lenard Harbor, which could make the route impassable at times. However, it is assumed that the occurrence of avalanches is very infrequent. Most of the road is the same road used to access the existing King Cove Airport.

Total travel time from King Cove to ANC for medevac purposes is estimated to be 3.7 hours. Appendix C provides a complete look at medevac travel times for the marine, airport, and helicopter alternatives.

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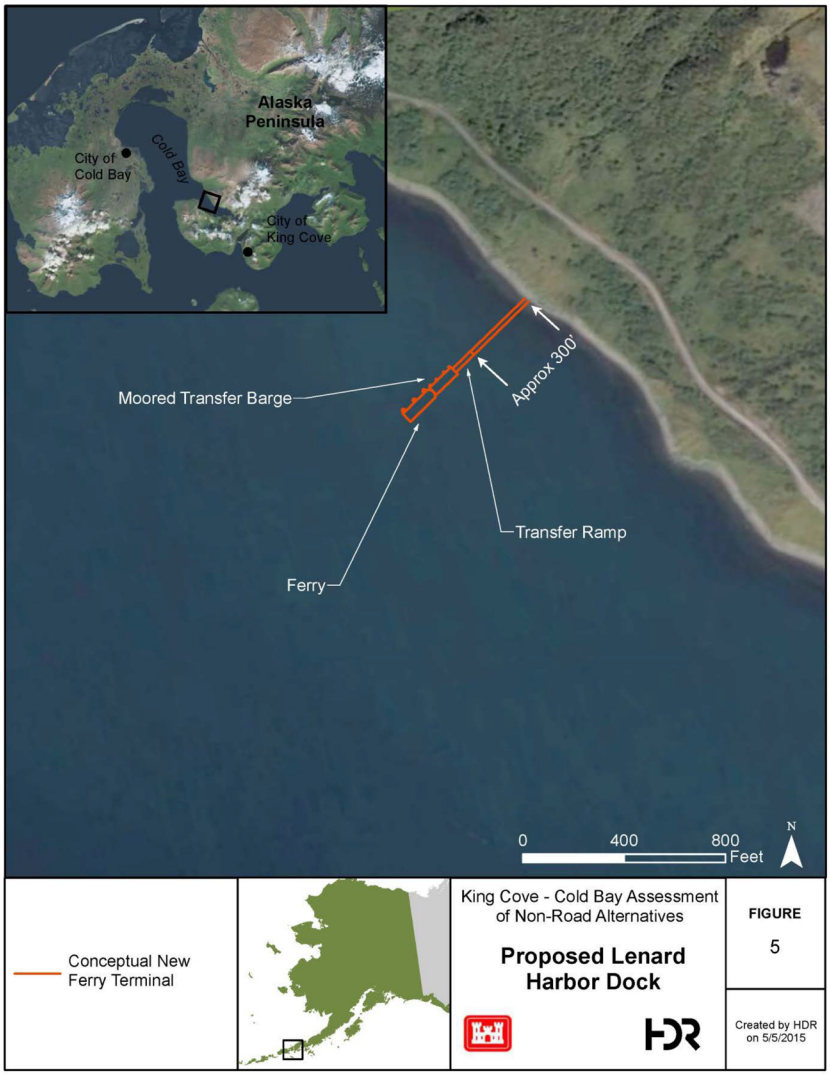


Figure 5. Proposed Lenard Harbor Dock

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4.2.4 Direct Ferry (Alternative 1c)

The Direct Ferry alternative would include a ferry terminal on the north shore of King Cove and modifications to the dock at Cold Bay. The existing bathymetry is such that the new trestle would need to be approximately 400 feet long to eliminate the need for dredging. A breakwater would be required to minimize wave exposure, and would be approximately 950 feet long with a crest elevation +15 feet. The side slopes of the breakwater would range between 1.5H:1V and 2H:1V. See Figure 6.

The terminal would be linked closely to existing King Cove infrastructure and would use existing roads, with virtually no road construction or road-based transportation time required. It would have immediate access to the existing electrical power supply in King Cove. The ferry route would include a stretch of approximately 13 miles in waters open to the Pacific Ocean between King Cove and Cold Bay, and it would have a the longest total transit time with more susceptibility to harsh sea conditions and passenger discomfort. The route would consist of approximately 27 miles total of ferry travel. The advantage to this alternative is the elimination of exposure to snow and ice, as well as to the avalanche risk for the road portion of the route that may be experienced in the other alternatives.

Total travel time from King Cove to ANC for medevac purposes is estimated to be 5 hours. Appendix C provides a complete look at medevac travel times for the marine, airport, and helicopter alternatives.

4.2.5 Comparison of Mode Options

Table 1 provides a comparative summary of the relative pros and cons of the three marine alternatives. This is meant to summarize the material above and to include relative information on the costs presented later in this document, but is not necessarily a complete list of criteria that should be used for selection of ferry terminal locations. Rather, it is a tool to present a quick snapshot of some relative advantages and disadvantages.

Table 1. Summary Comparison of Marine Alternatives

Alt	Description	Comfort / Rough Seas	Road Hazards[a]	Medevac Travel Time	Operations and Maintenance Cost	Capital Cost	Sum
1a	Northeast Ferry	0	-1	0	0	-1	-2
1b	Lenard Harbor Ferry	0	0	0	0	0	0
1c	Direct Ferry	-1	1	-1	-1	-1	-3

1=Favorable; 0=Neutral; -1=Unfavorable
[a] Road hazards such as snow/avalanche

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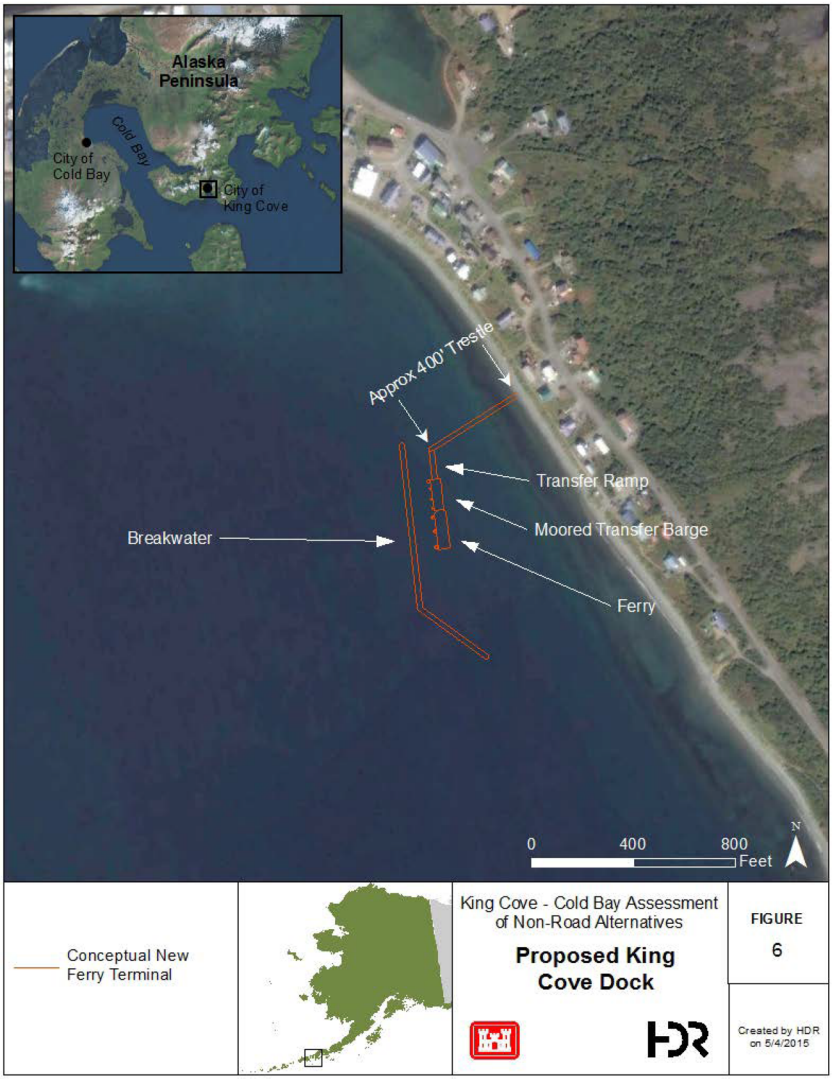


Figure 6. Proposed King Cove Dock

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4.3 Construction and 75-Year Life-Cycle Costs

Notes on methods used to determine costs for this document appear in Section 2. The capital costs are similar for all marine options, based on the assumption that the Direct (King Cove) and Northeast Ferry terminals would require a breakwater, while the Lenard Harbor Ferry terminal would be sufficiently protected to eliminate the need for a breakwater. The vessel type and modifications to the Cold Bay Dock are identical for all three options. It is assumed that existing roads would provide sufficient access without upgrades. Capital costs for the marine facilities and ferry vessel were based on the unit costs and quantities provided in the "King Cove Facilities Concept Report."

Table 2 summarizes the costs of the marine alternatives. The table reports capital costs in 2015 dollars and—for simplicity—uses the assumption that the ferry and docks would be built in 1 year, although vessel construction in reality would take longer. O&M costs shown are the costs projected for the first year of operations, in 2015 dollars. The O&M costs were bundled with the capital costs and applied over 75 years, accounting for inflation, and then brought back to 2015 dollars using a discount rate to provide a net present value (cost) of each alternative. Note that it is assumed the vessel life would be at least 75 years. The 75-year costs do not include provisions for periodic major replacements, such as engine replacement, as that level of analysis is beyond the scope of this study.

Table 2. Costs of the Marine Alternatives

Description	Alt 1a	Alt 1b	Alt 1c
Capital Costs (millions)	$41.8	$29.9	$39.0
Annual Operations and Maintenance Costs	$872,300	$925,600	$1.14 M
75-Year Life-Cycle Costs (2015 Net Present Value, millions)	$65.7	$56.7	$71.9

Notes:
All costs are presented in 2015 dollars. 75-year costs are escalated to 2095 and then brought back to 2015 dollars.
Capital costs include the ferry vessel and all dock/terminal components on both shores of Cold Bay, including provisions for electricity and (where applicable) a breakwater.
Vessel operating costs are based on an annual average of 1.5 round trips per day using a four-person crew. O&M costs also include (where applicable) road maintenance for any road dedicated to ferry access.

Annual O&M costs are based on the cost breakdowns provided in the "King Cove Facilities Concept Report" for the ice-strengthened ferry vessel, as well as maintenance costs for shoreside facilities. The additional wear and tear on the vessel associated with the Direct Alternative (Alternative 1c) has been captured by scaling up the hull and machinery maintenance costs based on the additional travel distance. Below is a list of items captured in the ongoing annual operating costs.

- Vessel hull maintenance costs, based on vessel weight
- Vessel machinery costs, based on propulsion and generator power output
- Crew costs to operate the vessel
- Fuel/lube oil costs as a function of travel distance and propulsion power
- Longshore/berthing costs
- Shoreside facilities maintenance

- Road maintenance (based on DOT&PF guidance and includes annual cost associated with grading, plowing, dust control, minor repairs, and similar activities necessary to keep the roads safe and operational).

4.4 Risks

Appendix A details key risks associated with the marine alternatives, including risks to implementing the alternative and risks of operating it once the project was complete.

Methods for assessing risk for all marine, airport, and helicopter alternatives are explained in Section 2. Multiple types of risks were identified and ranked using a matrix (shown in Appendix A). An average risk score was calculated. For the marine alternatives, the average risk scores were:

- Northeast Ferry (Alternative 1a): 2.4—medium-serious
- Lenard Harbor Ferry (Alternative 1b): 2.4—medium-serious
- Direct Ferry (Alternative 1c): 2.4—medium-serious

For all marine alternatives, the most important risks identified were related to operations at night and in extreme weather, permitting, and delays in getting the project built in an area with known important wildlife resources both on land and in the ocean. In addition, acquisition of the funding needed for construction and ability to financially sustain the operation in perpetuity are also important risks.

The principal risks to the marine alternatives are:

- Capital funding: This is critical to implementation of any of the marine alternatives.
- Operational funding: Annual O&M costs of the ferry system are unlikely to be offset by passenger fares. Inability to adequately fund annual operations was a primary factor in the AEB halt of the hovercraft marine connection in 2010.
- Regulatory permitting implications of installing a breakwater and construction of the ferry terminals: Effects to marine mammals and seabirds are an issue for the marine alternatives.
- No redundancy in the ferry system in the event of unplanned maintenance.

The most important risk *differences* among the marine alternatives are related to whether the ferry will be required to cross open water. Alternative 1c (Direct Ferry) has higher risk in a few key areas:

- Long travel time, which would put certain critical patients at greater risk of death or long-term complications. Recovering stroke victims, for example, have much better outcomes with prompt medical intervention at a hospital.
- Rough seas/open water travel, which could mean the vessel would not travel or could be at risk of capsizing if it did.

4.5 Dependability

Dependability of the marine alternatives would be based on:

- Wind speed (and related wave conditions) on the ferry route.
- Snow conditions, including snow and ice on the road and potential avalanche closure of the road (for Alternatives 1a and 1b).
- Downtime for maintenance of the ferry vessel, including maintenance of its ramps, and the trestles that allow vehicles and passengers to board.
- Unplanned maintenance and repair work that could take the ferry out of service

It is assumed the ferry would not operate in wind speeds exceeding 40 knots (46 MPH), based on operational restrictions and landing limitations in place at other ferry terminals in the region. Historic instantaneous wind data (see Appendix B) were examined to determine how often winds would exceed 40 knots (46 MPH). It is assumed that the vessel would be able to operate in any weather up to that speed, and this is the primary determinant of dependability. Table 3 indicates dependability by month based on wind speed.

Table 3. Marine Alternatives, Dependability by Month (%)

Alt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1a	99.9	99.5	99.6	100	99.9	99.7	100	100	99.9	99.6	99.9	99.7	99.9
1b	99.9	99.5	99.6	100	99.9	99.7	100	100	99.9	99.6	99.9	99.7	99.9
1c	99.8	99	99.2	100	99.8	99.4	100	100	99.8	99.2	99.8	99.4	99.6

Note: No wind data were obtained for the open water portion of Alternative 1c. However, it is assumed that the impact of more wind and wave exposure would increase the inoperable time period by a factor of 2 in comparison with Alternatives 1a and 1b.

Based on 3 years of historical wind data available (see Appendix B), the percentage of time during an average year that wind speeds exceed 40 knots (46 MPH) is 0.128 percent. On that basis, the ferry has 99.6 percent to 99.9 percent dependability based on historic wind data and the proposed ferry route. However, for medevac purposes, the dependability of all transportation modes in the medevac chain should be considered for total dependability. For example, there may be rare times when winds are below the operating threshold for ferry travel, but exceed the safe air travel threshold at Cold Bay Airport based on combined wind direction and speed.

For purposes of this conceptual document, based on 40-knot (46-MPH) wind speed, it is assumed that dependability for Alternative 1c (Direct Ferry) would be slightly less than dependability for the other two marine alternatives. While Glosten Associates' *Marine Alternative Study* indicated the proposed ferry vessel should provide 100 percent weather capability in the waters of Cold Bay, this may not be the case in the open water stretch. The potential for more severe sea conditions with the seafaring capability of the monohull ferry vessel should be investigated in more detail should this alternative be carried forth into a full feasibility study.

Alternatives 1a and 1b (Northeast Ferry and Lenard Harbor Ferry) have a slightly higher weather dependability for the ferry route portion, but the risk of heavy snow on the road and of avalanches reduces the dependability of the road portion of these alternatives. The Direct Ferry from King Cove (Alternative 1c) would not require driving out of the community. Although the scope of this study did not include local stakeholder input, further investigation into the expected frequency of

impassable road conditions on the access road from King Cove to the northeast shore of Cold Bay is recommended during more detailed studies to validate the assumptions used in this analysis and to determine with greater precision which route has the highest overall dependability. This could include gathering information from and possibly interviewing local residents based on their historical observations.

4.6 Other Marine Considerations

Ferry Revenue. It is likely that the ferry would not operate at capacity most of the time, and thus revenues would not cover the operating expenses. The "King Cove-Cold Bay Transportation Improvement Assessment: Facilities Concept Report" indicates that the ferry may be loaded to 16 percent of capacity on average, based on several trips per day and operating 5 days per week.

Smaller Landing Craft. There have been recent discussions about the possibility of using a much smaller landing craft to provide a marine link between King Cove and Cold Bay. This type of craft can land directly on the shore with minimal infrastructure needed, and can carry a vehicle as well as passengers. However, shore landings for this type of craft can often be carried out only in ideal conditions. Given the prevailing wind and sea conditions within Cold Bay, it is questionable how often the landing craft could be used in this fashion.

These smaller vessels typically are not ice-capable and thus would not be able to perform shore landings in ice conditions. While the vessel could be fitted with a deeper and heavier hull to accommodate light ice and heavier seas, it would then have a draft that prevented it from shore landings and would require some type of infrastructure on both ends of the route.

The landing craft would not meet the design criteria developed by AEB for the marine route alternative. At this time it appears that it would not be suitable for year-round medevac use. Further study of this option may be warranted, however, as a limited-purpose marine vessel for medevacs.

Special Purpose Medevac Boat. Another possible alternative that warrants further study is the use of a smaller, special purpose severe-duty rescue boat for the sole purpose of medevac. These rescue boats can come in a variety of configurations, such as self-righting or shore-landing-capable vessels. A vessel of this type would require significantly less capital investment in both the vessel and the terminal requirements, and lower maintenance costs.

There are, however, a few drawbacks to this alternative. The first is that these vessels are typically not ice-capable and thus not able to reach the shore in the event of bay ice. Another drawback to a smaller, special-purpose rescue boat is that passengers would be subjected to significantly more pitch and roll of the vessel and overall discomfort during inclement weather than with the larger monohull ferry vessel. Lastly, this alternative would have the sole purpose of medical evacuation. It would not be suitable for customary passenger travel and could not transport roll-on/roll-off cargo. Some rescue vessels have a bow ramp that could allow for transfer from the boat to a shore-based, ice-capable vehicle such as a small hovercraft or snowmobile in the event of significant bay ice. Specifications and photographs of this kind of boat and other specialty boats are available online; see, for example, www.safeboats.com or www.kvichak.com.

5 Airport Alternatives

5.1 Introduction to Airport Concept

The airport concept includes a new airport built for the City of King Cove that would function better in poor weather conditions, including instrument capability, than the existing airport. The one technically feasible site for a new airport that is away from mountain hazards and wind-channeling terrain and does not physically encroach into the Izembek NWR is located northwest of Mount Dutton and just east of the existing (abandoned) hovercraft landing. This site affords airspace with few obstructions on approaches from the north, west, or east. An approach from the south would be high over a mountain ridge west of Mount Dutton. Two airport alternatives, designed to accommodate two different medevac aircraft, are considered:

- Alternative 2a (5,000-foot paved runway)
- Alternative 2b (3,500-foot gravel runway)

These alternatives are further described below. See Figure 7.

The two airport alternative designs give specific consideration to accommodating aircraft used in the Aleutian Region for medevac operations. The typical destination for medevac flights from the Aleutian region is Anchorage. The primary medevac provider for the Aleutians, Guardian Flight, maintains a remote base at Unalaska. Guardian Flight would probably prefer to respond to medevac needs at King Cove from Unalaska. Guardian Flight uses both Learjet 35 aircraft (a small jet) and Beechcraft King Air aircraft (a twin-engine turboprop airplane), but because of the limited length of the runway at Unalaska (4,100 feet), Guardian Flight bases only the King Air there. A response with the Learjet 35 would come from Anchorage, possibly increasing costs for the medevac provider. Airport Alternative 2a is designed with the Learjet 35 in mind. Alternative 2b is designed for the Beechcraft King Air.

The Learjet 35 is a multi-role business jet that can carry eight passengers. It has a cruise speed of 480 mph. The Beechcraft King Air has two turboprop engines and can carry up to 13 passengers. It has a cruise speed of 330 mph. Each of the aircraft can be configured for use as an air ambulance.

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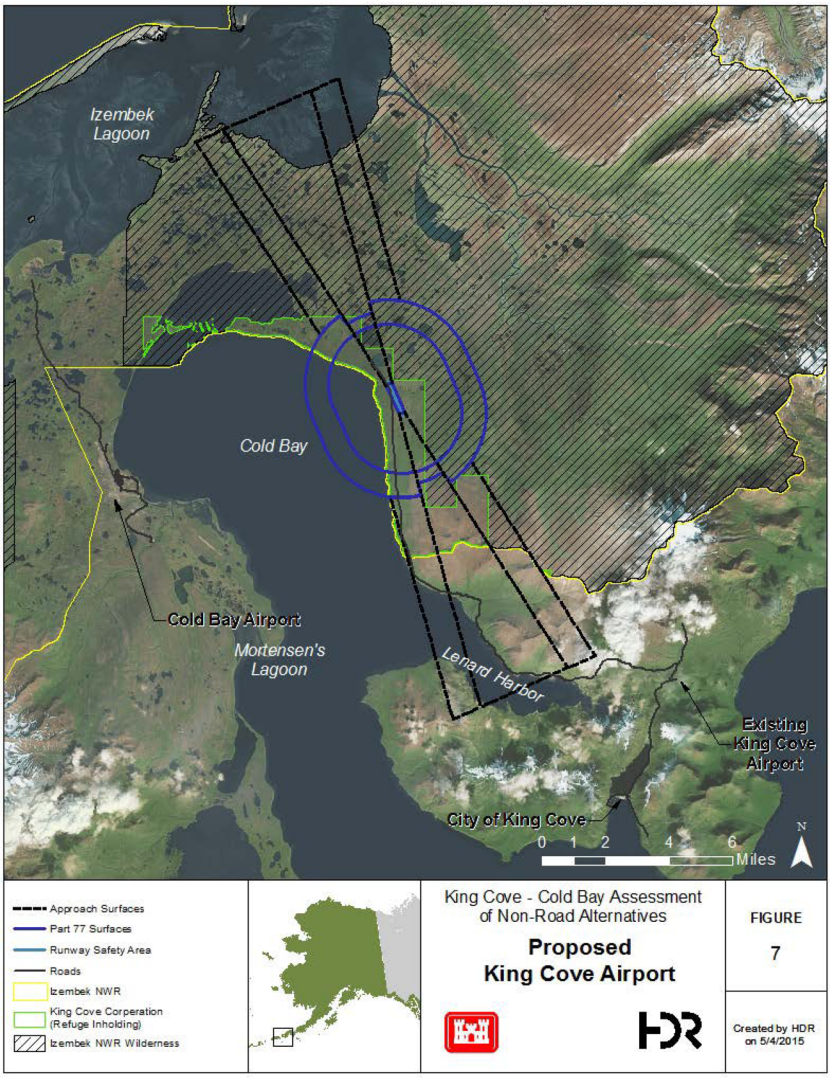


Figure 7. Proposed King Cove Airport

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The new airport would be close enough to the Cold Bay Airport that aircraft movement patterns could be coordinated between the two airports by the Cold Bay FAA Flight Service Station. Local reports are that wind and cloud conditions would still be severe at the proposed airport site, but—much like the Cold Bay Airport—there would be fewer obstructions to compound weather and visibility problems, and instrument-based flights would be more practical than at the existing King Cove Airport.

In accordance with the Statement of Work for this project, both airport alternatives include a Category 1 Instrument Landing System (ILS). However, the FAA is no longer installing ILSs; their preferred system is now RNAV (aRea NAVigation), a method of instrument flight rules (IFR) navigation based on a satellite-based Global Positioning System. Regardless, for design and estimating purposes for this project, ILS approach dimensional and clearance standards also apply to RNAV approaches.

The new airport would include a runway, an apron, and a connecting taxiway. The runway alignment is assumed to be the same as for Cold Bay Airport's primary runway, located approximately 9 miles directly west across the bay from that location. A site-specific wind study could alter this assumption or require the addition of a crosswind runway.

Power for the runway lighting system and navigation aids is assumed to be generated on-site. Snow removal for the road would be provided from King Cove. Snow Removal Equipment (SRE) dedicated for airport maintenance would be housed in an SRE Building located on the apron.

The airport site would be accessed by an existing gravel road extending 21 miles from the City of King Cove. Between King Cove and the existing airport, a distance of about 5 miles, the road is two lanes wide with a gravel surface. From the existing airport to the proposed airport site, a distance of about 16 miles, the road is a single-lane gravel road with inter-visible turnouts for passing. As described in this document, the road would not be widened. Given the low level of traffic expected on this route, one driving lane with turnouts is appropriate. It would also minimize maintenance costs.

5.2 Detailed Descriptions—Airport Alternatives

Both airport alternatives would be designed to the same FAA A/B II standard. The “Critical Aircraft” is defined by the FAA as the most demanding aircraft anticipated to operate at the airport more than 500 times per year—in this case, a Cessna 208, as defined by the DOT&PF *Alaska Transportation Plan* (2004). The Cessna 208 and Beechcraft King Air (the primary medevac aircraft serving the region) have similar runway requirements. For Alternative 2a, however, the runway is extended and paved to support occasional use by the more demanding Learjet 35. Figure 8 illustrates the standard airport layout and the relative length of the 3,500-foot runway versus the 5,000-foot runway.

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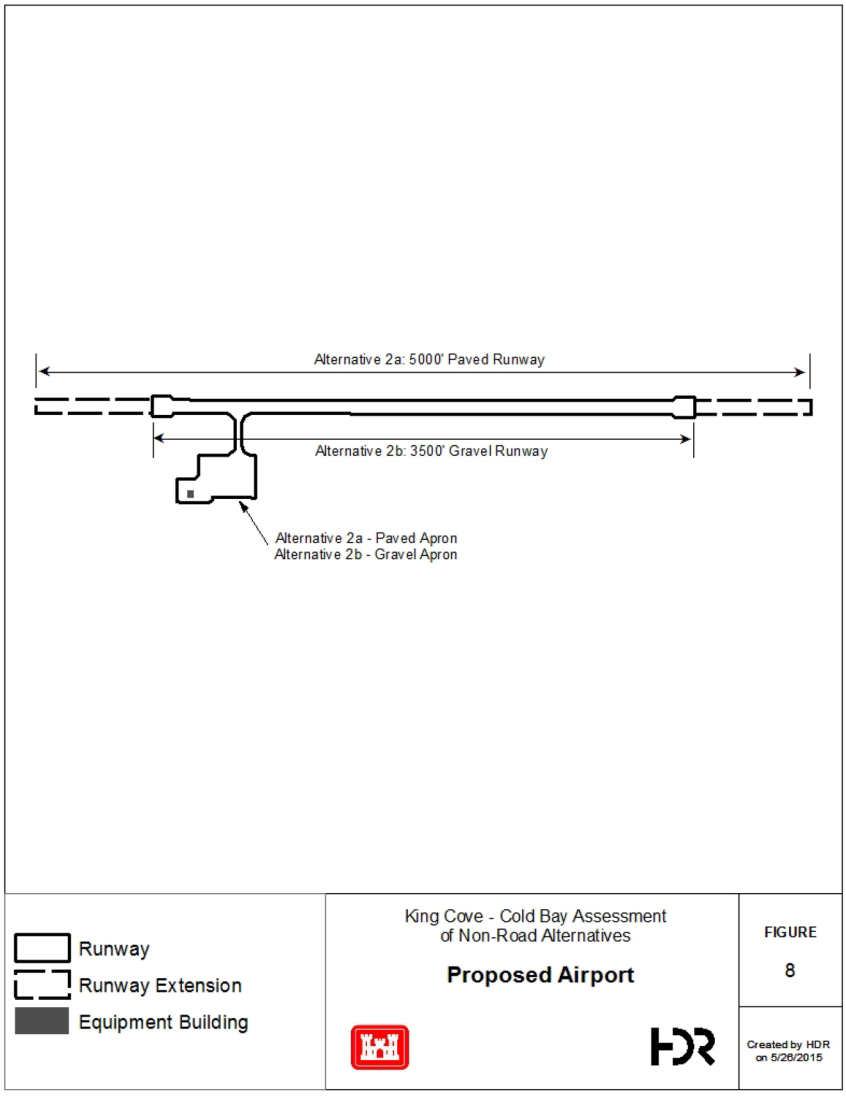


Figure 8. Airports Concept

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Either alternative would include Object Free Areas around the runway (300 feet on the sides, 500 feet at each end) and Runway Safety Areas (150 feet on the sides, and 300 feet at each end of the runway), per FAA standards. The airport would be fenced.

The following sections detail the differences between the two alternatives.

5.2.1 Alternative 2a (5,000-foot runway/Learjet 35)

Alternative 2a would provide a runway 75 feet wide and 5,000 feet long, to accommodate occasional service by the Learjet 35. The difference between the "standard" length for an A/B II airport (3,500 feet) and the desired length would have to be approved by the FAA if federal Airport Improvement Program (AIP) funds were to be used to construct the airport.

The Learjet does not operate on a gravel surface, because gravel can cause catastrophic damage to jet engines. The runway therefore would be paved. In addition, to maintain adequate friction on the runway surface to permit safe operations in winter conditions, the runway would require a higher level of maintenance than is common at gravel surface airports. At minimum, this would require a grader, a mechanical broom, a broom truck, and a sand spreader. This equipment would be stored in a heated, three-bay snow removal equipment (SRE) building, and the airport would probably be staffed by an airport maintenance staff of three in the winter, and possibly fewer in summer.

Total medevac travel time from King Cove to ANC using the Learjet 35, inclusive of traveling the road between King Cove and the new airport, is estimated to be 2.4 hours.

5.2.2 Alternative 2b (3,500-foot runway/King Air)

Alternative 2b would provide a runway 75 feet wide and approximately 3,500 feet long. The runway surface would be gravel. This runway length, width, and surfacing are very similar to conditions at the existing King Cove Airport and are standard for the aircraft typically serving community airports in the region from the Unalaska Airport regional hub. The Beechcraft King Air is an appropriate aircraft to operate at the small gravel-surfaced community airports typical of the Aleutian Region. Airport-dedicated snow removal equipment typical for unpaved remote airports—a bulldozer, a grader, or both—would be sufficient for surface maintenance. Maintenance equipment would be stored in a heated, single-bay SRE building. Maintenance staff for the access road would share airport maintenance duties, but additional staff would be required.

The runway length proposed for this alternative (3,500 feet) is slightly longer than the 3,300-foot runway proposed for King Cove by the *Southwest Alaska Transportation Plan Revised* (DOT&PF 2004), but matches the runway length of the existing King Cove Airport.

Total travel time from King Cove to ANC using the King Air, inclusive of traveling the road between King Cove and the new airport, is estimated to be 3 hours.

5.2.3 Comparison of Airport Options

Table 4 provides a comparative summary of the relative pros and cons of the two airport alternatives. This is meant to summarize the material above and include relative information on costs presented later in this document, and is not necessarily a complete list of criteria that should

be used for alternative selection. Rather, it is a tool to present a snapshot of some relative advantages and disadvantages.

Table 4. Summary Comparison of Airport Alternatives

Alt	Description	Medevac Travel Time	Operations and Maintenance Cost	Appropriate for Critical Aircraft	Sum
2a	5,000-ft Runway/Learjet 35	1	-1	-1	-1
2b	3,500-ft. Runway/Beechcraft King Air	-1	1	1	1

1=Favorable; 0=Neutral; -1=Unfavorable

5.3 Construction and 75-Year Life-Cycle Cost

Capital costs used in this document for construction of a new airport are based on recent construction of the Akutan Airport, on Akun Island. The lump sum total for the airport is the basis for figures used here, with adjustments for runway length and surface type, with allowance for inflation.

The capital costs would be higher for Alternative 1a because it would have a longer runway, it would be paved, and the runway would require a larger building to house SRE. The paved runway for jet service would require more maintenance at higher cost. Both would require maintenance of an additional 16 miles of road to reach the airport. Table 5 shows capital costs and O&M costs. This document presents the full costs of the alternatives. If the existing King Cove Airport were to be closed upon completion of the new airport, which is likely, the existing operating and maintenance costs accruing to the DOT&PF operating budget for the existing airport would be replaced by the costs of the new airport.

Table 5 reports capital costs in 2015 dollars and assumes that all airport alternatives would be built in 1 year. O&M costs shown are the costs projected for the first year of operations, in 2015 dollars. The O&M costs were bundled with the capital costs and applied over 75 years, accounting for inflation, and then brought back to 2015 dollars using a discount rate to provide a net present value (cost) of each alternative. Note that this does not include provisions for periodic replacement of snow removal equipment, the navigation system, or recurring tasks such as repaving (Alternative 2a only) the runway .

Table 5. Costs of the Airport Alternatives

Description	Alt 2a	Alt 2b
Capital Cost	$84 M	$47 M
Annual Operations and Maintenance Cost	$674,700	$223,300
75-Year Life-Cycle Cost (Net Present Value)	$97.0 M	$49.3 M

Notes:
All costs are in 2015 dollars. M = million.
Capital costs include a complete airport. Assumes no road construction necessary.
O&M costs include airport O&M and road O&M for the road segment dedicated to airport use.
The 75-year total cost is escalated to account for inflation over time and brought back to 2015 dollars.
This table presents the full costs of the alternative. Potential savings to the DOT&PF operating budget resulting from closure of the existing King Cove Airport are not included.

5.4 Risks

Methods for assessing risk for all marine, airport, and helicopter alternatives are explained in Section 2. Risk assessment tables for all of the alternatives appear in Appendix A. Multiple types of risks were identified and ranked using a matrix (shown in Appendix A). This qualitative assessment resulted in an average risk score. For the airport alternatives, the average risk scores were:

- Alternative 2a (5,000-foot runway): 2.4—medium-serious
- Alternative 2b (3,500-foot runway): 2.5—medium-serious

The risks identified in the assessment tables for each of the two airport alternatives are nearly identical. Those considered to be of the greatest concern are discussed below.

The risks of night operations and air travel in general for the King Cove-Cold Bay area, as well as for the Aleutian Island region, are significant. Various sources describe the Aleutian Islands as the windiest and rainiest region in the United States. The mountainous terrain can cause dangerous turbulence, increased wind speeds due to venturi effects, and accumulation of clouds. These factors, together with the remoteness of both communities, place a premium on the appropriate implementation and use of technology, pilot training for good decision-making, and timely weather data collection and reporting, particularly when night operations compound the regional weather effects.

The road between King Cove and the identified airport site passes through three possible avalanche areas, based upon a preliminary examination of aerial photography. Two of these areas are located along the road to the existing King Cove Airport. The third is located about 5 miles west of the existing airport. Further information on the frequency of avalanches should be collected, but anecdotal accounts indicate that avalanches are not annual occurrences. In addition to representing a risk to travelers on the road, an avalanche would effectively close the new airport until the avalanche debris could be cleared from the road.

Animal behaviors are a concern for the safe operation of the airport, due mainly to the potential for conflicts with animals on the runway and birds in the runway approach airspace. Fencing would

mitigate the danger from animals but not guarantee removal of all danger. Snow drifts, failure to close gates, and poor maintenance can facilitate animal passage over or through fences. Avoiding the creation of additional water bodies through the use of best management practices during construction and the revegetation of disturbed terrain near the airport would help reduce the concentration of birds near the airport.

The ability to secure construction funding would be critical to the success of either alternative. The most likely source of funding would be a grant from the FAA Airport Improvement Program (AIP). Acceptance of an AIP grant carries with it many obligations, including the ability to ensure the long-term support of the facility, which would include the maintenance of any associated single-purpose airport access road. In Alaska, DOT&PF is most often the owner/operator of rural public airports. In assuming responsibility for the cost of the proposed airport, DOT&PF could minimize the impact to their maintenance budget by closing the existing King Cove Airport. However, DOT&PF also would assume the cost of maintaining approximately 16 miles of roadway past the existing airport that they are not currently maintaining. Given recent reductions to the state operating budget, this could be problematic. In theory, these same ownership and maintenance responsibilities could be assumed by the AEB or the City of King Cove, but the cost and administrative burdens may be beyond the abilities of either entity to support.

5.5 Dependability

Weather is the chief determinant of dependability of access in the Aleutian Islands region. How weather affects the safety and operability of airports within the region is highly site-specific. On-site weather data were not collected for the proposed airport site, but data collected at Cold Bay Airport were evaluated as a reasonable proxy. It should be noted, however, that the topography differs at the two sites. About 5 miles to the southeast of the proposed airport site is a ridge (elevations less than 3,000 feet) off Mount Dutton. For the Cold Bay Airport, Mount Frosty is somewhat higher (6,300 feet) and lies about 9 miles to the southwest. Winds coming from the southeast at the proposed airport site likely would generate more turbulence than might be expected at Cold Bay Airport from that direction. The mountains may also tend to affect the accumulation or departure of cloud cover differently.

Cold Bay Airport has an ILS but, according to information compiled by the Medallion Foundation,[3] is not able to support safe operations 100 percent of the time.

Guidance provided by the Medallion Foundation also indicates that, at wind speeds above 35 knots (40 MPH), commercial pilots should consider not operating at Cold Bay Airport. Wind conditions are expected to be similar at the proposed site. An examination of monthly average wind speeds at the airport (see Appendix B) shows that higher wind speeds occur most often in the winter—October through March. There is not a strong seasonal trend in wind direction on an annual basis at Cold Bay (Weatherspark.com 2015). For this document, a wind speed of 40 knots (46 MPH) was used as a cutoff. Appendix B shows that wind speeds of 40 knots (46 MPH) are exceeded about

[3] The Medallion Foundation is an Alaska-based non-profit organization that promotes aviation safety. Medallion guidance, compiled from information submitted by its member commercial air carriers, identifies thresholds for safe wind speeds at Alaska's commercial airports, beyond which aircraft operations are not advised.

0.128 percent of the time on an annual basis. Note that the data set for June is probably an anomaly, possibly an issue with the data collection equipment.

Finally, the snow events and avalanche-prone areas on the 21-mile access road may reduce dependability an additional 5 percent, but only in the winter.

Wind data used for all marine, airport, and helicopter alternatives appear in Appendix B. Table 6 indicates dependability of Alternatives 2a and 2b by month based on wind speed.

Table 6. Alternatives 2a and 2b, Dependability by Month (%)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
94.9	94.6	94.6	95.0	95.0	94.9	95.0	95.0	95.0	94.7	95.0	94.8	94.9

Notes: Based on 2012-2013 wind measurements at Cold Bay Airport. Dependability is based primarily on winds each month at greater than 40 knots (46 MPH). Data source: National Climatic Data Center.

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6 Helicopter Alternative

6.1 Introduction to Helicopter Concept and Common Design Features

The helicopter concept is modeled on the helicopter service AEB currently employs between the community of Akutan and the community's airport on Akun Island. This service would feature the following elements:

- A leased helicopter (Bell 212 or similar on floats) and crew. Minimum on-station crew would consist of one pilot and one mechanic.
- A lighted heliport facility with a pad of 100 feet by 100 feet.
- A hangar of 40 feet by 80 feet for sheltering the helicopter when not in use, providing space for performing helicopter maintenance, and storing spare parts and fuel. The hangar would accommodate a B 212 helicopter with the main rotor blades folded.
- Road access from King Cove.

This document examines four possible alternative locations on the King Cove side of the bay:

- Alternative 3a: Northeast Heliport (located on the northeast shore of Cold Bay)
- Alternative 3b: Lenard Harbor Heliport (located at the north shore of Lenard Harbor)
- Alternative 3c: Peninsula Heliport (located on the peninsula at the western end of Lenard Harbor)
- Alternative 3d: King Cove Heliport (located at the City of King Cove)

The features above would be common to all locations. See Figure 9 for heliport locations.

The Cold Bay Airport does not have a designated heliport, but it is assumed the helicopter would follow normal landing procedures and hover-taxi to and from an existing aircraft parking apron. It is assumed the helicopter and crew would be located on the King Cove side of the bay; however, see "Other Considerations" at the end of Section 6.

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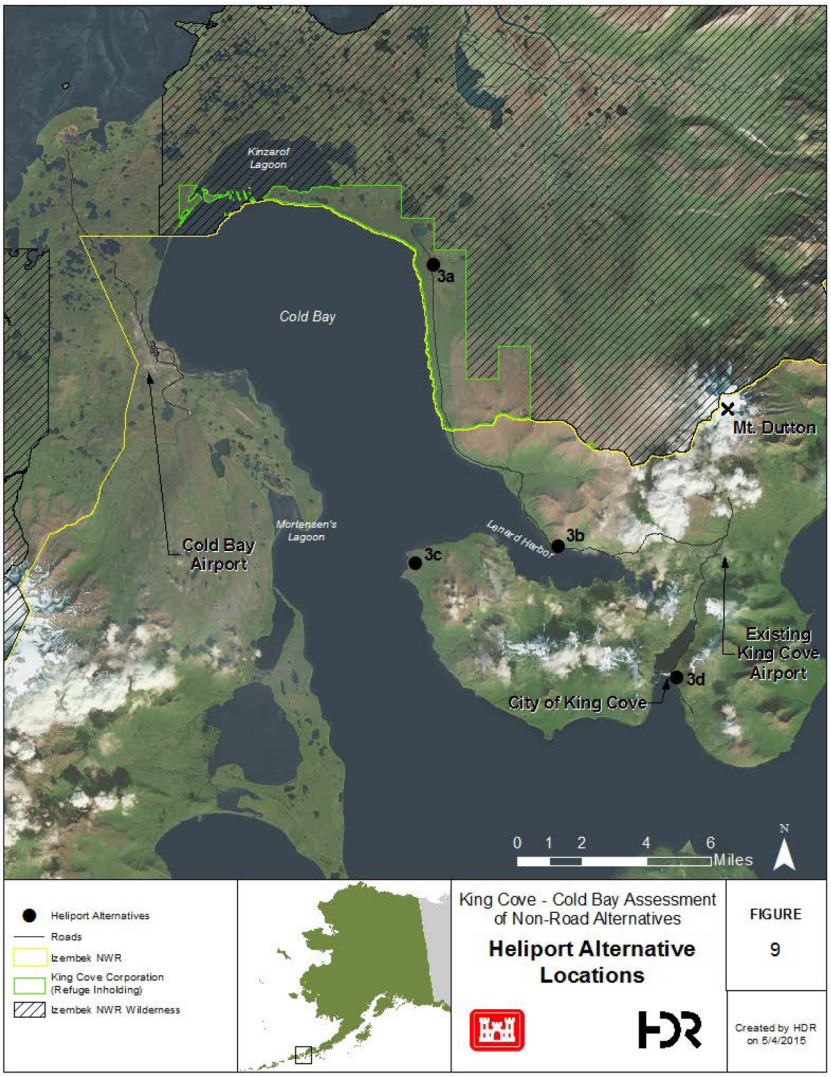


Figure 9. Heliport Alternative Locations

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6.2 Detailed Descriptions—Helicopter Alternatives

The new heliport would be designed in accordance with FAA Advisory Circular No. 150/5390-2C, *Heliport Design*, with lighting and navigation aids appropriate for operation in Visual Flight Rules (VFR) conditions. Figure 10 illustrates the basic layout. The dimensions of the heliport would be based on a Design Helicopter; i.e., the most demanding helicopter anticipated to use the facility. In this case, the Design Helicopter would be the U.S. Coast Guard (USCG) HH-60 (currently based in Kodiak). Although the Bell 212 (or similar) helicopter would provide routine service between King Cove and Cold Bay, it is anticipated that the USCG HH-60 would operate occasionally at King Cove in conjunction with search and rescue missions or if the Bell 212 (or similar) was out of service. The hangar to support helicopter service would be sized to accommodate the Bell 212, because there should be no need to shelter the USCG helicopter in King Cove.

The following sections describe the four alternative sites and outline the advantages and disadvantages of each.

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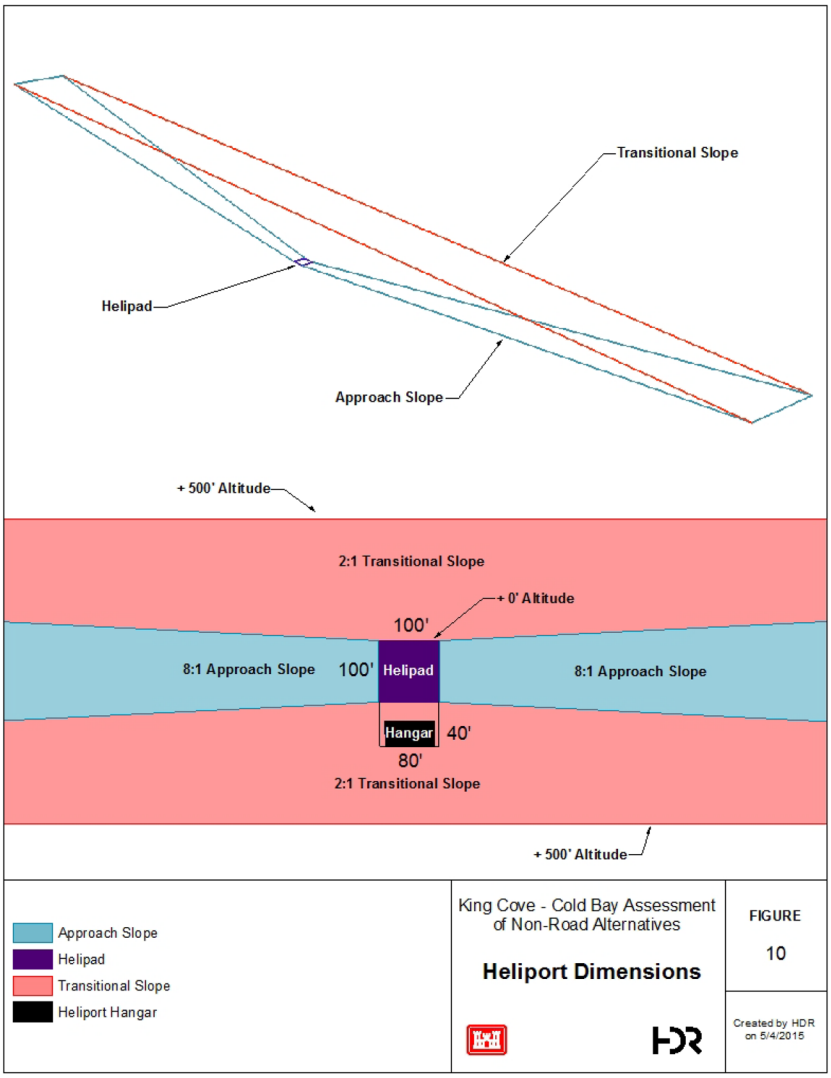


Figure 10. Heliport Dimensions

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6.2.1 Alternative 3a (Northeast Heliport)

This alternative provides a heliport at the existing (abandoned) hovercraft ramp on the northeast shore of Cold Bay. Passengers and crew would access the heliport via the existing 21-mile road from King Cove. Electricity for lighting and navigation aids is assumed to be generated on site.

This alternative may be able to incorporate the existing concrete hovercraft ramp into the design of the heliport, which could reduce construction costs. The cost estimate in this document does not reflect this potential cost reduction. A detailed verification of the usability of the existing concrete ramp for use in this alternative was beyond the scope of this assessment. However, this activity should be considered if this alternative is carried forward to a feasibility study. The approaches to this location are unobstructed. This site is accessible by an existing road.

Potential disadvantages of this site include its distance from King Cove. Access to this site requires maintenance of 16 miles of road beyond the existing King Cove Airport that are not currently maintained. The heliport owner would be required to ensure maintenance of the road if federal funds were used to construct the heliport.

Medevac travel time from King Cove to ANC from this location would require 3.1 hours, the longest time required for any heliport alternative. Appendix C provides a complete overview of medevac travel time for the marine, airport, and helicopter alternatives.

6.2.2 Alternative 3b (Lenard Harbor Heliport)

This alternative provides a heliport about 6 miles west of the existing King Cove Airport at an existing materials site near the head of Lenard Harbor. This is the heliport site identified in the *King Cove Access Project FEIS* (2003). Passengers and crew would access the heliport via an 11-mile road from King Cove, about half of which is currently maintained. Electricity for lighting and navigation aids is assumed to be generated on site.

This alternative would incorporate a cleared/filled area produced during construction of the existing road, possibly reducing construction costs. This site is accessible via the existing road.

Potential disadvantages of his site include a constrained location. The approaches to this location are partially obstructed. It is in terrain that could channel winds and trap clouds. Turbulence is likely to occur at this location whenever the prevailing north wind cascades over the mountainous terrain to the north. Access to this site would require the airport owner to ensure maintenance of about 6 additional miles of road if federal funds were used to construct the heliport.

Medevac travel time from King Cove to ANC from this location would require 2.6 hours. Appendix C provides a complete overview of medevac travel time for the marine, airport, and helicopter alternatives.

6.2.3 Alternative 3c (Peninsula Heliport)

This alternative provides a heliport on the west end of a peninsula directly east of Mortensen's Lagoon. Passengers and crew would access the heliport via a 22.5-mile drive from King Cove. Approximately 14 miles of the road currently exists. An additional 8.5 miles of new road would be

constructed through mountainous terrain. Electricity for lighting and navigation aids is assumed to be generated on site.

The approaches to this location are unobstructed. It is also free of terrain that could channel winds and trap clouds.

One disadvantage of this alternative is that access to the site would require construction of 8.5 miles of new road, which also would need to be maintained. The airport owner would be required to ensure maintenance of the road if federal funds were used to construct the heliport.

Medevac travel time from King Cove to ANC from this location would require 2.7 hours. Appendix C provides a complete overview of medevac travel time for the marine, airport, and helicopter alternatives.

6.2.4 Alternative 3d (King Cove Heliport)

This alternative provides a heliport in or adjacent to the community of King Cove. A site selection study would be necessary to determine the most appropriate location for the heliport. Passengers and crew would access the heliport by a relatively short access road of undetermined length.

Access to this location primarily would be via existing roads. Minimal road maintenance would be required to ensure access. Electricity is presumed available nearby.

Disadvantages of this site relate primarily to terrain. Approaches to this location are not unobstructed. It is located in terrain that could channel winds and trap clouds.

Medevac travel time from King Cove to ANC from this location would require 2.1 to 2.2 hours, depending upon whether the helicopter took a straight line route over the mountains or followed the coast west and then north to Cold Bay Airport. This is the least time required by any alternative, because there would be no road travel component. Appendix C provides a complete overview of medevac travel time for the marine, airport, and helicopter alternatives.

6.2.5 Comparison of Heliport Options

Table 7 provides a comparative summary of the relative pros and cons of the four heliport alternatives. This is meant to summarize the material above and include relative information on costs presented later in this document, but is not necessarily a complete list of criteria that should be used for selection of heliport locations. Rather, it is a tool to present a quick snapshot of some relative advantages and disadvantages.

Table 7. Summary Comparison of Heliport Alternatives

Alt.	Location	Use Existing Infra-structure	Un-obstructed Airspace	Weather Conditions	Use Existing Road	Travel Time for Medevac	M&O Cost	Available Electricity	Capital Cost	Sum
3a	Northeast	1	1	1	1	-1	-1	-1	1	2
3b	Lenard Harbor	1	-1	-1	1	0	0	-1	1	0
3c	Peninsula	-1	1	1	-1	-1	-1	-1	-1	-4
3d	King Cove	0	-1	-1	1	1	1	1	1	3

1=Favorable; 0=Neutral; -1=Unfavorable

6.3 Construction Cost and 75-Year Life-Cycle Cost

The construction cost at each alternative location, with hangar, would be approximately the same, at $2.5 million ($1.5 million for the heliport and $1 million for the hangar). There may be small savings for Alternatives 3a and 3b, because they would use existing developments (former hovercraft terminal and former gravel extraction area).

Construction of the heliport would cost about $150 per square foot. Construction of the hangar is estimated at $300 per square foot.

The cost of Alternative 3c (Peninsula Heliport) would include a substantial additional expense, the construction of approximately 8.5 miles of single-lane roadway with turnouts at $3,000,000 per mile, or $25 million.

Table 8 summarizes the costs of the heliport alternatives. The table reports capital costs in 2015 dollars and uses the assumption that any of the heliport alternatives would be built in 1 year. O&M costs shown are the costs projected for the first year of operations, in 2015 dollars. The O&M costs were bundled with the capital costs and applied over 75 years, accounting for inflation, and then brought back to 2015 dollars using a discount rate to provide a net present value (cost) of each alternative. Note that this does not include provisions for periodic maintenance tasks such as replacement of the hangar or navigation system or repaving the heliport.

Table 8. Costs of the Heliport Alternatives (millions)

Description	Alt 3a	Alt 3b	Alt 3c	Alt 3d
Capital Cost	$2.8	$2.8	$28.3	$2.8
Annual Operations and Maintenance Cost	$2.34	$2.25	$2.28	$2.19
75-Year Life-Cycle Cost (Net Present Value)	$78.3	$75.3	$99.1	$73.5

Notes:
All costs are in 2015 dollars.
Capital costs include a complete heliport. Assumes no road construction necessary except under Alternative 3c; road construction accounts for the cost difference for Alternative 3c. Assumes electricity is generated on site.
O&M costs include heliport O&M (at 5% of heliport capital cost each year) and road O&M for the road segment dedicated to airport use.
The 75-year total cost is escalated to account for inflation over time and brought back to 2015 dollars.
This table presents the full costs of the alternative. It does not account for cost reductions that might be possible by using partially developed sites under Alternatives 3a and 3b.

Annual heliport operating and maintenance costs are based primarily on the assumption that the heliport owner would contract with a helicopter company for the helicopter, its pilot, and its mechanic at about $2 million per year. The cost of maintaining the access roads to Alternatives 3a, 3b, and 3c are assumed to be a separate cost (not part of the helicopter contract) at about $8,700 per lane mile per year.

6.4 Risks

Methods for assessing risk for all marine, airport, and helicopter alternatives are explained in Section 2. Risk assessment tables for all of the alternatives appear in Appendix A. Multiple types of risks were identified and ranked using a matrix (shown in Appendix A). This qualitative assessment resulted in an average risk level for each alternative. For the heliport alternatives, the average risk scores were:

- Alternative 3a (Northeast Heliport): 2.6—medium-serious
- Alternative 3b (Lenard Harbor Heliport): 2.5—medium-serious
- Alternative 3c (Peninsula Heliport): 2.6—medium-serious
- Alternative 3d (King Cove Heliport): 2.3—medium (+)

The risks identified in the assessment tables for each of the four heliport alternatives are nearly identical. Those considered to be of the greatest concern are discussed below.

As with the airport alternatives, the risks of night operations and air travel in general for the King Cove-Cold Bay area, as well as for the Aleutian Island region, are significant. Various sources describe the Aleutian Islands as the windiest and rainiest region in the United States. The mountainous terrain can cause dangerous turbulence, increased wind speeds due to venturi effects, and accumulation of clouds. These factors, together with the remoteness of both communities, place a premium on the appropriate implementation and use of technology, pilot training for good decision-making, and timely weather data collection and reporting.

The road between the City of King Cove and the heliport sites for Alternatives 3a and 3b passes through three possible avalanche areas, based upon a preliminary examination of aerial photography. Two of these areas are located along the road to the existing King Cove Airport. A possible third area is located about 5 miles west of the existing airport. Further information on the frequency of avalanches should be collected, but anecdotal accounts indicate that avalanches may not be annual occurrences. In addition to representing a risk to travelers on the road, an avalanche would effectively close the heliports until the debris could be cleared from the road. In addition to the two avalanche areas on the road to the existing King Cove Airport, about 8 miles of the unconstructed portion of the road needed for access to Alternative 3c would be susceptible to avalanches. Alternative 3d would be in or immediately adjacent to the community of King Cove and would be free of road risk and avalanche danger.

Animal behaviors are a concern for the safe operation of the heliports mainly due to the potential for conflicts with birds in the approach and departure airspace. Avoiding the creation of additional

water bodies through the use of best management practices during construction and the revegetation of disturbed terrain near the heliport would help reduce the concentration of birds near the heliport. In the case of Alternative 3d, care should be taken to locate the heliport in King Cove at least 10,000 feet from landfills, sewer lagoons, or waste from fish processing facilities (FAA AC 150/5200-33B).

Securing construction funding would be critical to the success of any alternative. The most likely source of funding for the heliport would be a grant from the FAA AIP. Eligible grant recipients would include DOT&PF, AEB, or the City of King Cove. Acceptance of an AIP grant carries with it many obligations, such as ensuring the long-term support of the facility, which would include the maintenance of any associated single-purpose heliport access roads. For Alternatives 3a, 3b, and 3c, this would include the cost of maintaining approximately 16, 6, and 9 miles, respectively, of roadway beyond the existing airport. Given recent reductions to the state operating budget, this could be problematic.

Although the distances from the heliports to Cold Bay Airport vary, the duration of the helicopter flight would be relatively brief. The time required for a passenger to travel from King Cove to Cold Bay Airport and on to Anchorage is determined in large part by the amount of road travel required. At an assumed speed of 20 miles per hour, the trip by road from King Cove to Alternative 3a would take about 1 hour. Road travel to Alternatives 3b and 3c would require traveling 30 and 40 minutes, respectively. Because Alternative 3d is in or very near the community of King Cove (exact location to be determined), road travel would be almost eliminated, and the length of time required to reach Anchorage would be the lowest of any alternative. The elimination of the road segment, including the time needed to drive it and the potential risk of avalanche, ice, or snow on it, is the primary reason for the slightly lower average risk determined for Alternative 3d when compared to other alternatives.

6.5 Dependability

As with the airport alternatives, weather is the chief determinant of dependability of helicopter access in the Aleutian Islands region. How weather affects the safety and operability of heliports within the region is highly site-specific. Because King Cove Airport does not have automated weather data collection equipment, weather data for Cold Bay Airport were used as a proxy for this project. As with the airport alternatives, wind speeds are an important consideration in determining dependability. Unlike the airport alternatives, however, the heliport alternatives and the leased helicopter service are assumed to operate under VFR only, as is the case with the existing helicopter contract AEB holds for access to the Akutan/Akun Island airport. It would not incorporate navigation aids to allow the helicopters to function in low- or “no”-visibility conditions. Cloud cover increases and visibility decreases in the Aleutian region in summer. Poor visibility is expected to have an adverse effect on dependability in both the winter (10 percent) and the summer (15 percent) at each of the alternative heliport sites. Further investigation may determine that appropriate electronic navigation aids are available and compatible with helicopters offered as part of a leased helicopter service.

Conditions at the Alternative 3a site are anticipated to be somewhat similar to those at Cold Bay, except that topography south and southeast of the new site may contribute to turbulence and wind gusts. Snow events and avalanche-prone areas on the 21-mile access road may reduce dependability an additional 5 percent, but only in winter. Average dependability of access via the Alternative 3a heliport throughout the year is expected to be about 82.6 percent, varying from a high of 85 percent in the summer to a low of about 79 percent in some of the winter months. These percentages are based on wind data, adjusted for summer cloud cover and winter avalanche or snow events.

The topography adjacent to heliport sites 3b, 3c, and 3d is mountainous, unlike the terrain near Cold Bay Airport. Wind in these locations is likely to be accelerated by venturi effects and generate considerably more turbulence than might be expected at Cold Bay Airport. The mountains may also affect the accumulation or departure of cloud cover differently. The chief executive officer for PenAir has been quoted as saying that, on an annual basis, up to 30 percent of scheduled PenAir flights have been cancelled due to weather considerations. PenAir provided the Medallion Foundation with guidance to help identify wind regimes that represent hazardous conditions at King Cove Airport. Given that Alternatives 3b and 3c have similar settings and are reached by traveling access roads of significant length, the dependability assessments for each are similar. The annual average dependability is estimated to be about 67.5 percent varying from a high of 75 percent in the summer to a low of about 60 percent in some of the winter months. Dependability for Alternative 3d is somewhat better, because the access road to the heliport is assumed to be very short. Estimates are based on the PenAir assessment of 70 percent, minus summer clouds and winter avalanche or snow events as appropriate. Dependability and wind data for all marine, airport, and helicopter alternatives appear in Appendix B.

Table 9 shows dependability of the heliport alternatives, by month.

Table 9. Heliport Alternatives, Dependability by Month (%)

Alt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
3a	79.6	79.2	79.2	85	85	79.8	85	85	85	79.4	85	84.5	82.6
3b	60	60	60	75	75	75	75	75	75	60	60	60	67.5
3c	60	60	60	75	75	75	75	75	75	60	60	60	67.5
3d	65	65	65	75	75	75	75	75	75	65	65	65	70

6.6 Other Considerations

While this document generally assumes the new hangar, the helicopter, and the crew would be based on the King Cove side of the bay, it would be possible to locate them at the Cold Bay Airport. The location of the hangar would not affect the time required to medevac a patient to Anchorage unless the heliport and hangar were co-located in King Cove. For the other heliport locations, travel by the patient from King Cove to the heliport and the helicopter's flight from the hangar to the

heliport would occur at about the same time. The following sections present brief consideration of the pros and cons of the hangar location.

6.6.1 Helicopter Hangar on the King Cove Side of the Bay

This alternative does not require the helicopter to cross the open water of Cold Bay from Cold Bay Airport to pick up passengers/patients departing King Cove. The helicopter flight and maintenance crew would likely lodge in King Cove, regardless of whether the heliport were in King Cove or at one of the remote sites. This leads to the pros and cons of this option:

Pro: If the both the King Cove heliport and the hangar were located in King Cove, this alternative would achieve the lowest overall travel time required for medevac and would somewhat facilitate logistical considerations for the helicopter flight and maintenance crew, who would lodge in King Cove.

Con: If the hangar were located at one of the more remote sites on the King Cove side of the bay (i.e., not in King Cove), the helicopter flight and maintenance crew would need to travel to the heliport for flight preparations and helicopter maintenance, which would be more time-consuming overall and could delay medevac flights slightly.

6.6.2 Helicopter Hangar at Cold Bay Airport

Pro: If an existing hangar facility at Cold Bay Airport were available for the helicopter, capital costs could be reduced.

Con: Medevac flights would have to transit to King Cove before picking up a patient, increasing response time. If the King Cove heliport were located at one of the more remote sites, this disadvantage would be negated—the helicopter could easily cross the waterbody of Cold Bay in the time required for the patient to reach one of the remote heliport sites—but the response time still would be greater than if the hangar were in King Cove.

Table 10 summarizes the positive and negative aspects of the hangar locations of the heliport alternatives.

Table 10. Pros and Cons of Hangar Locations

Alt		Flying Time for Medevac	Facilitates Crew Logistics	Capital Costs	Sum
Located on King Cove Side of the Bay					
3a	Northeast Heliport	0	-1	-1	-2
3b	Lenard Harbor	0	-1	-1	-2
3c	Peninsula Heliport	0	-1	-1	-2
3d	King Cove Heliport	1	1	-1	1
Located at Cold Bay Airport					
	Cold Bay Airport	-1	1	1	1

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King Cove-Cold Bay Assessment of Non-Road Alternatives

Appendix A

Risk Matrix and Risk Assessment Tables

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Risk Assessment Matrix				
	Severity			
Likelihood	Negligible IV	Marginal III	Critical II	Catastrophic I
Frequent A				
Probable B				*High 4*
Occasional C			*Serious 3*	
Remote D		*Medium 2*		
Improbable E	*Low 1*			

Severity Scale Definitions	
Catastrophic	Results in fatalities and/or loss of the system.
Critical	Severe injury and/or major system damage.
Marginal	Minor injury and/or minor system damage.
Negligible	Less that minor injury and/or less than minor system damage.

Likelihood Scale Definitions		
Frequent	Individual Fleet	Likely to occur often. Continuously experienced.
Probable	Individual Fleet	Will occur several times. Will occur often.
Occasional	Individual Fleet	Likely to occur sometime. Will occur several times.
Remote	Individual Fleet	Unlikely to occur, but possible. Unlikely but can reasonably be expected to occur.
Improbable	Individual Fleet	So unlikely, it can be assumed it will not occur. Unlikely to occur, but possible.

Source:
U.S. Forest Service and Bureau of Land Management. April 2010.
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Qualitative Risk Assessment Alternative 1a - Northeast Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing / damaged or power loss to navaids and dock lights	Emergency response plan; use of electronic chart plotting systems and GPS with hazards identified	Remote	Marginal	Medium	2	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training, implement crew management procedures and relief crew members	Occasional	Critical	Serious	3	Costs and availability of relief crew members questionable for this region.
3	Weather - Ferry travel	Life-Safety, Operations	High winds or extreme wave conditions that could blow the vessel off course or capsize the vessel	Restrict operations based on weather conditions	Remote	Catastrophic	Serious	3	Assume ferry can operate 99% of the time based on weather limitations.
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and the ferry terminal	Staffing, equipment, and operational funding for road maintenance	Occasional	Critical	Serious	3	Assume road is passable 95% of the time, with 5% downtime due to avalanches or heavy snow.
5	Sea Ice	Operations		Requires Ice Class A0 vessel to safely navigate Lenard Harbor	Occasional	Negligible	Low	1	

Qualitative Risk Assessment Alternative 1a - Northeast Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Long-Term Operational Funding	Financial	Annual maintenance and operations expenses could exceed available funding	Annual ferry operating costs can be partially offset by passenger fares with scheduled ferry service, as well as usage fees for medevac	Probable	Catastrophic	High	4	Based on assumption that AEB would be responsible for subsidies needed and on recent AEB experience with hovercraft and helicopter.
7	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting for marine structures could take up to a year depending on permit requirements and regulatory hurdles.
8	Vessel Maintenance	Operations	Dry dock required every 2 years, 40-day planned downtime; no vessel redundancy for unplanned maintenance	Contract a backup vessel and plan dry dock and maintenance during mild weather seasons with no sea ice risk	Occasional	Negligible	Low	1	
9	Faunal Response to Construction and Operations	Environmental	Disruption and displacement of wildlife during construction and ferry operations	Marine mammal monitoring during construction; construction mitigation methods to reduce environmental impact such as bubble curtains for pile driving	Probable	Marginal	Serious	3	Presence of certain marine species present in construction area during in-water work period could cause construction delays. Ferry service could disrupt certain migratory patterns.

Qualitative Risk Assessment Alternative 1a - Northeast Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
10	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Ferry terminals at each end of route likely to have security fencing; use of ferry terminals by unauthorized vessels is low	Remote	Negligible	Low	1	
11	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorites	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	
12	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies en route	Frequent	Marginal	Serious	3	
13	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Marginal	Medium	2	Could lead to unplanned maintenance and additional vessel downtime.
				Average Risk Score				2.4	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

Qualitative Risk Assessment Alternative 1b - Lenard Harbor Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing / damaged or power loss to navaids and dock lights	Emergency response plan, use of electronic chart-plotting systems and GPS with hazards identified	Remote	Marginal	Medium	2	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training, implement crew management procedures and relief crew members	Occasional	Critical	Serious	3	Costs and availability of relief crew members questionable for this region.
3	Weather - Ferry travel	Life-Safety, Operations	High winds or extreme wave conditions that could blow the vessel off course or capsize the vessel	Restrict operations based on weather conditions	Remote	Catastrophic	Serious	3	Assume ferry can operate 99% of the time based on weather limitations.
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and the ferry terminal	Staffing, equipment, and operational funding for road maintenance	Occasional	Critical	Serious	3	Assume road is passable 95% of the time, with 5% downtime due to avalanches or heavy snow.
5	Sea Ice	Operations	Lenard Harbor historically known for icing over	Requires Ice Class A0 vessel to safely navigate Lenard Harbor	Occasional	Negligible	Low	1	Less chance of encountering sea ice with the avoidance of Lenard Harbor and terminals located sufficiently offshore to avoid most ice near shoreline.

Qualitative Risk Assessment Alternative 1b - Lenard Harbor Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Long-Term Operational Funding	Financial	Annual maintenance and operations expenses could exceed available funding	Annual ferry operating costs can be partially offset by passenger fares with scheduled ferry service, as well as usage fees for medevac	Probable	Catastrophic	High	4	Based on assumption that AEB would be responsible for subsidies needed and on recent AEB experience with hovercraft and helicopter.
7	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting for marine structures could take up to a year depending on permit requirements and regulatory hurdles.
8	Vessel Maintenance	Operations	Dry dock required every 2 years, 40-day planned downtime; no vessel redundancy for unplanned maintenance	Contract a backup vessel and plan dry dock and maintenance during mild weather seasons with no sea ice risk	Occasional	Negligible	Low	1	
9	Faunal Response to Construction and Operations	Environmental	Disruption and displacement of wildlife during construction and ferry operations	Marine mammal monitoring during construction; construction mitigation methods to reduce environmental impact such as bubble curtains for pile driving	Probable	Marginal	Serious	3	Presence of certain marine species present in construction area during in-water work period could cause construction delays. Ferry service could disrupt certain migratory patterns.
10	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Ferry terminals at each end of route likely to have security fencing; use of ferry terminals by unauthorized vessels is low	Remote	Negligible	Low	1	

Qualitative Risk Assessment Alternative 1b - Lenard Harbor Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
11	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	
12	Total Travel Time Required (King Cove to Anchorage hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Frequent	Marginal	Serious	3	
13	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Marginal	Medium	2	Could lead to unplanned maintenance and additional vessel downtime.
				Average Risk Score				2.4	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

Qualitative Risk Assessment Alternative 1c: Direct Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops	Life-Safety, Operations	Missing / damaged or power loss to navaids and dock lights	Emergency response plan; use of electronic chart plotting systems and GPS with hazards identified	Remote	Marginal	Medium	2	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training; implement crew management procedures and relief crew members	Occasional	Critical	Serious	3	Costs and availability of relief crew members questionable for this region.
3	Weather - Ferry travel	Life-Safety, Operations	High winds or extreme wave conditions that could blow the vessel off course or capsize the vessel	Restrict operations based on weather conditions	Occasional	Catastrophic	High	4	Assume ferry can operate 98% of the time based on weather limitations. More susceptible to rough seas between King Cove and Cold Bay.
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous within King Cove	Staffing, equipment, and operational funding for road maintenance	Occasional	Negligible	Low	1	This applies only to road between ferry landings and airport. Much shorter distances and likelihood of other on-land transportation alternatives for these areas.
5	Sea Ice	Operations	Shore ice may be present	Requires Ice Class A0 vessel to safely navigate Lenard Harbor	Occasional	Negligible	Low	1	Less chance of encountering sea ice with the avoidance of Lenard Harbor and terminals located sufficiently offshore to avoid most ice near shoreline.

Qualitative Risk Assessment Alternative 1c: Direct Ferry									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Long-Term Operational Funding	Financial	Annual maintenance and operations expenses could exceed available funding	Annual ferry operating costs can be partially offset by passenger fares with scheduled ferry service, as well as usage fees for medevac	Probable	Catastrophic	High	4	Based on assumption that AEB would be responsible for subsidies needed and on recent AEB experience with hovercraft and helicopter.
7	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting for marine structures could take up to a year depending on permit requirements and regulatory hurdles.
8	Vessel Maintenance	Operations	Dry dock required every 2 years, 40-day planned downtime. No vessel redundancy for unplanned maintenance	Contract a backup vessel and plan dry dock and maintenance during mild weather seasons with no sea ice risk	Occasional	Negligible	Low	1	
9	Faunal Response to Construction and Operations	Environmental	Disruption and displacement of wildlife during construction and ferry operations	Marine mammal monitoring during construction; construction mitigation methods to reduce environmental impact such as bubble curtains for pile driving	Probable	Marginal	Serious	3	Presence of certain marine species present in construction area during in-water work period could cause construction delays. Ferry service could disrupt certain migratory patterns.
10	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Ferry terminals at each end of route likely to have security fencing; use of ferry terminals by unauthorized vessels is low	Remote	Negligible	Low	1	

Qualitative Risk Assessment
Alternative 1c: Direct Ferry

					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
11	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	
12	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Frequent	Critical	High	4	Total medevac transit time over 5 hours, highest travel time of all alternatives.
13	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Marginal	Medium	2	Could lead to unplanned maintenance and additional vessel downtime.
				Average Risk Score				2.4	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

Qualitative Risk Assessment Alternative 2a - 5,000-foot Runway									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing/damaged navaids and lighting; loss of electrical power	Emergency response plan, use of GPS / Capstone navigation systems	Occasional	Catastrophic	High	4	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training; implement crew management procedures and relief crew members	Occasional	Catastrophic	High	4	
3	Weather - Air travel	Life-Safety, Operations	Flight operations in conditions beyond recommended wind speeds or VFR operations in IFR conditions	Preflight planning; Just say NO (accept fact that mission cannot be completed); instrument flight and landing systems	Remote	Catastrophic	Serious	3	
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and Lenard Harbor	Staffing, equipment, and operational funding for road maintenance	Occasional	Critical	Serious	3	Assume road is passable 95% of the time, with 5% downtime due to avalanches or heavy snow.
5	Long-Term Operational Funding	Financial	State or local project sponsor could default on capital grant obligations	User fees; dedicated funds; close redundant facility (existing KC Airport)	Remote	Critical	Medium	2	

Qualitative Risk Assessment
Alternative 2a - 5,000-foot Runway

					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting could take up to 3 years depending on permit requirements and regulatory hurdles.
7	Long-Term Management Response	Regulatory	Refuge may need to update current plan		Occasional	Negligible	Low	1	
8	Faunal Response to Construction and Operations	Environmental	Animals on runway or in airspace; changes in nesting/feeding behaviors	Fencing; restrictions on aircraft operations; revegetation	Occasional	Critical	Serious	3	
9	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Patrols by airport maintenance staff; pilot reporting	Remote	Negligible	Low	1	
10	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	
11	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Frequent	Marginal	Occasional	2	Alt 2a delivers medevac patient to Anchorage about 40 minutes quicker than Alt 2b.
12	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Negligible	Low	1	Likely a State-owned facility.
				Average Risk Score				2.4	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

Qualitative Risk Assessment Alternative 2b - 3,500-foot Runway									
					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing/damaged navaids and lighting; loss of electrical power	Emergency response plan, use of GPS / Capstone navigation systems	Occasional	Catastrophic	High	4	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training, implement crew management procedures and relief crew members	Occasional	Catastrophic	High	4	
3	Weather - Air travel	Life-Safety, Operations	Flight operations in conditions beyond recommended wind speeds or VFR operations in IFR conditions	Preflight planning; just say NO (accept fact that mission cannot be completed); instrument flight and landing systems	Remote	Catastrophic	Serious	3	
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and Lenard Harbor	Staffing, equipment, and operational funding for road maintenance	Occasional	Critical	Serious	3	Assume road is passable 95% of the time, with 5% downtime due to avalanches or heavy snow.
5	Long-Term Operational Funding	Financial	State or local project sponsor could default on capital grant obligations	User fees; dedicated funds; close redundant facility (existing KC Airport)	Remote	Critical	Medium	2	

Qualitative Risk Assessment
Alternative 2b - 3,500-foot Runway

					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting could take up to 3 years depending on permit requirements and regulatory hurdles.
7	Long-Term Management Response	Regulatory	Refuge may need to update current plan		Occasional	Negligible	Low	1	
8	Faunal Response to Construction and Operations	Environmental	Animals on runway or in airspace; changes in nesting/feeding behaviors	Fencing; restrictions on aircraft operations; revegetation	Occasional	Critical	Serious	3	
9	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Patrols by airport maintenance staff; pilot reporting	Remote	Negligible	Low	1	
10	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	
11	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Frequent	Critical	Serious	3	Alt 2a delivers medevac patient to Anchorage about 40 minutes quicker than Alt 2b.

Qualitative Risk Assessment Alternative 2b - 3,500-foot Runway									
					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
12	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Negligible	Low	1	Likely a State-owned facility.
				Average Risk Score				2.5	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

Qualitative Risk Assessment
Alternative 3a - Northeast Heliport

					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing/damaged nave aids and lighting; loss of electrical power	Emergency response plan; use of GPS / Capstone navigation systems	Occasional	Catastrophic	High	4	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training[implement crew management procedures and relief crew members	Occasional	Catastrophic	High	4	
3	Weather - Air travel	Life-Safety, Operations	Flight operations in conditions beyond recommended wind speeds or VFR operations in IFR conditions	Preflight planning; just say NO (accept fact that mission cannot be completed); instrument flight and landing systems	Remote	Catastrophic	Serious	3	
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and Lenard Harbor	Staffing, equipment, and operational funding for road maintenance	Occasional	Critical	Serious	3	Assume road is passable 95% of the time, with 5% downtime due to avalanches or heavy snow.
5	Long-Term Operational Funding	Financial	State or local project sponsor could default on capital grant obligations	User fees; dedicated funds	Remote	Critical	Medium	2	

Qualitative Risk Assessment Alternative 3a - Northeast Heliport									
					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting could take a year depending on permit requirements and regulatory hurdles.
7	Long-Term Management Response	Regulatory	Refuge may need to update current plan		Occasional	Negligible	Low	1	
8	Faunal Response to Construction & Operations	Environmental	Animals on runway or in airspace; changes in nesting/feeding behaviors	Fencing; restrictions on aircraft operations; revegetation	Occasional	Negligible	Low	1	Heliport site is already disturbed (hovercraft ramp). Uses existing access road.
9	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Patrols by airport maintenance staff; pilot reporting	Remote	Negligible	Low	1	
10	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	
11	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Frequent	Critical	Serious	3	Longest total travel time (road + helicopter) to Cold Bay Airport required of all heliport alternatives.

Qualitative Risk Assessment Alternative 3a - Northeast Heliport									
					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
12	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Negligible	Low	1	Heliport could be State, AEB, or city owned/operated.
13	Helicopter Contractor Performance	Operations	Lapses in staffing availability, training, and certification; absent or poorly maintained equipment and supplies	Contract oversight and periodic inspections	Remote	Catastrophic	Serious	3	
				Average Risk Score				2.4	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

Qualitative Risk Assessment
Alternative 3b - Lenard Harbor Heliport

					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing/damaged navaids and lighting; loss of electrical power	Emergency response plan, use of GPS / Capstone navigation systems	Occasional	Catastrophic	High	4	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training; implement crew management procedures and relief crew members	Occasional	Catastrophic	High	4	
3	Weather - Air travel	Life-Safety, Operations	Flight operations in conditions beyond recommended wind speeds or VFR operations in IFR conditions	Preflight planning; just say NO (accept fact that mission cannot be completed), instrument flight and landing systems	Remote	Catastrophic	Serious	3	
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and Lenard Harbor	Staffing, equipment, and operational funding for road maintenance	Occasional	Critical	Serious	3	Assume road is passable 95% of the time, with 5% downtime due to avalanches or heavy snow.
5	Long-Term Operational Funding	Financial	State or local project sponsor could default on capital grant obligations	User fees; dedicated funds	Remote	Critical	Medium	2	

Qualitative Risk Assessment Alternative 3b - Lenard Harbor Heliport									
					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting could take a year depending on permit requirements and regulatory hurdles.
7	Long-Term Management Response	Regulatory	Refuge may need to update current plan		Occasional	Negligible	Low	1	
8	Faunal Response to Construction and Operations	Environmental	Animals on runway or in airspace; changes in nesting/feeding behaviors	Fencing; restrictions on aircraft operations; revegetation	Occasional	Negligible	Low	1	Heliport site is already disturbed (material site). Uses existing access road.
9	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Patrols by airport maintenance staff; pilot reporting	Remote	Negligible	Low	1	
10	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	

Qualitative Risk Assessment
Alternative 3b - Lenard Harbor Heliport

					Post-mitigation				
	Risk	Categories *	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
11	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Probable	Negligible	Medium	2	Third longest total travel time (road + helicopter) to Cold Bay Airport of all heliport alternatives.
12	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Negligible	Low	1	Heliport could be State, AEB, or city owned/operated.
13	Helicopter Contractor Performance	Operations	Lapses in staffing availability, training, and certification; absent or poorly maintained equipment and supplies	Contract oversight and periodic inspections	Remote	Catastrophic	Serious	3	
				Average Risk Score				2.3	

*** Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other**

Qualitative Risk Assessment
Alternative 3c - Peninsula Heliport

					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing/damaged navaids and lighting; loss of electrical power	Emergency response plan, use of GPS / Capstone navigation systems	Occasional	Catastrophic	High	4	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training; implement crew management procedures and relief crew members	Occasional	Catastrophic	High	4	
3	Weather - Air travel	Life-Safety, Operations	Flight operations in conditions beyond recommended wind speeds or VFR operations in IFR conditions	Preflight planning, just say NO (accept fact that mission cannot be completed); instrument flight and landing systems	Remote	Catastrophic	Serious	3	
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and Lenard Harbor	Staffing, equipment, and operational funding for road maintenance	Probable	Critical	High	4	Unconstructed portion of road corridor has considerable avalanche potential.
5	Long-Term Operational Funding	Financial	State or local project sponsor could default on capital grant obligations	User fees; dedicated funds	Remote	Critical	Medium	2	

Qualitative Risk Assessment Alternative 3c - Peninsula Heliport									
					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Probable	Negligible	Medium	2	Permitting could take a year depending on permit requirements and regulatory hurdles.
7	Long-Term Management Response	Regulatory	Refuge may need to update current plan		Occasional	Negligible	Low	1	
8	Faunal Response to Construction and Operations	Environmental	Animals on runway or in airspace; changes in nesting/feeding behaviors	Fencing; restrictions on aircraft operations; revegetation	Occasional	Negligible	Low	1	Site is most environmentally sensitive of all heliport alternatives. Greenfield site. Requires construction of 8.5 miles of new access road.
9	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Patrols by airport maintenance staff; pilot reporting	Remote	Negligible	Low	1	
10	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	

Qualitative Risk Assessment
Alternative 3c - Peninsula Heliport

					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
11	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Probable	Negligible	Medium	2	Second longest total travel time (road + helicopter) to Cold Bay Airport of all heliport alternatives.
12	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Negligible	Low	1	Heliport could be State, AEB, or city owned/operated.
13	Helicopter Contractor Performance	Operations	Lapses in staffing availability, training, and certification; absent or poorly maintained equipment and supplies	Contract oversight and periodic inspections	Remote	Catastrophic	Serious	3	
				Average Risk Score				2.4	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

Qualitative Risk Assessment
Alternative 3d - King Cove Heliport

					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
1	Night Ops - Environmental risks	Life-Safety, Operations	Missing/damaged navaids and lighting; loss of electrical power	Emergency response plan; use of GPS / Capstone navigation systems	Occasional	Catastrophic	High	4	
2	Night Ops - Physiological hazards	Life-Safety, Operations	Incidents or errors caused by physiological challenges (circadian rhythm deviations, impaired vision, fatigue)	Education and training; implement crew management procedures and relief crew members	Occasional	Catastrophic	High	4	
3	Weather - Air travel	Life-Safety, Operations	Flight operations in conditions beyond recommended wind speeds or VFR operations in IFR conditions	Preflight planning; just say NO (accept fact that mission cannot be completed); instrument flight and landing systems	Remote	Catastrophic	Serious	3	
4	Weather - Road travel	Life-Safety, Operations	Heavy snow and avalanches could make the road impassable or extremely hazardous between King Cove and Lenard Harbor	Staffing, equipment, and operational funding for road maintenance	Remote	Marginal	Medium	2	Heliport located in community at site TBD; avalanche danger negligible unless heliport located at existing airport.
5	Long-Term Operational Funding	Financial	State or local project sponsor could default on capital grant obligations	User fees; dedicated funds	Remote	Critical	Medium	2	

Qualitative Risk Assessment
Alternative 3d - King Cove Heliport

					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
6	Standard Permitting Process Required	Development/Permitting	Standard permitting process required	Keep in mind BMPs and construction techniques / design approaches with least amount of environmental impact	Remote	Negligible	Low	1	NEPA documentation likely would be Categorical Exclusion.
7	Long-Term Management Response	Regulatory	Refuge may need to update current plan		Occasional	Negligible	Low	1	
8	Faunal Response to Construction and Operations	Environmental	Animals on runway or in airspace; changes in nesting/feeding behaviors	Fencing; restrictions on aircraft operations; revegetation	Occasional	Negligible	Low	1	Heliport site is already disturbed - in community core area. Uses existing access road.
9	Uncontrolled Use by Non-Medical Evac	Operations	Uncontrolled use by non-medical evac	Patrols by airport maintenance staff; pilot reporting	Remote	Negligible	Low	1	
10	Capital Funding	Financial	Lack of project sponsor; competing federal, State, or local priorities	In-kind contributions of surface and sub-surface holdings from stakeholders	Remote	Catastrophic	Serious	3	
11	Total Travel Time Required (King Cove to Anchorage Hospital)	Life-Safety, Operations	Time-sensitive medical conditions	Efficient transfer between modes; use of best medical technologies	Probable	Negligible	Medium	2	Shortest total travel time (road + helicopter) to Cold Bay Airport of all heliport alternatives.

Qualitative Risk Assessment Alternative 3d - King Cove Heliport									
					Post-mitigation				
	Risk	Categories*	Hazards	Mitigation	Likelihood	Severity	Outcome	Score	Comments
12	Liability	Other	Lapses in facility maintenance; delays in reporting conditions	Sufficient operational funding for staffing and equipment	Remote	Negligible	Low	1	Heliport could be State, AEB, or city owned/operated.
13	Helicopter Contractor Performance	Operations	Lapses in staffing availability, training, and certification; absent or poorly maintained equipment and supplies	Contract oversight and periodic inspections	Remote	Catastrophic	Serious	3	
				Average Risk Score				2.2	

*Life-Safety, Life-Cycle, Development, Regulatory, Permitting, Environmental, Operations, Financial, Other

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King Cove-Cold Bay Assessment of Non-Road Alternatives

Appendix B

Wind Data

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Cold Bay Hazardous Wind

2012	January	February	March	April	May	June	July	August	September	October	November	December
Perfect Number of Readings	744	696	744	720	744	720	744	744	720	744	720	744
Actual Number of Readings	735	687	743	720	743	720	743	743	718	743	717	741
Number of Non-Recorded Data Points	9	9	1	0	1	0	1	1	2	1	3	3
> 40 knots any direction	0.136%	0.908%	0.135%	0.000%	0.000%	0.000%	0.000%	0.000%	0.139%	0.404%	0.000%	0.405%
> 60 knots any direction	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

2013	January	February	March	April	May	June	July	August	September	October	November	December
Perfect Number of Readings	744	672	744	720	744	720	744	744	720	744	720	744
Actual Number of Readings	742	667	741	718	728	707	733	732	717	744	717	743
Number of Non-Recorded Data Points	2	5	3	2	16	13	11	12	3	0	3	1
> 40 knots any direction	0.000%	0.000%	0.675%	0.000%	0.138%	0.424%	0.000%	0.000%	0.000%	0.403%	0.000%	0.135%
> 60 knots any direction	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

2014	January	February	March	April	May	June	July	August	September	October	November	December
Perfect Number of Readings	744	672	744	720	744	720	744	744	720	744	720	744
Actual Number of Readings	741	664	733	719	741	713	735	742	718	737	710	740
Number of Non-Recorded Data Points	3	8	11	1	3	7	9	2	2	7	10	4
> 40 knots any direction	0.135%	0.155%	0.273%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.141%	0.000%
> 60 knots any direction	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

Combined Monthly Average **2012 - 2014**	January	February	March	April	May	June	July	August	September	October	November	December	Average
> 40 knots any direction	*0.090%*	*0.354%*	*0.361%*	*0.000%*	*0.046%*	*0.141%*	*0.000%*	*0.000%*	*0.046%*	*0.269%*	*0.047%*	*0.180%*	*0.128%*
> 60 knots any direction	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*	*0.000%*

Note: Table reflects hourly readings recorded by Automated Weather Observing System equipment at Cold Bay Airport.

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Appendix C

Medevac Elapsed-Time Tables

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Estimated Medevac Travel Times, City of King Cove to Ted Stevens Anchorage International Airport (ANC)

		Distance (miles)	Speed (mph)	Time Required (hours)*	
Alternative 1a: Northeast Ferry					
	King Cove to NE Boat Landing	21	20	1.1	
	NE Boat Landing to CB Dock	6	11.5	0.5	Assumes 10-knot average cruising speed per Glosten report in EIS appendix
	CB Dock to Cold Bay Airport	1	20	0.1	
	Cold Bay Airport to ANC (King Air)	630	330	1.9	
Total Time Required				**3.5**	
Alternative 1b: Lenard Harbor Ferry					
	King Cove to Lenard Harbor Boat Landing	11	20	0.6	
	Lenard Harbor Boat Landing to CB Dock	14	11.5	1.2	Assumes 10-knot average cruising speed per Glosten report in EIS appendix
	CB Dock to Cold Bay Airport	1	20	0.1	
	Cold Bay Airport to ANC (King Air)	630	330	1.9	
Total Time Required				**3.7**	
Alternative 1c: Direct Ferry					
	King Cove to KC Boat Landing	1	20	0.1	
	KC Boat Landing to CB Dock	27	9	3.0	Assumes 8-knot average cruising speed based on half of trip at 6 knots in open water
	CB Dock to Cold Bay Airport	1	20	0.1	
	Cold Bay Airport to ANC (King Air)	630	330	1.9	
Total Time Required				**5.0**	
Alternative 2a: 5,000-foot Runway					
	King Cove to New Airport	21	20	1.1	
	New Airport to ANC	630	480	1.3	
Total Time Required				**2.4**	

		Distance (miles)	Speed (mph)	Time Required (hours)*
Alternative 2b: 3,500-foot Runway				
	King Cove to New Airport	21	20	1.1
	New Airport to ANC	630	330	1.9
Total Time Required				**3.0**
Alternative 3a: Northeast Heliport				
	King Cove to Heliport	21	20	1.1
	Heliport to Cold Bay Airport	9	80	0.1
	Cold Bay Airport to ANC (King Air)	630	330	1.9
Total Time Required				**3.1**
Alternative 3b: Lenard Harbor Heliport				
	King Cove to Heliport	11	20	0.6
	Heliport to Cold Bay Airport	14	80	0.2
	Cold Bay Airport to ANC (King Air)	630	330	1.9
Total Time Required				**2.6**
Alternative 3c: Peninsula Heliport				
	King Cove to Heliport	14	20	0.7
	Heliport to Cold Bay Airport	10.5	80	0.1
	Cold Bay Airport to ANC (King Air)	630	330	1.9
Total Time Required				**2.7**
Alternative 3d: King Cove Heliport - Direct Flight Path				
	King Cove to Heliport	0	20	0.0
	Heliport to Cold Bay Airport	19	80	0.2
	Cold Bay Airport to ANC (King Air)	630	330	1.9
Total Time Required				**2.1**

	Distance (miles)	Speed (mph)	Time Required (hours)*
Alternative 3d: King Cove Heliport - Coastal Flight Path			
King Cove to Heliport	0	20	0.0
Heliport to Cold Bay Airport	23	80	0.3
Cold Bay Airport to ANC (King Air)	630	330	1.9
Total Time Required			**2.2**

*Some totals may not be exact, due to rounding.

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The Predicted Influence of Climate Change on Lesser Prairie-Chicken Reproductive Parameters

Blake A. Grisham , Clint W. Boal, David A. Haukos, Dawn M. Davis, Kathy K. Boydston, Charles Dixon, Willard R. Heck

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Abstract

The Southern High Plains is anticipated to experience significant changes in temperature and precipitation due to climate change. These changes may influence the lesser prairie-chicken (*Tympanuchus pallidicinctus*) in positive or negative ways. We assessed the potential changes in clutch size, incubation start date, and nest survival for lesser prairie-chickens for the years 2050 and 2080 based on modeled predictions of climate change and reproductive data for lesser prairie-chickens from 2001–2011 on the Southern High Plains of Texas and New Mexico. We developed 9 *a priori* models to assess the relationship between reproductive parameters and biologically relevant weather conditions. We selected weather variable(s) with the most model support and then obtained future predicted values from climatewizard.org. We conducted 1,000 simulations using each reproductive parameter's linear equation obtained from regression calculations, and the future predicted value for each weather variable to predict future reproductive parameter values for lesser prairie-chickens. There was a high degree of model uncertainty for each reproductive value. Winter temperature had the greatest effect size for all three parameters, suggesting a negative relationship between above-average winter temperature and reproductive output. The above-average winter temperatures are correlated to La Niña events, which negatively affect lesser prairie-chickens through resulting drought conditions. By 2050 and 2080, nest survival was predicted to be below levels considered viable for population persistence; however, our assessment did not consider annual survival of adults, chick survival, or the positive benefit of habitat management and conservation, which may ultimately offset the potentially negative effect of drought on nest survival.

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Competing interests: Dr. Charles Dixon is the sole employee of Wildlife Plus Consulting and was not paid to collect the Lesser Prairie-Chicken data presented herein. He provided expert opinion about model development and helped write a large section of the study area and methods. Therefore, his inclusion on the manuscript does not alter the authors' adherence to all the PLOS ONE policies on sharing data and materials.

Introduction

The lesser prairie-chicken has experienced as much as a 97% decline in population size [1] and similar suspected declines in occupied area from historic levels. The species is currently proposed as threatened under the United States Endangered Species Act and is a priority species under the Great Plains Landscape Conservation Cooperative (GPLCC). The semi-arid region of the Southern High Plains encompasses the entire distribution of lesser prairie-chickens, which is considered a principal indicator species of the ecosystem. Previous studies have examined the reproductive ecology of lesser prairie-chickens on the Southern High Plains [2], [3], [4], [5] and similar studies are currently being conducted elsewhere across the species distribution. However, the influence of drought and climate change on lesser prairie-chicken reproductive ecology has, to date, been largely overlooked. This is of concern, as lesser prairie-chickens appear to be particularly sensitive to landscape alterations [6], [7] and drought [8], [9]. Drought is suspected to negatively influence prairie grouse through reduced growth of vegetation that provides nesting, roosting, and escape cover, and food [10], [11]. Furthermore, there is evidence that home range sizes increase [10], [12] and recruitment is lower during drought years [10], [13]. Home range size expansion during drought years may lead to localized abandonment, especially in fragmented landscapes. Furthermore, landscape alterations and management (e.g., herbicide treatment of shrubs, grazing systems) appear to influence resource selection, survival, and reproductive success of lesser prairie-chicken populations.

One of the primary science goals for the Landscape Conservation Cooperatives and the U. S. Geological Survey National Climate Change and Wildlife Science Center is to assess the vulnerability and risk of species to climate change. The issue of climate change as a challenge to bird conservation in arid and semi-arid regions also was identified by federal and state fish and wildlife management agencies as a high priority issue. A key issue in conservation of lesser prairie-chickens in context of climate change is the lack of estimates for many specific vital rates and sufficient sample sizes. Despite substantial efforts to conserve lesser prairie-chickens and their habitat, long-term studies that provide adequate data to properly allow for predictive modeling of the role climate change may have on the reproductive ecology of this species are lacking. This is important in that the Great Plains is anticipated to experience increased maximum and minimum temperatures, increased intensity but reduced occurrence of precipitation events, and spring and the associated environmental phenology occurring earlier [14]. In particular, climate change forecasts indicate the Southern High Plains will become drier with more frequent extreme heat events and decreased precipitation events [15].

Increased surface and ambient temperature may lead to egg death and/or nest abandonment. This may be exacerbated if, due to low precipitation, nesting phenology shifts to later in the year when temperatures are increased. Thus, lesser prairie-chickens will be exposed to increased temperatures that may exceed both thresholds of egg survival and tolerances of adults. These climate change predictions may have long-term negative impacts on lesser prairie-chicken populations in these regions as survival of chicks from hatch to the next breeding season has been identified as the key demographic parameter affecting lesser prairie-chicken populations [16].

Our goals were two-fold. First, was an analysis and assessment of an 11-year data set of lesser prairie-chicken reproductive ecology in response to seasonal weather conditions. This included documentation of clutch size, incubation start date, and nest survival. Second, we assessed these parameters in context of projected climate change scenarios for the region. We believe our study will provide a compilation and analysis of existing phenological data from a long-term data set and an assessment of reproductive data that can be used to develop predictive models of response to future climate change.

Materials and Methods

Ethics Statement

All methods were approved under Texas Tech University Institutional Animal Care and Use Protocol #1052-08. Any use of trade names or products does not constitute endorsement by the U.S. Government. We thank a multitude of private land owners in Texas for private land access. We thank Jim Weaver and all members of the Grasslans Charitable foundation for providing financial and logistical support and study site access in New Mexico. We thank Apple Wood and a plethora of field technicians for field data collection in New Mexico and Texas. We thank the Sutton Avian Research Center for data collection on the New Mexico study area from 2001–2005. Financial and logistical support was provided by Texas Tech Department of Natural Resources Management, United States Geological Survey, Texas Parks and Wildlife, New Mexico Game and Fish, Great Plains Landscape Conservation Cooperative, and The Nature Conservancy.

Capture

We captured subadult and adult lesser prairie-chickens on leks during spring (March–April) using walk-in funnel traps [17], rocket nets, and drop-nets from 2001–2011. We recorded gender, age, lek of capture, time of capture, weight, wing cord (mm), pinnae length (mm), and tail length (mm) for each bird. We determined gender using pinnea length, presence of an eye comb, tail feather markings, and other plumage characteristics [12]. We determined age by plumage characteristics; subadults have white spotting within 2.5 cm of the tip of the 9^{th} and 10^{th} primaries, whereas white spotting is absent within 2.5 cm of primary tips in adult birds [12]. We banded each female with either a New Mexico Department of Game and Fish or a Texas Parks and Wildlife Department aluminum blunt-end leg band. We equipped each bird with a 13 gram loop style radio-transmitter (American Wildlife Enterprises, Florida, USA; Advanced Telemetry Systems, Minnesota, USA) with an eight-hour mortality sensor and then released them at the capture site.

Nest Location

We determined nest locations by approaching the hen via homing when locations remained unchanged daily between two subsequent location attempts. We revisited a nest only if the hen was determined via telemetry to be off the nest; nest revisits were to assess the status of the nest (e.g., depredated, hatched, abandoned). At each nest, we counted the number of eggs present at the initial flush and each subsequent visit (when applicable). We calculated nest initiation by backdating from the start of incubation 1 day for each egg in nest [18]. We made all attempts to reduce observer disturbance to the nest site.

Weather Data Collection and Modeling

A digital recording rain gauge (Rainwise, Incorporated; Harbor, Maine, United States) was established on each study area to monitor precipitation. In addition, a weather station was placed on each study area to monitor daily weather conditions. We calculated the mean temperature and total rainfall for each month within each year of the study. We compiled the data and modeled clutch size, incubation initiation, and nest survival as a function of seasonal weather conditions. Because our interest was the influence of seasonal conditions, we did not model reproductive parameters as a function of daily weather variables; rather we averaged temperatures and precipitation across biological meaningful seasons (Table S1). We did not include any renest attempts from the incubation analysis because timing of renests is dependent on failure of the initial nest, and may influence these attempts more than seasonal weather patterns.

We developed seasonal weather models that were most likely to affect percent vegetation cover, food availability, and physiology. For example, we incorporated winter and spring precipitation and temperature because they were most likely to reflect food availability and short-term cover for nesting; shinnery oak (*Quercus harvardii*) and sand sagebrush (*Artemisia filifolia*) leaf out is determined by winter and spring conditions [4]. We incorporated yearly and wet-season precipitation as a parameter affecting cover, because sand shinnery oak has the ability to store large amounts of water over long periods of time [19] and lesser prairie-

chickens nest in residual grass cover from previous growing seasons. Spring and winter temperature and precipitation may affect reproductive ecology disproportionately compared to other parameters [20]. Therefore, we included these as individual parameters to assess per unit change in reproductive parameter for each environmental variable given in each linear equation for each factor acting individually as well as acting as additive factors.

We used Akaike's Information Criterion (AIC) [21] to assess the role of seasonal weather conditions on clutch size and incubation initiation. We modeled clutch size and incubation initiation, as a function of yearly precipitation, wet season precipitation, winter temperature, winter precipitation, spring temperature, spring precipitation, winter severity (temperature and precipitation), spring severity (temperature and precipitation), and a global model that incorporated all parameters (Table S2).

We modeled daily nest survival [22] as a function of the same nine seasonal *a priori* models used to model clutch size and incubation initiation. We used the logit-link function in program MARK [23] to model daily survival rates. Weather data were not collected in 2000, one year before the New Mexico project was initiated. Therefore, yearly rainfall, wet season rainfall, winter temperatures and winter precipitation were not available for the 2001 nesting season. We searched for supplementary weather data (www.mesonet.ttu.edu) but these data were not available for the study area. Therefore, in 2001, we used the mean of the variable of interest as a surrogate for missing data in program MARK.

Statistical Analysis

For each model, we obtained the residual sums of squares and then calculated Akaike's Information Criterion for small samples (AIC*c*), changes in AIC*c* and ΔAIC*c* values, and Akaike weights (AIC*w*). We used the preceding model selection criteria to evaluate model performance and select the best approximating model [24]. For each analysis, we selected the individual parameters that had the most support from Akaike's Information Criterion. If there was no overwhelming support for any parameter, we modeled the change in reproductive parameter as a function of all seasonal weather parameters in the global model.

Future Forecasting

We obtained future climatic forecasts from www.climatewizard.org. Climatewizard.org is a web-based, spatial tool that allows users to obtain downscaled future forecast of changes of average temperature and precipitation for the years 2050 and 2080. Climate wizard allows users to obtain future forecasts from three carbon dioxide (CO_2) emission models (B1, A1B, A2; Table S3; [25]) and 16 Atmospheric and Oceanic General Circulation Models (AOGCMs). Users can select three scenarios within each CO_2 emission model: best case, worst case, and ensemble averages. The worst case scenario estimates the largest change projected by each general circulation model across each CO_2 model. The best case scenario estimates the smallest change projected by each general circulation model across each CO_2 model. The ensemble model estimates the value where half of the models projected the largest change and the other half projects the smallest change for each general circulation model across each CO_2 model.

For our analysis, we obtained six estimates of future predictions: worst case scenario 40 years into the future, best case scenario 40 years into the future, ensemble average 40 years into the future, worst case scenario 70 years into the future, best case scenario 70 years into the future, and ensemble average 70 years into the future. We determined the mean value and variance for each variable by averaging the predictive value over 16 general circulation models and 3 carbon dioxide (CO_2) emission models. Therefore, each predictive value was based on a vector of 48 future predictions. We chose to average across three CO_2 emission models for two reasons. First, an independent analysis of changes in variables for each scenario would result in 9 total values (best, worst, and ensemble averages for A2, A1B, and B1) with no clear indication of what best, worst, and ensemble averages would be given some of these values overlap (Figure 1). Within this rationale, evidence suggests humans have released more gigatons of CO_2 into the atmosphere than the B1 emission scenario predicts, thus the worst case values for the B1 scenario are likely the best case scenario in terms of CO_2 emissions. We contend it was warranted to have a clear delineation of what was best and worst case scenarios. Averaging the predicted values across all three CO_2 emission models within the context of best case, worst case, and ensemble averages met this criteria, and subsequently reduced the uncertainty of the estimates because the sample size increased from 16 values (1 from each AOGCM for each CO_2 model) to 48 values (1 from each AOGCM within 3 CO_2 models; Figure 1).

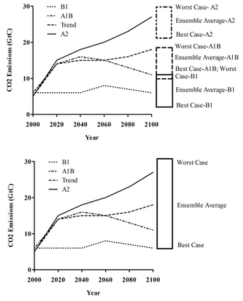


Figure 1. Default and manipulated data arrangement for CO_2 emission models.
Top) Default data arrangement of future values presented by climatewizard.org. For each carbon dioxide emission model (A2, A1B, B1) climate wizard allows the user to obtain values that correspond to the best, worst, and ensemble averages from 16 general circulation models. Bottom) Data arrangement used to obtain future values for our climate change impact assessment. For this assessment, we averaged the best, worst, and average values from 16 general circulation models across all three carbon dioxide emission models.
https://doi.org/10.1371/journal.pone.0068225.g001

If the climatic forecast changed a variable, we applied the change to the corresponding variable in the 11-year data set. For example, if the 40-year best-case forecast called for a 3.03°C increase in winter temperatures (October-March), we applied that increase to the mean winter temperature for our 11-year data set:

$$[3.03^{\circ}C\ increase(40\ year\ forecast\ change) + 7.61^{\circ}C(average\ winter\ temperature\ for\ 11\ year\ data\ set) = 11.39^{\circ}C]$$

We changed each seasonal variable based on the averaged model predictions across the 6 future scenarios. We then used PROC UNIVARIATE in SAS 9.2 to assess the probability distribution of each predictive variable and then used program R 2.13.1 (The R Foundation for Statistical Computing) to create a vector of 1,000 randomly selected numbers for each seasonal variable based on the mean change of each variable in each scenario, its variance, and the probability distribution. If the data were not uniformly distributed, we log-transformed the data and used a normal probability distribution. We used PROC GAM in SAS 9.2 (Figures S1, S2, S3, S4, S5, S6, S7; Output S1) to assess the relationship between predictor and response variables and then inserted the 1,000 randomly selected variables into the equation that best estimated clutch size, incubation initiation, or nest survival to assess future climatic scenarios.

We extrapolated the predicted values for clutch size, incubation start date, and nest survival (dependent variables) from the equation produced from the interpolated relationship between the dependent and independent variables. Extrapolation of these data are warranted because the goal of our study was to assess the potential changes in reproductive parameters in relation to future climate change using ecological field data collected over ten years [26].

Results

Clutch Size

We assessed the relationship between seasonal weather patterns and clutch size for 156 nests. Based on model selection criteria, there was a high degree of model uncertainly among our 9 *a priori* candidate models. The individual parameters winter precipitation (AIC*w*=0.74) and spring precipitation (AIC*w*=0.60; Table 1) had the most support. There was moderate support for the global model (AIC*w*=0.44), but this was likely because this model incorporated the top two competing parameters. Due to the high degree of uncertainty among our models, we obtained the beta coefficients for all variables by model averaging across the 9 *a priori* models. Based on this assessment, the relationship between clutch size and seasonal patterns was:

$$\begin{aligned} Clutch\ size = {} & (-0.01)(wetseason\ precipitation) \\ & + (0.01)(yearly\ rainfall) + (0.12)(winter\ precipitation) \\ & - (0.06)(winter\ temperature) + (0.57)(spring\ temperature) \\ & + (0.02)(spring\ precipitation) - 1.43 \end{aligned}$$

Model	AICc	Delta AIC_c	AIC_c Weight	Likelihood	K	Deviance
Global	1092.94	0	0.44	1	7	1003.72
WinPrecip	1094.53	1.58	0.20	0.92	2	1085.84
SprPrecip	1094.92	1.98	0.16	0.90	2	1088.57
Winter	1095.71	2.76	0.11	0.87	3	1079.57
Spring	1096.86	3.92	0.00	0.82	3	1087.59
WinTemp	1099.65	6.70	0.00	0.71	2	1122.06
YearlyPrecip	1104.41	11.47	0.00	0.56	2	1156.85
WetSeason	1106.60	13.70	0.00	0.50	2	1173.55
SprTemp	1106.69	13.74	0.00	0.50	2	1173.55

WinTemp - Winter Temperature.
WinPrecip - Winter Precipitation.
YearlyPrecip - Yearly Precipitation.
SprTemp - Spring Temperatures.
SprPrecip - Spring Precipitation.
WetSeason - Wet Season Precipitation.
doi:10.1371/journal.pone.0068225.t001

Table 1. Output from 9 *a priori* models used to assess the relationship between clutch size and seasonal weather patterns for 156 lesser prairie-chicken nests in Roosevelt County, NM, and Cochran, Hockley, Terry, and Yoakum counties, TX, USA, 2001–2011.
https://doi.org/10.1371/journal.pone.0068225.t001

From this equation, the weather model based estimate of mean clutch size is 7.25 eggs per nest.

We obtained future predicted values of mean clutch size using model averaged beta parameters across all 9 *a priori* candidate models. The change in value, variance, and predicted value for each seasonal variable under the 40-year and 70-year climate scenarios (Tables 2,3) result in a predicted mean clutch size of 5 eggs per nest by 2050 and 9 eggs by 2080 (Figure 2).

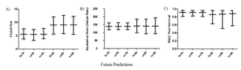


Figure 2. Future predicted values for clutch size, incubation start date, and nest survival.
Mean and lower and upper 95% confidence limits of future lesser prairie-chicken A) clutch size, B) incubation start date, and C) nest survival from 1,000 simulations. Each graph presents results from six scenarios: wc50 - worst case scenario, 2050; bc50 - best case scenario, 2050; ea50 - ensemble average scenario, 2050; wc80 - worst case scenario, 2080; bc80 - best case scenario, 2080; ea80 - ensemble average scenario, 2080.
https://doi.org/10.1371/journal.pone.0068225.g002

Parameter	Scenario	Predicted Change	Variance
Winter Temperatures	Best Case 40	1.98 ↑	0.63
	Ensemble Average 40	1.98 ↑	0.64
	Worst Case 40	2.02 ↑	0.70
Winter Precipitation	Best Case 40	0.01 ↑	4.08
	Ensemble Average 40	0.01 ↑	4.08
	Worst Case 40	0.01 ↑	4.00
Spring Precipitation	Best Case 40	0.12 ↓	3.20
	Ensemble Average 40	0.13 ↓	3.23
	Worst Case 40	0.13 ↓	3.23
Spring Temperature	Best Case 40	2.56 ↑	0.46
	Ensemble Average 40	2.55 ↑	0.47
	Worst Case 40	2.57 ↑	0.46
Yearly Precipitation	Best Case 40	0.04 ↓	1.94
	Ensemble Average 40	0.04 ↓	1.57
	Worst Case 40	0.04 ↓	1.78
Wet Season Precipitation	Best Case 40	0.01 ↓	2.93
	Ensemble Average 40	0.02 ↓	2.22
	Worst Case 40	0.03 ↓	1.71

↑ - Projected Increase.
↓ - Projected Decrease.
doi:10.1371/journal.pone.0068225.t002

Table 2. Mean predicted change for temperature (°C) and precipitation (cm) from 3 climatic forecasts used to predict mean clutch size, incubation initiation, and daily survival rates for lesser prairie-chicken populations in 2050.
https://doi.org/10.1371/journal.pone.0068225.t002

Parameter	Scenario	Predicted Change	Variance
Winter Temperatures	Best Case 70	2.88 ↑	1.09
	Ensemble Average 70	3.03 ↑	1.32
	Worst Case 70	3.03 ↑	1.33
Winter Precipitation	Best Case 70	0.02 ↓	5.5
	Ensemble Average 70	0.02 ↓	5.5
	Worst Case 70	0.03 ↓	5.5
Spring Precipitation	Best Case 70	0.17 ↓	6.00
	Ensemble Average 70	0.17 ↓	6.29
	Worst Case 70	0.22 ↓	5.00
Spring Temperature	Best Case 70	3.74 ↑	1.47
	Ensemble Average 70	3.76 ↑	1.34
	Worst Case 70	3.78 ↑	1.35
Yearly Precipitation	Best Case 70	0.05 ↓	2.29
	Ensemble Average 70	0.05 ↓	2.08
	Worst Case 70	0.06 ↓	2.57
Wet Season Precipitation	Best Case 70	0.05 ↑	5.21
	Ensemble Average 70	0.03 ↑	5.16
	Worst Case 70	0.05 ↓	4.03

↑ - Projected Increase.
↓ - Projected Decrease.
doi:10.1371/journal.pone.0068225.t003

Table 3. Mean predicted change for temperature (°C) and precipitation (cm) from 3 climatic forecasts used to predict mean clutch size, incubation initiation, and daily nest survival for lesser prairie-chicken populations in 2080.
https://doi.org/10.1371/journal.pone.0068225.t003

Incubation Start Date

We assessed the relationship between seasonal weather patterns and incubation start date for 207 nests. Based on model selection criteria, there was overwhelming support for the global model (AIC*w*>0.90; Table 4), which incorporates all the parameters; therefore, we did not model average results and we used the beta coefficients from the top competing model.

$$\begin{aligned} Incubation\,start = {} & (-0.03)(wetseason\,precipitation) \\ & -(0.46)(yearly\,rainfall) + (0.16)(winter\,precipitation) \\ & +(8.91)(winter\,temperature) - (6.75)(spring\,temperature) \\ & +(0.02)(spring\,precipitation) + 168.66 \end{aligned}$$

Model	AIC*c*	Delta AIC*c*	AIC*c* Weight	Likelihood	*K*	Deviance
Global	2057.82	0	0.98	1	7	19357
Winter	2071.50	13.68	0.00	0.50	3	21541
WinPrecip	2074.20	16.38	0.00	0.44	2	22042
WinTemp	2080.64	22.82	0.00	0.31	2	22739
YearlyPrecip	2085.40	27.66	0.00	0.25	2	23277
WetSeason	2090.65	32.83	0.00	0.19	2	23865
Spring	2098.38	40.56	0.00	0.13	3	24528
SpiPrecip	2099.99	42.16	0.00	0.12	2	24966
SprTemp	2103.50	45.68	0.00	0.10	2	25394

WinTemp - Winter Temperature.
WinPrecip - Winter Precipitation.
YearlyPrecip - Yearly Precipitation.
SprTemp - Spring Temperatures.
SpiPrecip - Spring Precipitation.
WetSeason - Wet Season Precipitation.
doi:10.1371/journal.pone.0068225.t004

Table 4. Output from 9 *a priori* models used to assess the relationship between mean incubation initiation (Julian Date) and seasonal weather patterns for 207 nests in Roosevelt County, NM, and Cochran, Hockley, Terry, and Yoakum counties, TX, USA, 2001–2011.
https://doi.org/10.1371/journal.pone.0068225.t004

Based on the above equation, the weather model based estimate of incubation initiation was 140 (20-May).

Based on model selection criteria, there was a high degree of model certainty among our 9 *a priori* candidate models. Therefore, we obtained future predicted value of mean incubation initiation using beta coefficients from the top competing model. Based on change in value, variance, and predicted value for each seasonal variable under the 40-year and 70-year scenarios (Tables 2, 3), average incubation initiation is not predicted to change in either 2050 or 2080 (Figure 2).

Nest Survival

2080 (Figure 2).

Nest Survival

We assessed nest survival for 229 lesser prairie-chicken nests. Based on model selection criteria (Table 5), there was a high degree of uncertainty for seasonal trends for this analysis. The top three competing models all had ΔAICc values <2. However, based on individual parameter weights, there was strong support for winter temperatures (AICw=0.70) compared to the other individual variables (Table 5). We obtained predictive beta coefficient estimates by model averaging the beta coefficient using a back-transformed logit-link function and likelihood values:

$$\begin{aligned} Logit\,daily\,survival\,rate = {} & (0.005)(wetseason\,precipitation) \\ & -(0.0001)(yearly\,rainf\,all) \\ & -(0.02)(winter\,precipitation) \\ & -(0.37)(winter\,temperature) \\ & -(0.03)(spring\,temperature) \\ & +(0.003)(spring\,precipitation)+6.37 \end{aligned}$$

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	K	Deviance
WinTemp	1261.72	0.00	0.28	1.00	2	1257.72
Winter	1261.97	0.24	0.24	0.88	3	1255.96
Global	1262.51	0.78	0.18	0.67	7	1248.48
SprPrecip	1264.78	3.06	0.06	0.21	2	1260.78
Spring	1264.78	3.06	0.06	0.21	2	1260.78
WinPrecip	1265.03	3.31	0.05	0.19	2	1261.03
SprTemp	1265.04	3.32	0.05	0.19	2	1261.04
Wet Season	1265.05	3.32	0.05	0.18	2	1261.04
YearlyPrecip	1431.95	170.22	0.00	0.00	1	1429.95

WinTemp - Winter Temperature.
WinPrecip - Winter Precipitation.
YearlyPrecip - Yearly Precipitation.
SprTemp - Spring Temperatures.
SprPrecip - Spring Precipitation.
WetSeason - Wet Season Precipitation.
doi:10.1371/journal.pone.0068225.t005

Table 5. Output from 9 *a priori* models used to estimate daily nest survival rates for 229 lesser prairie-chicken nests in Roosevelt County, NM, and Cochran, Hockley, Terry, and Yoakum counties, TX, USA, 2001–2011.
https://doi.org/10.1371/journal.pone.0068225.t005

Based on the model averaged variables above, the probability of daily nest survival on the study area was 0.98. Assuming a 28 day exposure period (i.e., the incubation period) this translates to a probability of a nest surviving the entire incubation period as 0.57 (0.98^{28}).

We obtained future predicted values of daily survival rates using model averaged beta coefficient across all 9 *a priori* candidate models (Tables 2, 3). Average daily survival is predicted to decrease across all six climatic scenarios by 0.50–0.56 from current estimates (Figure 2). Thus, predicted survival of nests through the incubation period to hatching is ≤10% under all 40-year and 70-year scenarios.

Discussion

Our results suggests with high certainty that nest survival will decrease to a level that is considered below the threshold for population persistence by 2050. The level of precision and repeatability observed in our modeling effort is not common in biological systems. The low standard errors and confidence intervals are ultimately a function of our modeling effort that was weighted to changes in temperature 40 and 70 years into the future that also had high precision. We suggest the results we witnessed for nest survival are reliable because current ambient environmental conditions on the study area often exceed ranges that are considered suitable for stable nest environments (34–40°C; <10% relative humidity; [39]), and temperatures are predicted to increase with subsequent climate change. We do caution that this concern is specifically for lesser prairie chicken populations on the Southern High Plains. Temperatures and relative humidities during nest incubation on the Southern High Plains are, on average, 7°C greater and 7% less, respectively, compared to lesser prairie-chickens in the northeast population (30 year means for Dodge City, Kansas and Lubbock, Texas). The effects of climate change may affect lesser prairie-chickens differently in the northern extent of their range, but we hypothesize that warmer, drier winters and springs, which ultimately influence vegetation and hen condition, will be beyond the threshold for optimal nesting environments on the Southern High Plains.

We found no overwhelming support for any one *a priori* model for clutch size as a function of seasonal weather patterns. Aside from spring temperatures, effect size for each seasonal weather condition in relation to clutch size was relatively weak. These results suggest that weather parameters in general are a weak predictor of clutch size, and other factors may be influencing clutch size to a greater extent. We propose two reasons that may best explain clutch size of lesser prairie-chickens.

First, clutch size is a proximate result of hen condition, which is influenced by environmental conditions [4]. Therefore, we would expect to see larger clutches in years that promote better hen condition. Our results suggest that no such relationship exists, and we hypothesize that visitations to water sources before, during, and after incubation are supplementing egg development and

formation during period of drought. Prior knowledge suggested lesser prairie-chickens obtain necessary moisture through food and metabolism [27]. The potential need for free surface water has been generally disregarded, despite information that surface water is used [2], [28]. Based on our ongoing studies on the Southern High Plains, we suspect the contention that free water is not needed by lesser prairie-chicken may be erroneous, at least in terms of reproductive output. Our collaborative studies have photo-documented 1245 different visits to water sources by individual and groups of prairie-chickens during our year-round monitoring of water sources. Males are seen visiting water sources in high numbers from December – June (27–80 detections per month), with few visits during July – November. An estimated 87% of female visits are during the latter part of April, then May – June. This suggests hen use of water sources is strongly associated with egg-formation, laying period, and incubation. It also suggests that water use is not necessarily tied to ambient temperature unless in times of extreme drought; hens rarely visited water sources during the hottest months of July – September, except during 2011 (an extreme drought year), when we recorded 67 different visits. We suggest the proximate reason why we failed to detect a correlation between current and climatic conditions and clutch size is the use of free standing water as an aid to metabolic processes during oogenesis [29], [30].

Hens in the northern extent of lesser prairie-chicken range typically have larger clutches compared to females on the Southern High Plains. Renest attempts are more common in the north [4], [18] compared to our studies. Differences in clutch size, incubation dates, and renest attempts could be attributed to different life history strategies of lesser prairie-chickens between the two ecoregions [4]. On the Southern High Plains, daily nest survival is consistent, clutch sizes are smaller, and renests are rarer compared to populations occupying the northern portion of their occupied range. These patterns suggest that lesser prairie-chickens on the Southern High Plains invest heavily into one nesting attempt, and that may be the ultimate reason we failed to find evidence that clutch size was a function of seasonal weather conditions.

Our results suggest that any one seasonal weather condition is a poor predictor of incubation start date. We did witness strong support for the global model, which incorporated all of the seasonal weather conditions. This suggests that incubation start date was influenced by a combination of seasonal weather conditions, with winter and spring temperatures having the strongest influence on incubation start date. Likewise we found evidence suggesting that winter temperature was the main, strong influence of nest survival among the weather variables considered.

Timing of incubation and nest survival appear to be correlated; previous studies suggest that nests have a higher probability of survival if they are initiated earlier in the year [18], [31]. We hypothesize hot, dry conditions in the winter and spring affect the growth and composition of nest vegetation on our study area, which subsequently influence incubation and nest survival. The two main components of nesting habitat on the Southern High Plains are shrubs and grasses, primarily sand shinnery oak and bluestems (*Andropogon* spp; [32]). Grasses lack the water storage capacity of shrubs and are more reliant on short term precipitation for growth, and when available, hens select bluestems over shrubs for nest sites [32]. Sand shinnery oak roots can extend 10 meters into the soil and enable the shrub to obtain and store water in dry conditions [19]. These and other shrubs are the first plant species on the study area to leaf out [19] because they are less reliant on short-term precipitation. In dry years, we have evidence to suggest that hens select shrubs over grasses. This may explain why we did not find a strong effect of precipitation on reproductive parameters.

We suspect that our findings for incubation start date and nest survival are the result of the El Niño- Southern Oscillation, as the La Niña stage of this oscillation brings warmer, drier winters and springs to the southwest United States [33]. During these years, the probability of drought increases on the Southern High Plains [34], [35], [36], [37]. Lesser prairie-chickens appear to be particularly sensitive to long-term drought [10]. There is additional evidence that lesser prairie-chicken numbers were greatly reduced in the southern population during the extended drought of the 1950s, and took several years to recover to pre-drought numbers [2]. It is important to note that lesser prairie-chickens evolved with drought, and their ability to recover during post-drought years has been documented [9]. However, their ability to recover from long-term (3–10 years) drought on a changing, increasingly fragmented landscape is an unknown, warranted concern for this species.

The 2011 nesting season provides insight to how an extreme La Niña event and subsequent drought affects lesser prairie-chicken reproductive ecology. From 15 October 2010 to 31 August 2011, the total precipitation on the study site was only 2.46 cm (0.97 inches), constituting the worst drought and warmest La Niña event on record. The drought of 2011 was so severe that sand shinnery oak and grasses on the study site did not leaf out, eliminating nesting cover and subsequently delaying nest initiation [38]. Cover provides protection from predators and thermal stress, and when thermal cover is lacking, nests are exposed to the elements (Figure S7).

Preliminary data from nest thermal profiles indicate that temperatures on the ground during the daylight hours exceeded 54.4°C (130°F), and humidity was consistently below 10% in 2011, which is well beyond the threshold for egg viability [39] and nest survival. These data are based on roughly 10% of our nest (22 of 225) from 3 years of study (2010–2012), but indicate there are potential temperature and humidity thresholds for incubating hens. One important aspect of predictive modeling that we did not incorporate into our assessment, but that would benefit future species-level impact assessments, is the incorporation of current and predicted future frequencies of extreme weather events. In some cases, averages may not distinguish between seasonal mean conditions that may have record cold and heat events, and these events may effectively cancel each other out, but still affect demographic parameters. However, this study began in 2001 without the inclusion of climate change as a study objective, and as such, we were ultimately limited by our data in regards to modeling extreme events.

For our extrapolation to be meaningful, we must assume that seasonal weather patterns will have a continued influence on reproductive parameters. Previous studies have demonstrated that reproductive parameters may be influenced by hen age (clutch size, nest survival; [18]) nesting attempt (clutch size; [18]), hen condition (clutch size, nest survival; [4]), and geographic location (clutch size, incubation start, nest survival; [4], [5], [12]). We agree that there are multiple influences on lesser prairie-chicken reproductive parameters, and we contend that clutch size and incubation start date may not be influenced to any extent that is cause for concern in the future. In contrast to these findings, however, is that nest survival is predicted to fall well below the threshold for population persistence [40]. There is sufficient evidence to suggest that lesser prairie-chickens usually experience either booms or busts in reproductive success [16]. The "boom bust" reproductive strategy suggests that lesser prairie-chickens

maximize reproductive efforts when conditions are optimal. For the Southern High Plains population, cooler, wetter springs maximize both food and cover for lesser prairie-chickens. Evidence suggests precipitation and temperature influence nest survival [31] and we contend these variables will subsequently continue to influence nest survival in the future.

The role of daily weather on productivity [20] and nest survival [31] of prairie grouse is not well understood, and to the best of our knowledge, this is the first study that has examined the role of seasonal weather conditions on reproductive parameters for lesser prairie-chickens. Although we lack corroboration from other studies, we suggest the main driver of nest survival in the southern population is weather. Fragmentation and habitat destruction have exacerbated the importance of nest survival and reproductive output within small, isolated pockets of lesser prairie-chickens, as the range of lesser prairie-chickens is now restricted to two, unconnected geographic populations.

We attribute the loss of useable space as a primary reason why weather conditions have become a concern for lesser prairie-chickens on our study areas. We hypothesize this relationship will not only continue in the future, but become more prevalent by the persistent loss and fragmentation of current habitats through multiple mechanisms. Since lesser prairie-chickens on the Southern High Plains are isolated to a small portion of shinnery oak-grasslands on the most agriculturally impacted region in the Western Hemisphere, surrounding landscapes that are predominantly cotton fields or livestock pastures dominated by mesquite or juniper trees will not support the species. Therefore, the population of concern currently has no real options in terms of movement and distribution shifts, which exacerbates the troublesome nature of our findings.

Previous studies that have examined shifts in incubation in birds suggest incubation start date will occur earlier due to shifting spring phenology [41], [42], [43], [44], [45]. However, the nesting phenology of lesser prairie-chickens on the study site is predicted to remain stable through 2050 and 2080. These results are based on our inability to find evidence to support seasonal weather variables as a good predictor/influence of incubation start date.

We cannot attribute the 2011 drought and extreme temperatures to climate change, but these types of abnormalities/anomalies and extreme events are expected to occur in greater frequency with subsequent climate change [14]. Current carbon dioxide emissions will ultimately create similar weather patterns that are witnessed during La Niña events, albeit at much higher frequencies [15]. Therefore, under current CO_2 emission rates, the outlook for nest survival in the southern region of their distribution is not positive. What remains unknown within our assessment is the future relationship between all relevant demographic parameters, habitat availability, climate change, adaptation potential, and the positive benefit of habitat management [46]. Without an entire demographic and landscape assessment, we only have a small piece of a complex puzzle, as the interaction between climate change and main effects (e.g., nest survival) may be offset by the relationship between climate change and interactive effects (e.g. changes in landscape patterns coupled with recruitment).

Future Directions

Future assessments specifically designed to address climate related objectives for the genera *Tympanuchus* and similar species (Family Phasianidae) may benefit from incorporating 2 important components not used herein. First, climatic predictions using 10, 15 or 20 year intervals would be useful in order to assess when populations may reach critical threshold in terms of population viability. Second, impact assessments that include downscaled weather data from observations collected on site and future predicted values obtained from atmospheric and oceanic general circulation models are well suited to assess short term impacts (5–10 year intervals) at various spatial scales. For existing data sets, the methodologies used herein demonstrate the value of modeling demographic parameters in context of seasonal averages and totals when the ecology of the species suggests an existing relationship. For lesser prairie-chickens, we have demonstrated that on the Southern High Plains, nest survival is influenced by seasonal weather parameters, which is a cause of given future forecasts call for increase probability of drought.

Supporting Information

Figure S1.
Linear relationship between clutch size and winter precipitation.
https://doi.org/10.1371/journal.pone.0068225.s001
(PNG)

Figure S2.
Linear relationship between clutch size and winter temperature.
https://doi.org/10.1371/journal.pone.0068225.s002
(PNG)

Figure S3.
Linear relationship between incubation start date and winter precipitation.
https://doi.org/10.1371/journal.pone.0068225.s003
(PNG)

Figure S4.
Linear relationship between incubation start date and winter temperature.
https://doi.org/10.1371/journal.pone.0068225.s004
(PNG)

Figure S5.
Linear relationship between nest survival and winter precipitation.
https://doi.org/10.1371/journal.pone.0068225.s005
(JPG)

Figure S6.
Linear relationship between nest survival and winter temperature.
https://doi.org/10.1371/journal.pone.0068225.s006
(JPG)

Figure S7.
Interannual differences in nesting cover. Differences in nesting cover between a cool, wet spring (2010; top) and hot, dry spring (2011; bottom) on the study area in Roosevelt County, NM, and Cochran, Hockley, Terry, and Yoakum counties, TX, USA, 2001–2011.
https://doi.org/10.1371/journal.pone.0068225.s007
(TIF)

Table S1.
Values, means, and standard errors for weather data collected on site. Values, means, and associated standard errors (in parenthesis) for winter temperature (°C),winter precipitation (cm), yearly precipitation, spring temperatures, spring precipitation, and wet season precipitation used to evaluate lesser prairie-chicken nest survival in Roosevelt County, NM, and Cochran, Hockley, Terry, and Yoakum counties, TX, 2001–2011.
https://doi.org/10.1371/journal.pone.0068225.s008
(DOCX)

Table S2.
Names and description of weather models developed to assess the effects of seasonal weather patterns on lesser prairie-chicken reproductive parameters. Description, names, and number of parameters for nine *a priori* seasonal weather models used to assess daily nest survival, clutch size, and incubation initiation in Roosevelt County, NM, and Cochran, Hockley, Terry, and Yoakum counties, TX, USA, 2001–2011.
https://doi.org/10.1371/journal.pone.0068225.s009
(DOCX)

Table S3.
Detailed description of three greenhouse gas emission scenarios used to obtain predicted values of climatic variables.
https://doi.org/10.1371/journal.pone.0068225.s010
(DOCX)

Output S1.
Output from Proc GAM in SAS 9.2.
https://doi.org/10.1371/journal.pone.0068225.s011
(MHT)

Author Contributions

Conceived and designed the experiments: BG CB DH DD KB CD WH. Performed the experiments: BG CB DH DD KB CD WH. Analyzed the data: BG. Contributed reagents/materials/analysis tools: BG CB DH DD KB CD WH. Wrote the paper: BG CB DH DD KB CD WH.

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The Washington Post
Democracy Dies in Darkness

This study just undermined a huge myth about the Endangered Species Act

By Chelsea Harvey
December 14, 2015 at 3:32 p.m. EST

The Endangered Species Act (ESA) has raised continual controversy since its enactment more than four decades ago, inciting many a heated debate over the need to protect threatened plants and animals versus how such protections could crimp land use or economic development. But a surprising new analysis shows that the Act might not be quite the economic threat that critics believe it is — at least, not anymore.

The new research, which was published in Proceedings of the National Academy of Sciences, takes a look at the impact of an especially highly debated section of the ESA: Section 7, which requires federal agencies to consult with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service before moving forward with any form of development that they fund, authorize or carry out. This means that non-federal companies or organizations proposing development projects that require federal approval can be affected, since they must wait until the responsible federal agency has completed its Section 7 consultation.

These consultations are meant to ensure that development projects do not jeopardize species that have been listed under the act or "adversely modify" their critical habitats. If the Fish and Wildlife Service or National Marine Fisheries Service finds that they do, the projects can be altered or stopped.

To be clear, Section 7 does not embody all of the protections offered by the ESA nor is it the focus of all criticisms of the Act. While Section 7 is generally used to review larger-scale industrial development proposals, the Act still has significant bearing on the actions of individuals in other ways — for instance, by preventing landowners from shooting protected gray wolves, even if the landowners see the wolves as a threat to their livestock.

But Section 7 is one of the aspects of the Act with the potential to cause the most disruption to large-scale development projects, often with large numbers of jobs and large amounts of money at stake.

Yet the new analysis finds that, in the past seven years, not a single project has been halted or extensively changed as a result of a Section 7 consultation — effectively removing the teeth from modern arguments claiming that this aspect of the ESA is a hindrance to economic growth. The analysis was conducted by employees of Defenders of Wildlife, an environmental advocacy group, but the paper has been reviewed and published by a peer-reviewed journal. The authors' affiliations are made known in a conflict of interest statement included in the paper, which also notes that "the results do not necessarily reflect the positions of Defenders of Wildlife."

That's not to say that the ESA hasn't resulted in some high-profile conflicts in the past — perhaps the best known of these was the huge controversy surrounding the listing of the northern spotted owl in the 1990s. Because its critical habitat lies primarily in old-growth forests in the Pacific Northwest, the decision to list the bird as an endangered species caused a bitter rift between environmentalists and loggers, who argued that the decision was costing thousands of jobs.

Such stories are often cited by lobbyists calling for adjustments to the ESA on economic grounds, said Ya-Wei Li, senior director of Endangered Species Conservation at Defenders of Wildlife and a co-author on the new paper, who pointed to dozens of riders and bills introduced in the 114th session of Congress targeting the Act.

"The claim is that this consultation process is essentially killing jobs, it's ruining the economy, it's stopping projects left and right — all of these claims that the Section 7 process is very onerous to comply with," Li said. "We want to tell the real story."

Li and colleague Jacob Malcom, also of Defenders of Wildlife, used a Fish and Wildlife Service database to comb through all the Section 7 consultations that had been recorded by the Service between 2008 and 2015 — nearly 90,000 in all. They found that, ultimately, no project was stopped or extensively altered during this time as a result of a Section 7 consultation.

The analysis did pinpoint two consultations which resulted in a "jeopardy" call — the decision that a project proposal threatens a species listed under the ESA — although neither ultimately led to substantial action. The first of these was a project proposed by the U.S. Forest Service, according to the paper, and would have applied fire retardants on national forests. After a formal Section 7 consultation, the Fish and Wildlife Service found that the proposal jeopardized or adversely modified the critical habitats of 45 listed species. However, the authors explained, the decision was rejected in court in 2011 and a revised consultation found no jeopardy of adverse modification, according to the authors.

A second project was also found to result in jeopardy to a listed species — a small fish called the delta smelt — but was ultimately allowed to proceed with minor concessions.

These results are at odds with several similar studies conducted in the past, Li pointed out. An analysis of Section 7 consultations between 1979 and 1981 found that 173 of them resulted in jeopardy, although fewer than 10 were ultimately halted. Another analysis of consultations between 1987 and 1991 found 350 cases of jeopardy, and 18 projects were ultimately stopped.

The results beg the question of why there's been an apparent decline in the cases of jeopardy or adverse modification of habitat found during Section 7 consultations. The analysis can't point to any sure answers — but Li highlighted a few likely possibilities.

On the one hand, there's the optimistic conclusion that federal agencies have simply learned to design projects with minimal impact on endangered species in the first place — meaning they're already set to proceed by the time they make it to a Section 7 consultation, Li said. On the more pessimistic end, there's the theory that Section 7 enforcers have become less stringent in recent years — and the authors point out that this could be the result of a variety of factors, including budget cuts and political pressure.

A third, more middle-of-the-road explanation is that the Fish and Wildlife and National Marine Fisheries services, along with other federal agencies, have become better negotiators in recent years, meaning they've been able to talk through potential conflicts and make adjustments to proposals before having to resort to a jeopardy call.

Li said it seems likely that "all three of these hypotheses have occurred" — now, it's just a matter of figuring out whether one factor is dominant over the others.

"The most important implication of this paper is that these myths about the Endangered Species Act killing jobs, killing economies — they're not reflected in the data," Li said. So, he suggested, any calls to weaken the Act on the basis of its destructive effects on the economy should be dismissed.

Another pressing issue, moving forward, will be to determine just how well the Act is continuing to protect endangered and threatened species. "There really should be some evaluation of the extent to which Section 7, as currently administered, is contributing to the conservation of the species," Li said.

In order to facilitate more research on this front moving forward, the authors have created a web app that compiles all the consultation data in a more easily searchable way and will be open to the public.

"Without this data being publicly available, and without us analyzing it, we would never have been able to tell this story," Li said. "There's so much value in making this regulatory information, these day-to-day decisions of the government [available]. When you have 88,000 of them and put them together, you start seeing these incredible patterns. And that is really important to improving the transparency and accountability of how federal environmental laws are being implemented."

April 11, 2022

President Joseph R. Biden Jr.
The White House
1600 Pennsylvania Avenue, N.W.
Washington, DC 20500

Dear President Biden:

On behalf of many of the country's leading philanthropic institutions, we thank the Biden-Harris Administration for its leadership in setting an ambitious and inclusive conservation vision through the America the Beautiful initiative. We applaud the launch of the $1 billion America the Beautiful Challenge as a means to leverage federal conservation and restoration investments with private and philanthropic contributions to accelerate land, water, and wildlife conservation efforts across the country. We stand ready to help realize the Administration's vision.

The initial commitment of $440 million of federal resources over the next five years to the new America the Beautiful Challenge — a public-private grant program, administered by the National Fish and Wildlife Foundation (NFWF) — will provide much needed resources to states, Tribes, territories, local groups, and non-governmental organizations. It will facilitate the coordination of public and private funding for projects across the country to achieve even greater and more lasting positive impacts for communities on the ground. This new mechanism will also deploy funds through a streamlined application process and without cumbersome requirements, which allows for more resources to be spent directly on conservation activities in a timeframe that more closely matches both the challenge and opportunity. We commend the Administration for working to more efficiently to align resources and eliminate unnecessary red tape.

As philanthropic organizations, we are currently investing $250 million annually to address our country's biodiversity and climate crises by accelerating conservation and stewardship of US lands, ocean, and waters. While we are located in different parts of the United States and have may have different geographic and conservation priorities, we are united by a common understanding that reversing the decline of biodiversity in the U.S. and meeting our climate commitments requires an ambitious national mission

to expand the network of conserved lands, ocean, and waters. By supporting community-led and community-supporting efforts across the U.S., we are ensuring the most resilient landscapes and seascapes, threatened species and habitats, and critical wildlife corridors are linked together.

Together with these protections of our treasured Federal public lands and waters, improved stewardship and restoration on state, Tribal and private lands, farms, forests, grasslands, and wetlands can secure carbon in natural systems and turn carbon sources into sinks that can supply 20% of the climate mitigation needed for the country to achieve carbon neutrality by mid-century. This will have tremendous benefits for the health and wellbeing of our planet and our diverse communities across the U.S.

Between now and 2030, the signatories will continue to support efforts that propel the country toward achieving this vision and the six goals established under America the Beautiful:

1. Creating more parks and safe outdoor opportunities in nature-deprived communities.
2. Supporting Tribal and Indigenous-led conservation and restoration priorities.
3. Expanding collaborative conservation of fish and wildlife habitats and corridors.
4. Increasing access for outdoor recreation.
5. Incentivizing and rewarding the voluntary conservation efforts of fishers, ranchers, farmers, and forest owners.
6. Creating jobs by investing in restoration and resilience projects and initiatives.

We thank the Biden-Harris Administration for its commitment to keeping our communities strong, healthy, and prosperous by tackling biodiversity loss, the climate crisis, and addressing the inequitable access to nature. We stand ready to support these efforts and to work together towards making these ambitious plans a reality.

Sincerely,

444S Foundation

Harold K.L. Castle Foundation

The Christensen Fund

Conservation Alliance

Doris Duke Charitable Foundation

Edgerton Foundation

William and Flora Hewlett Foundation

The Holocene Foundation

The J.M. Kaplan Fund

Lazar Foundation

Merck Family Fund

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Patagonia

William Penn Foundation

The Pew Charitable Trusts

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Resources Legacy Fund

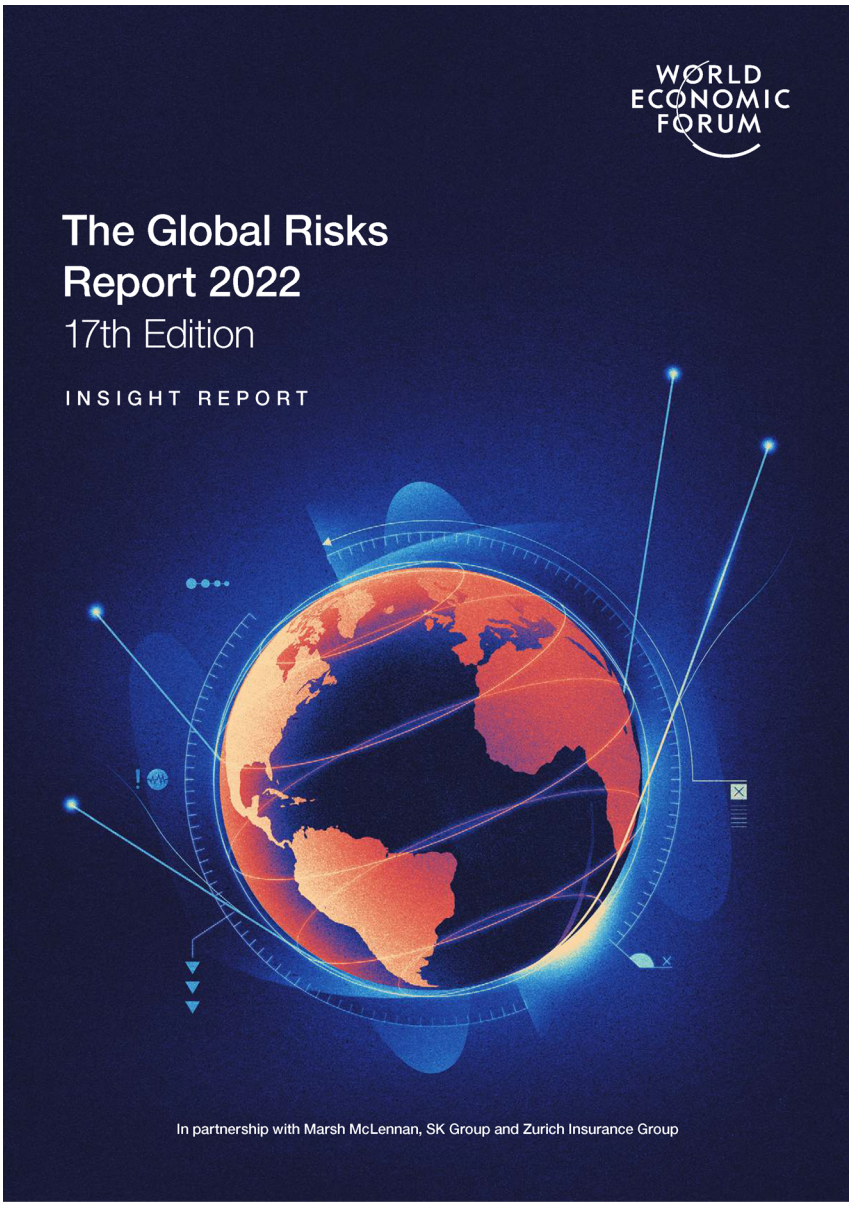
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The Global Risks Report 2022 17th Edition

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CONTENTS

Preface 5—6

Executive Summary 7—10

CHAPTER 1
Global Risks 2022: Worlds Apart including Global Risks Perception Survey 2021–2022 Results 11—29

CHAPTER 2
Disorderly Climate Transition 30—44

CHAPTER 3
Digital Dependencies and Cyber Vulnerabilities 45—56

CHAPTER 4
Barriers to Migration 57—69

CHAPTER 5
Crowding and Competition in Space 70—79

CHAPTER 6
Refreshing Resilience 80—91

Appendices
Appendix A: Description of Global Risks 2022
Appendix B: Executive Opinion Survey National Risk Perceptions
Appendix C: Technical Notes: Global Risks Perception Survey 2021–2022 92—112

Acknowledgements 113—116

Preface

By **Klaus Schwab** and **Børge Brende**

A divergent economic recovery from the crisis created by the pandemic risks deepening global divisions at a time when societies and the international community urgently need to collaborate to check COVID-19, heal its scars and address compounding global risks.

In some societies, rapid progress on vaccination, leaps forward on digitalization and a return to pre-pandemic growth rates herald better prospects for 2022 and beyond. Others could be weighed down for years by struggles to apply even initial vaccine doses, combat digital divides and find new sources of economic growth. Widening disparities within and between countries will not only make it more difficult to control COVID-19 and its variants, but will also risk stalling, if not reversing, joint action against shared threats that the world cannot afford to overlook.

Last year's edition of the *Global Risks Report* warned of potential knock-on economic risks that are now clear and present dangers. Supply chain disruptions, inflation, debt, labour market gaps, protectionism and educational disparities are moving the world economy into choppy waters that both rapidly and slowly recovering countries alike will need to navigate to restore social cohesion, boost employment and thrive. These difficulties are impeding the visibility of emerging challenges, which include climate transition disorder, increased cyber vulnerabilities, greater barriers to international mobility, and crowding and competition in space.

Restoring trust and fostering cooperation within and between countries will be crucial to addressing these challenges and preventing the world from drifting further apart.

The 17th edition of the *Global Risks Report* identifies tensions that will result from diverging trajectories and approaches within and between countries and then examines the risks that could arise from such tensions. This year's report also highlights the implications of these risks for individuals, governments and businesses.

The Global Risks Perception Survey (GRPS), which has underpinned the report since 2006, was refreshed this year to gather new and broader insights from nearly 1,000 global experts and leaders who responded. The 2021-2022 GRPS includes the following sections:

- **COVID-19 Hindsight** invites respondents to opine on the reverberations of the crisis, allowing comparability with the results from the previous year.
- **Future Outlook** captures respondent sentiment, informing our analysis of how individual contexts may influence global risk perceptions andaffect mitigation.
- **Horizon** captures respondents' perceived trajectory and sense of urgency of global risks, informing our analysis of choices and trade-offs that decision-makers may face.
- **Severity** ranks potential damage while **Effects** asks respondents to consider cascading impacts in conjunction with the severity of the risk itself.
- **International Mitigation** asks respondents to assess international efforts in 15 global governance areas to identify achievements and areas of opportunity for global action and cooperation.
- **Open questions on risks, trends and warning signs** source expert knowledge.

This year the *Global Risks Report* also draws on the views of over 12,000 country-level leaders who identified critical short-term risks to their 124 countries, gathered through the World Economic Forum's Executive Opinion Survey. The areas highlighted in these responses are likely to inform national decision-making and provide a perspective on how short-term risk national priorities may compare with global risks and perspectives.

We are ever grateful to our partners in the report's development: Marsh McLennan, SK Group and Zurich Insurance Group. We also thank our academic partners: the National University of Singapore, the Oxford Martin School at the University of Oxford and the Wharton Risk Management and Decision Processes Center at the University of Pennsylvania.

This report continues to leverage the collective intelligence of an expanding community of the world's foremost risk experts, convened by the World Economic Forum's Global Risks Practice: the Global Risks Report Advisory Board, the Chief Risk Officers Community and the Global Future Council on Frontier Risks, as well as a series of consultations with regional and thematic experts from the public and private sectors.

The report also draws from and supports the World Economic Forum's platforms dedicated to catalysing a new economy and society, accelerating climate action for people and planet, leveraging Fourth Industrial Revolution technologies, stewarding industry transformations and enhancing global and regional cooperation. These platforms and their stakeholders use the insights from this report to shape their agendas for tackling the world's greatest challenges and embedding greater resilience and cooperation.

Executive Summary

As 2022 begins, COVID-19 and its economic and societal consequences continue to pose a critical threat to the world. Vaccine inequality and a resultant uneven economic recovery risk compounding social fractures and geopolitical tensions. In the poorest 52 countries—home to 20% of the world's people—only 6% of the population had been vaccinated at the time of writing. By 2024, developing economies (excluding China) will have fallen 5.5% below their pre-pandemic expected GDP growth, while advanced economies will have surpassed it by 0.9%—widening the global income gap.

The resulting global divergence will create tensions—within and across borders—that risk worsening the pandemic's cascading impacts and complicating the coordination needed to tackle common challenges including strengthening climate action, enhancing digital safety, restoring livelihoods and societal cohesion and managing competition in space.

The *Global Risks Report 2022* presents the results of the latest Global Risks Perception Survey (GRPS), followed by an analysis of key risks emanating from current economic, societal, environmental and technological tensions. The report concludes with reflections on enhancing resilience, drawing from the lessons of the last two years of the COVID-19 pandemic. The key findings of the survey and the analysis are summarized below.

Global risks perceptions highlight societal and environmental concerns

Asked to take a view of the past two years, respondents to the GRPS perceive societal risks—in the form of "social cohesion erosion", "livelihood crises" and "mental health deterioration"—as those that have worsened the most since the pandemic began. Only 16% of respondents feel positive and optimistic about the outlook for the world, and just 11% believe the global recovery will accelerate. Most respondents instead expect the next three years to be characterized by either consistent volatility and multiple surprises or fractured trajectories that will separate relative winners and losers.

For the next five years, respondents again signal societal and environmental risks as the most concerning. However, over a 10-year horizon, the health of the planet dominates concerns: environmental risks are perceived to be the five most critical long-term threats to the world as well as the most potentially damaging to people and planet, with "climate action failure", "extreme weather", and "biodiversity loss" ranking as the top three most severe risks. Respondents also signalled "debt crises" and "geoeconomic confrontations" as among the most severe risks over the next 10 years.

Technological risks—such as "digital inequality" and "cybersecurity failure"—are other critical short- and medium-term threats to the world according to GRPS respondents, but these fall back in the rankings towards the long term and none appear among the most potentially severe, signalling a possible blind spot in risk perceptions.

The 2021-2022 GRPS included a question on international risk mitigation efforts. "Artificial intelligence", "space exploitation", "cross-border cyberattacks and misinformation" and "migration and refugees" are the areas where most respondents believe the current state of risk mitigation efforts fall short of the challenge—that is, efforts are "not started" or in "early development". Meanwhile, for "trade facilitation", "international crime" and "weapons of mass destruction", large majorities perceived risk mitigation efforts to be "established" or "effective".



REUTERS/HEO RAN

A divergent economic recovery threatens collaboration on global challenges

Economic challenges flowing from the pandemic persist. The outlook remains weak: at the time of writing, the global economy was expected to be 2.3% smaller by 2024 than it would have been without the pandemic. Rising commodity prices, inflation and debt are emerging risks. Moreover, with another spike in COVID-19 cases towards the end of 2021, the pandemic continues to stifle countries' ability to facilitate a sustained recovery.

The economic fallout from the pandemic is compounding with labour market imbalances, protectionism, and widening digital, education and skills gaps that risk splitting the world into divergent trajectories. In some countries, rapid vaccine rollout, successful digital transformations and new growth opportunities could mean a return to pre-pandemic trends in the short term and the possibility of a more resilient outlook over a longer horizon. Yet many other countries will be held back by low rates of vaccination, continued acute stress on health systems, digital divides and stagnant job markets. These divergences will complicate the international collaboration needed to address the worsening impacts of climate change, manage migration flows and combat dangerous cyber-risks.

Short-term domestic pressures will make it harder for governments to focus on long-term priorities and will limit the political capital allocated to global concerns. "Social cohesion erosion" is a top short-term threat in 31 countries—including Argentina, France, Germany, Mexico and South Africa from the G20. Disparities that were already challenging societies are now expected to widen—51 million more people are projected to live in extreme poverty compared to the pre-pandemic trend—at the risk of increasing polarization and resentment within societies. At the same time, domestic pressures risk stronger national interest postures and worsening fractures in the global economy that will come at the expense of foreign aid and cooperation.

A disorderly climate transition will exacerbate inequalities

Respondents to the GRPS rank "climate action failure" as the number one long-term threat to the world and the risk with potentially the most severe impacts over the next decade. Climate change is already manifesting rapidly in the form of droughts, fires, floods, resource scarcity and species loss, among other impacts. In 2020, multiple cities around the world experienced extreme temperatures not seen for years—such as a record high of 42.7°C in Madrid and a 72-year low of -19°C in Dallas, and regions like the Arctic Circle have averaged summer temperatures 10°C higher

than in prior years. Governments, businesses and societies are facing increasing pressure to thwart the worst consequences. Yet a disorderly climate transition characterized by divergent trajectories worldwide and across sectors will further drive apart countries and bifurcate societies, creating barriers to cooperation.

Given the complexities of technological, economic and societal change at this scale, and the insufficient nature of current commitments, it is likely that any transition that achieves the net zero goal by 2050 will be disorderly. While COVID-19 lockdowns saw a global dip in greenhouse gas (GHG) emissions, upward trajectories soon resumed: the GHG emission rate rose faster in 2020 than the average over the last decade. Countries continuing down the path of reliance on carbon-intensive sectors risk losing competitive advantage through a higher cost of carbon, reduced resilience, failure to keep up with technological innovation and limited leverage in trade agreements. Yet shifting away from carbon-intense industries, which currently employ millions of workers, will trigger economic volatility, deepen unemployment and increase societal and geopolitical tensions. Adopting hasty environmental policies will also have unintended consequences for nature—there are still many unknown risks from deploying untested biotechnical and geoengineering technologies—while lack of public support for land use transitions or new pricing schemes will create political complications that further slow action. A transition that fails to account for societal implications will exacerbate inequalities within and between countries, heightening geopolitical frictions.

Growing digital dependency will intensify cyberthreats

Growing dependency on digital systems—intensified by COVID-19—has altered societies. Over the last 18 months, industries have undergone rapid digitalization, workers have shifted to remote working where possible, and platforms and devices facilitating this change have proliferated. At the same time, cybersecurity threats are growing—in 2020, malware and ransomware attacks increased by 358% and 435% respectively—and are outpacing societies' ability to effectively prevent or respond to them. Lower barriers to entry for cyberthreat actors, more aggressive attack methods, a dearth of cybersecurity professionals and patchwork governance mechanisms are all aggravating the risk.

Attacks on large and strategic systems will carry cascading physical consequences across societies, while prevention will inevitably entail higher costs. Intangible risks—such as disinformation, fraud and lack of digital safety—will also impact public trust in digital systems. Greater cyberthreats will also hamper cooperation between states if governments continue to follow unilateral paths to control risks. As attacks become more severe and broadly impactful, already-sharp tensions between governments impacted by cybercrime and governments complicit in their commission will rise as cybersecurity becomes another wedge for divergence—rather than cooperation—among nation-states.

Barriers to mobility risk compounding global insecurity

Growing insecurity resulting from economic hardship, intensifying impacts of climate change and political instability are already forcing millions to leave their homes in search of a better future abroad. "Involuntary migration" is a top long-term concern for GRPS respondents, while 60% of them see "migration and refugees" as an area where international mitigation efforts have "not started" or are in "early development". In 2020, there were over 34 million people displaced abroad globally from conflict alone—a historical high. However, in many countries, the lingering effects of the pandemic, increased economic protectionism and new labour market dynamics are resulting in higher barriers to entry for migrants who might seek opportunity or refuge.

These higher barriers to migration, and their spill-over effect on remittances—a critical lifeline for some developing countries—risk precluding a potential pathway to restoring livelihoods, maintaining political stability and closing income and labour gaps. At the time of writing, the United States faced over 11 million unfilled jobs in general and the European Union had a deficit of 400,000 drivers just in the trucking industry. In the most extreme cases, humanitarian crises will worsen since vulnerable groups have no choice but to embark on more dangerous journeys. Migration pressures will also exacerbate international tensions as it is increasingly used as a geopolitical instrument. Destination-country governments will have to manage diplomatic relationships and immigrant skepticism among their populations.

Opportunities in space could be constrained by frictions

While humans have been exploring space for decades, recent years have witnessed increased activity, not only creating new opportunities but also signalling an emerging realm of risk, particularly with growing militarization and weaponization in the arena. New

commercial satellite market entrants are disrupting incumbents' traditional influence over the global space commons in delivering satellite services, notably internet-related communications. A greater number and range of actors operating in space could generate frictions if space exploration and exploitation are not responsibly managed. With limited and outdated global governance in place to regulate space alongside diverging national-level policies, risks are intensifying.

One consequence of accelerated space activity is a higher risk of collisions that could lead to a proliferation of space debris and impact the orbits that host infrastructure for key systems on Earth, damage valuable space equipment or spark international tensions. Limited governance tools increase the likelihood of space activity escalating geopolitical tensions, and recent weapons tests in space underscore such risks. Increased space activity could also lead to unknown environmental impacts or raise costs for public goods such as weather monitoring or climate change surveillance.

Year two of the pandemic yields insights on resilience

In 2021, countries deployed new mechanisms to respond to a public health crisis with shifting characteristics, leading to both successes and failures. Two interlinked factors were critical for effective management of the pandemic: first, the readiness of governments to adjust and modify response strategies according to changing circumstances; and second, their ability to maintain societal trust through principled decisions and effective communication.

Reflecting on the distinct resilience goals of governments, businesses and communities will help ensure that agendas are aligned in achieving a whole-of-society approach to tackling critical risks of any nature. For governments, balancing costs, regulating for resilience and adjusting data-sharing arrangements to ensure sharper crisis management are key to galvanizing stronger interaction between public and private sectors. Businesses—recognizing that better national-level preparedness is critical for planning, investing and executing their strategies—can leverage opportunities in areas such as supply chains, codes of conduct within their industry and inclusion of a resilience dimension into workforce benefit offerings. Communities can help local governments to join up with national efforts, improve communication and support grassroots resilience efforts. At an organizational level, strategies such as grounding resilience analyses in key delivery requirements, appreciating systemic vulnerabilities and embracing a diversity of approaches can help leaders build better resilience as well.



REUTERS/MUHAMMAD HAMED


CHAPTER 1
Global Risks 2022: Worlds Apart
6%
vaccination rate in poorest 52 countries
97%
public debt-to-GDP in 2020
51 million
increase in extreme poverty projections
197
countries aligned on the Glasgow Climate Pact
84%
of experts are worried or concerned about the world
GETTY/ABSTRACT AERIAL ART
The Global Risks Report 2022

A divergent recovery

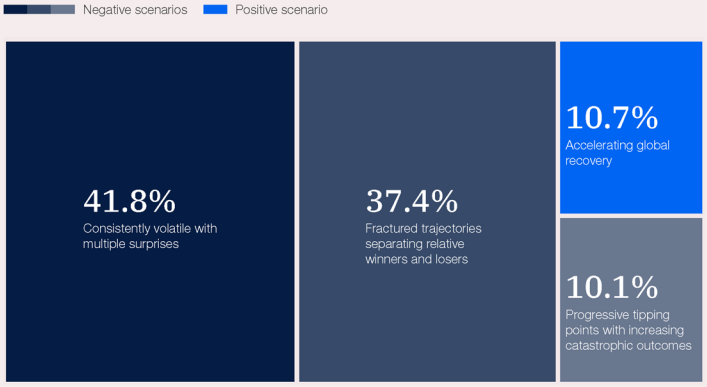
At the start of 2022, the COVID-19 crisis is still ongoing and its economic ructions continue to be felt. Disparities in progress on vaccination are creating a divergent economic recovery that risks compounding pre-existing social cleavages and geopolitical tensions. These tensions and the economic overhang of the pandemic will make it difficult to ensure a coordinated and sufficiently rapid approach to global challenges—most notably climate change.

Vaccination and accelerated digitalization have enabled some countries to recover rapidly from the economic crisis created by the COVID-19 pandemic, but many others are still struggling to avoid the worst consequences. At the time of writing, half of the world's population was still unvaccinated,[1] 40% remained offline,[2] and only 35% of the world's students lived in countries where schools are fully open.[3] Some 37% of respondents to this year's Global Risks Perceptions Survey (GRPS) believe the world will follow a fractured trajectory in the medium term, increasingly separating relative "winners" from "losers" of the COVID-19 crisis (see Figure 1.1). By the time the GRPS was conducted (see the Technical Notes in Appendix C), only 11% believed the global recovery would accelerate over the next three years.

Economic, geopolitical, public health and societal fractures—which increase after pandemics[4]—risk leading to divergent and delayed approaches to critical challenges facing people and planet: accelerating the green transition in response to climate change (see Chapter 2), coordinating against heightened digital vulnerabilities (see Chapter 3), managing mobility and migration (see Chapter 4) and safeguarding the next global commons: space (see Chapter 5).

FIGURE 1.1

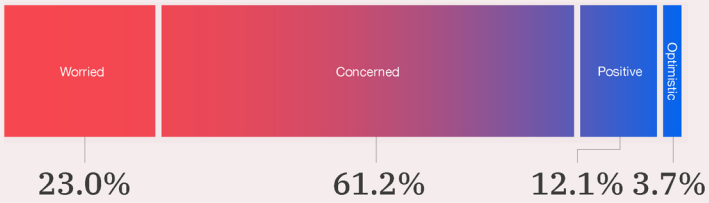
"What is your outlook for the world over the next three years?"



Source: World Economic Forum Global Risks Perception Survey 2021-2022

FIGURE 1.2

"How do you feel about the outlook for the world?"



Source: World Economic Forum Global Risks Perception Survey 2021-2022

Effective domestic and international action on these challenges depends on restoring trust within societies, galvanizing national and global leaders and finding new opportunities for collaboration (see Chapter 6). Fully 84% of GRPS respondents were either concerned or worried about the outlook for the world (see Figure 1.2); lack of optimism could create a vicious cycle of disillusionment and social unrest.

A turbulent global context

The pandemic persists

The world continues to grapple with the effects of COVID-19 on public health. At the start of 2022, 5.4 million deaths from COVID-19 had been reported globally, out of 282 million confirmed cases.[5] Moreover, a significant proportion of those infected by COVID-19 have long-lasting symptoms—some 10% show persistent ill health 12 weeks after having the disease.[6] COVID-19 vaccination has progressed steadily but unevenly around the world. At the time of writing, 50 countries had vaccinated more than 70% of their population,[7] with some now starting to receive booster shots, while the vaccination rate in the poorest 52 countries—home to 20% of the world's population—was still only 6%.[8] Potentially more infectious variants of the virus—notably the new Omicron variant—along with waning immunity among the vaccinated and a continued high proportion of people who are unvaccinated meant that the number of new cases increased again towards the end of 2021.[9] Unsurprisingly, "infectious diseases" are still considered a critical short-term threat to the world in the GRPS.

The COVID-19 crisis has also had extensive collateral health impacts, partly because other diseases were deprioritized. The pandemic led to an additional 53 million cases of major depression globally.[10] "Mental health deterioration" was one of the top five risks that GRPS respondents saw as having deteriorated the most during COVID-19. The incidence of non-communicable diseases—which cause 41 million deaths every year, mostly in low- and middle-income countries—has also worsened worldwide due to treatment delays caused by COVID-19.[11] Antimicrobial resistance caused nearly 2 million deaths in 2020 and this number may increase—particularly for malaria and tuberculosis—because of the inappropriate use of antibiotics to treat COVID-19.[12] The pandemic and its collateral health impacts

will continue to put pressure on health systems across the globe, widen health inequalities between and within countries, create social frictions and weigh down long-term economic growth potential.

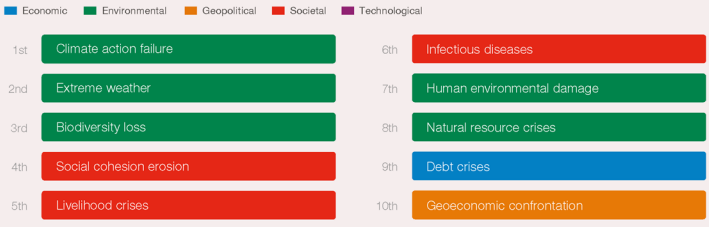
Risks to economic recovery

The global economic recovery from the recession caused by responses to the COVID-19 pandemic continues but is slowing. After a contraction of 3.1% in 2020, global economic growth is expected to reach 5.9% in 2021 and slow to 4.9% in 2022.[13] By 2024, the global economy is projected to be 2.3% smaller than it would have been without the pandemic.[14] Risks to economic growth are considerable, including risks from a potential resurgence of COVID-19 as new variants emerge. The previous edition of the GRPS identified "commodity shocks", "price instability" and "debt crises" as critical medium-term concerns. These are already emerging to some extent. At the time of writing, commodity prices had increased nearly 30% since end of 2020;[15] they could remain volatile because of growing tensions between Europe and Russia, China's energy shortage,[16] continued supply chain disruptions and transition challenges from disinvestment in fossil fuel reserves. Inflation has accelerated in many countries as a result of pandemic-related disruptions to supply chains combined with resurgent consumer demand and higher commodity prices. This will dampen consumer sentiment—which has been fundamental for recovery—and will increase risks from central bank interest rate rises.[17] In advanced and developing economies alike, higher prices and more expensive debt would impact lower-income households especially hard, while small and medium-sized enterprises (SMEs) that are still trying to avoid bankruptcy would suffer from weakening consumption.

Moreover, sovereign debt has spiked because of the pandemic. Government debt globally increased by 13 percentage points, to 97% of GDP, in 2020.[18] Already-strained public finances in developing countries are at heightened risk from debt deleveraging[19] and an appreciation of the US dollar—the US Dollar Index had risen 7% since the start of 2021.[20] GRPS respondents identified "debt crises" as a critical short- and medium-term threat to the world, and one of the most potentially severe risks over the next decade (see Figure 1.3). Debt overhangs will make it more difficult for countries to deal with the economic impacts of COVID-19 and finance a socially just, net zero transition.

FIGURE 1.3

"Identify the most severe risks on a global scale over the next 10 years"



Source: World Economic Forum Global Risks Perception Survey 2021-2022



GETTY/LIU JIN

Economic divergence

COVID-19 prompted a global recession, but stark differences in vaccination rates between countries now risk leading to even greater economic divergence than they experienced before the pandemic. A greater prevalence of COVID-19 in low-vaccination countries than in high-vaccination ones will weigh on worker availability and productivity, disrupt supply chains and weaken consumption. Moreover, a lower post-pandemic risk appetite in the vaccinated world—comprised mostly of advanced economies—could weaken their investment in the non-vaccinated world. The economic disruption from the pandemic has also created stronger incentives in the vaccinated world to prioritize resilience over cost minimization. Governments and industries may now drive regional convergence at the expense of global integration as they seek to minimize supply chain disruptions.

Polarized connectivity, education and income trajectories risk further fragmenting the global economy, and divergence is likely to be aggravated by slowing and disparate growth. Advanced economies are expected to surpass their pre-pandemic growth path by 0.9% by 2024, but developing economies (excluding China) will be 5.5% below it—with Latin America and Sub-Saharan Africa trailing even further behind.[21] Economic decoupling risks further hindering already-limited means to restore growth in developing economies. Such decoupling will make it harder for emerging economies to leverage young workforces, large consumer markets and competitive costs. They also risk having less access to financing and technology to face global challenges, including climate change.

Although employment is approaching pre-pandemic levels in many advanced economies, globally the jobs recovery from the COVID-19 crisis is lagging the economic recovery—global employment remains lower than it was before the pandemic and the Great Resignation in advanced economies has caused labour market

Income disparities risk increasing polarization and resentment within societies

participation to fall. Youth, women and lower-skilled workers have been especially affected. It will take the global economy at least until 2023 to create the jobs lost to COVID-19, but many of these jobs are expected to be of low productivity and poor quality, according to the International Labour Organization.[22] "Livelihood crises" is the second most immediate threat to the world in the GRPS, and the top one at the country level in the Executive Opinion Survey (EOS). It is the most immediate national threat in 97 countries, including 16 of the G20 economies.

A bifurcated economic recovery is likely to prompt an upsurge in economic migration. At the same time, worsening extreme weather and a rise in political instability, state fragility and civil conflict are likely to further swell refugee numbers. GRPS respondents rate "involuntary migration" as a critical threat to the world over the next decade. Yet, it is a top-10 concern in only 13 countries surveyed by the EOS—among them Armenia, El Salvador, Guatemala, Honduras, Nicaragua, Ukraine and Venezuela, which have recently experienced challenges related to migration and refugees. These results suggest that migration is perceived as a short-term challenge localized in certain countries, but a global risk in the longer term. However, the clash between heightened migration pressures in origin countries and increasing barriers to migration in destination countries risks creating tensions internationally and, in the worst cases, humanitarian crises.

Erosion of social cohesion

"Social cohesion erosion" is the risk that has worsened the most globally since the start of the COVID-19 crisis, according to the GRPS. It is perceived as a critical threat to the world across all time spans—short, medium and long term—and is seen as among the most potentially damaging for the next 10 years. In 31 out of the 124 countries surveyed in the EOS—including Argentina, France, Germany, Mexico and South Africa among the G20—"social cohesion erosion" was seen as a top-10 short-term threat to their countries. Inequality—economic, political, technological and intergenerational—was already challenging societies even before income disparities increased through the pandemic.[23] These disparities are now expected to widen further: research by the World Bank estimates that the richest 20% of the world's population will have recovered half their losses in 2021, while the poorest 20% will have lost 5% more of their income.[24] By 2030, 51 million more people are projected to live in extreme poverty compared to the pre-pandemic trend.[25] Income disparities exacerbated by an uneven economic recovery risk increasing polarization and resentment within societies.



GETTY/STR

Differing views over vaccinations and COVID-related restrictions are also adding to social pressures, with a number of countries, including in Europe, seeing riots by those opposed to government's COVID responses. Racial justice also remains a pressing issue in many countries, notably the United States.

A recent poll in the United States, for example, found "division in the country" to be voters' top concern: they expected it to worsen in 2022.[26] In Europe, another recent poll revealed significant generational differences, with 65% of respondents over 60 saying that they were "not impacted at all" by the pandemic, compared with just 43% of respondents under 30.[27] The attack on the US Capitol in January 2021 was one manifestation of the instability that political polarization risks creating.

Notwithstanding the agreements made at COP26 signal international commitment to climate action (see Box 1.1), short-term domestic pressures will make it harder for governments to focus on long-term national priorities and will limit the attention and political capital that some governments worldwide will be able or willing to allocate to global concerns. Such pressures could also lead to stronger national interest postures, which would worsen fractures in the global economy, potentially coming at the expense of foreign aid and cooperation needed to resolve conflicts, protect refugees and address humanitarian emergencies. The UK government, for instance, already dropped its target of spending 0.7% of gross national income on foreign aid until at least 2024.[28] Fragile economies could spiral into deeper crises.

Geopolitical tensions

Widening geopolitical fractures risk being another force for global divergence. Competition between the United States and China is increasing. China's growing military prowess is changing the balance of power in the Western Pacific.[29] The United States is strengthening alliances focused on the Pacific in response, most recently with the Australia-UK-US security pact

Countries may drive regional convergence at the expense of global integration

(AUKUS). Other states, such as Russia and Turkey, are also showing greater capability and willingness to project power abroad. Meanwhile, key global and regional powers are testing boundaries of international law and cooperation by conducting military exercises around tense areas, such as the Russia-Ukraine border and the Taiwan Strait. Competition is intensifying in newer dimensions and geographies, as evident in the militarization and weaponization of space (see Chapter 5) and in developments in cyberspace, where already-sharp tensions between governments impacted by cybercrime and governments complicit in their commission will continue to rise (see Chapter 3).

Competition is also increasing in the exercise of "soft power". For example, China's vaccine diplomacy, external financing strategy and economic rebound—its economy is expected to have grown by 8% annually in 2021[30]—have allowed it to continue to expand its influence throughout the developing world. Brazil, Indonesia, Mexico and Turkey are among the top buyers of Chinese COVID-19 vaccines,[31] and net debt payments to China rose by 62% in 2020.[32] Developing countries may increasingly look to China for financial, technological and scientific support to thrive in the post-pandemic economy.

Geopolitical tensions are spilling over into the economic sphere. For example, India and Japan put protectionist policies in place during the pandemic.[33] Western companies in sensitive sectors such as technology are encountering increasing difficulties in doing business in China and Russia, and Western countries are themselves restricting investment from geopolitical competitors in strategic sectors. GRPS respondents identified "geoeconomic confrontations" as a critical medium- and long-term threat

to the world, and the most potentially severe geopolitical risk for the next decade (see Figure 1.3). Geopolitical and geoeconomic tensions will make it more difficult to tackle common global challenges, notably climate change.

Risk of climate action failure

The 2021 United Nations Climate Change Conference (COP26) succeeded in getting 197 countries to align on the Glasgow Climate Pact and other landmark pledges (see Box 1.1), but even these new commitments are expected to miss the 1.5°C goal established in the 2016 Paris Climate Agreement and increase the risks from a disorderly climate transition (see Chapter 2).[34]

The economic overhang of the COVID-19 crisis and weakened social cohesion—in advanced and developing economies alike—may further limit the financial and political capital available for stronger climate action. The European Union, the United Kingdom and the United States, for example, were reluctant to commit to a formal climate finance target to respond to worsening climate change impacts in developing country Parties.[35] China and India lobbied to change the Pact's wording from "phase out" to "phase down" of "unabated coal power and inefficient fossil fuel subsidies".[36]

The economic crisis created by the COVID-19 pandemic risks delaying efforts to tackle climate change by encouraging countries to prioritize short-term measures to restore economic growth, regardless of their impact on the climate, over pursuing green transitions. Brazil, for example, joined the other 140 countries responsible for 91% of the Earth's forests in endorsing the Glasgow Leaders' Declaration on Forests and Land Use,[37] even as deforestation in the Amazon accelerated to a 15-year high in 2021 following the pandemic-induced recession of 2020.[38] Geopolitical tensions and nation-first postures will also complicate climate action. COP26 revealed heightened tensions on climate damage compensation, with affected countries facing pushback from large emitters, including the United States.[39]

Climate change continues to be perceived as the gravest threat to humanity. GRPS respondents rate "climate action failure" as the risk with potential to inflict the most damage at a global scale over the next decade (see Figure 1.3). However, EOS results hint at divergent senses of urgency between regions and countries. "Climate action failure" ranks 2nd as a short-term risk in the United States but 23rd in China—the two countries that are the world's largest CO_2 emitters. In addition to its 2nd place rank in the United States, it ranks among the top 10 short-term risks in 11 other G20 economies.



REUTERS/ANNIBAL HANSCHKE

BOX 1.1

Outcomes of COP26 and COP15

The 2021 United Nations Climate Change Conference (COP26, held in Glasgow, the United Kingdom), which passed the Glasgow Climate Pact,[1] concluded with important steps towards the 1.5°C scenario: it requested governments from 153 countries to update and strengthen their nationally determined contributions (NDCs), bolstered climate adaptation finance efforts, and continued the mobilization of billions of US dollars for climate funding and trillions to be reallocated by private institutions and central banks towards global net zero. COP26 was the first with financial sector attendance, represented by the Global Financial Alliance for Net Zero (GFANZ), whose members manage over US$130 trillion in assets and already actively fund sustainable investments.[2]

For the first time, the Pact made explicit mention of the importance of transitioning away from coal—but did not commit to "phase out" inefficient fossil fuel subsidies. However, as the United Nations Environment Programme (UNEP)'s Emissions Gap Report 2021 shows, reaching the 1.5°C target remains unlikely.[3]

Another key outcome was an agreement on the fundamental norms related to Article 6 of the Paris Agreement (on carbon markets), making it now fully operational.[4] Businesses and governments also agreed on more aggressive investment in clean technologies,[5] including a faster transition to electric vehicles and landmark pledges on methane emissions and deforestation.[6]

Key pledges achieved at COP26:

- India pledged to reach net zero emissions by 2070 and announced a target of 50% renewable energy by 2030. All the largest emitters have now agreed to start phasing out fossil fuels.
- 46 countries pledged to transition from coal to clean power by 2040.
- 104 countries pledged to a 30% cut in methane emissions by 2030. Methane accounts for 30% of historical global warming.
- 141 countries that account for 91% of the world's forests pledged to end deforestation by 2030.

The 2021 Conference of the Parties for the Convention on Biological Diversity (COP15, held in Kunming, China) resulted in "strong declarations for safeguarding life on Earth",[7] along with joint measures for conservation actions and addressing unsustainable production and consumption;[8] it also paved the way to negotiate a post-2020 global biodiversity framework for part two of COP15 in May 2022.[9]

Footnotes

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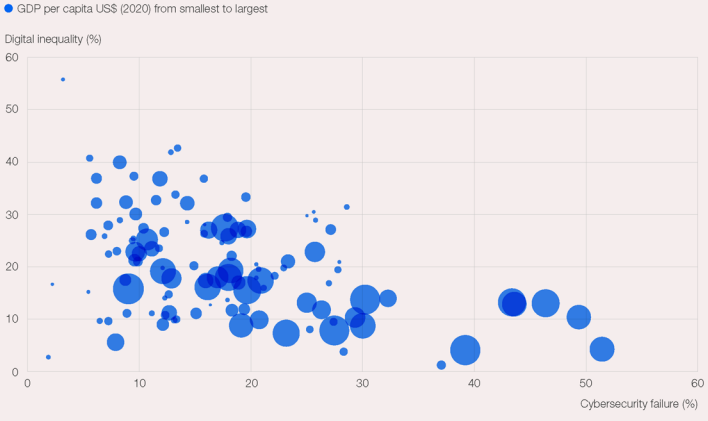
Secure digitalization

COVID-19 spurred a leap in digitalization, but to varying extents across countries. While moving towards hyperconnectivity has made some countries more competitive, others could remain stuck in a pre-pandemic analogue economy. In the latter economies, the need for rapid digitalization to avoid a widening digital divide remains pressing.[40] In the EOS, "digital inequality" is a top short-term risk in Latin America and Sub-Saharan Africa—the two regions expected to grow the least in 2022—as well as in low-income countries more widely. Governments, businesses and individuals in developing economies will be seeking to digitalize rapidly but may have limited technical and financial resources to enhance cyber defences against critical infrastructure breaches or cyber regulations to safeguard data and privacy.

More parts of the world risk becoming a base from which cybercriminals can attack globally, which could deepen digital divides if such countries then face restrictions on their access to digital technologies. Rapid digitalization in advanced economies during COVID-19 has also led to new cyber vulnerabilities. "Cybersecurity failure" was identified by GRPS respondents as a critical short-term threat to the world and scores especially high with EOS respondents in high-income countries (see Figure 1.4). There is a risk that concerns over cybersecurity could further hamper attempts to promote rapid and inclusive digitalization globally.

FIGURE 1.4

Score of "Digital Inequality" and "Cybersecurity Failure" in EOS 2021 versus GDP per Capita in 2020



Sources: World Economic Forum Executive Opinon Survey 2021; World Bank Open Data, "GDP per capita (current US$)", https://data.worldbank.org/indicator/NY.GDP.PCAP.CD, accessed 7 December 2021.

Note: Excludes Luxembourg, Switzerland and Ireland, which have the highest GDPs per capita in the EOS sample (all above US$80,000) and are distant from the rest of the sample (fourth highest is the United States, with US$63,544).

Space as a new frontier of divergence

Space is another area where global divergences risk complicating the collaboration needed to manage the development of a common good. Competition in space is rising and is a growing preoccupation for the world's leading militaries—evidenced by recent anti-satellite (ASAT) and hypersonic weapons tests.[41] Disparate economic and technological trajectories risk precluding many countries from accessing the opportunities that space entails for tackling climate change and expanding connectivity, and from ensuring that their interests are accounted for in global decision-making around space governance and commercialization. Meanwhile, increased private sector participation in space and a higher risk of congestion are creating new challenges for space governance. However, there is still time for countries to come together to ensure common benefits and sustainable management of what should be a universal resource.

Emerging tensions in global cooperation

The global divergence that risks resulting from ruptures within the world economy, stronger competition for geopolitical advantage and domestic pressures to prioritize national objectives will create complex challenges for global cooperation over the next years. Four such areas are analysed in the following deep dive chapters:

- Mounting conviction for a fast but disorderly climate transition, slowed by social, political and economic complexities, risks creating a kaleidoscope of net zero trajectories, each with different speeds and complications (see Chapter 2).
- Rapid digitalization risks exposing economies to new and more intense cyber vulnerabilities, as new technologies and an ever-expanding attack surface enable a more dangerous and diverse range of cybercrimes (see Chapter 3).
- Increased pressure for migration from origin countries as they become more insecure risks conflicting with higher barriers in destination countries (see Chapter 4).
- A new space race marked by accelerated commercial and military activity risks exacerbating tensions and oversaturation of this frontier common, highlighting the need for strengthening international governance of space (see Chapter 5).

The COVID-19 pandemic exposed the shortcomings of global cooperation, but the way forward is not clear. There is a need for stronger global governance and more effective international risk mitigation efforts, since the global, interconnected challenges highlighted in this report cannot be solved by national governments alone. Yet coming together with common purpose to achieve lasting results will be challenging: effective global governance depends on international cooperation,[42] and it will be difficult to secure traction, harness the necessary capabilities and achieve resolution on critical issues in an international relations context characterized by economic divergence, skepticism around globalization, a narrower focus on national interests and intensified geopolitical competition. Existing institutions of global governance are under pressure—as shown, for example, by the challenges that an under-resourced World Health Organization (WHO) continues to face in responding effectively to the COVID-19 pandemic.[43]

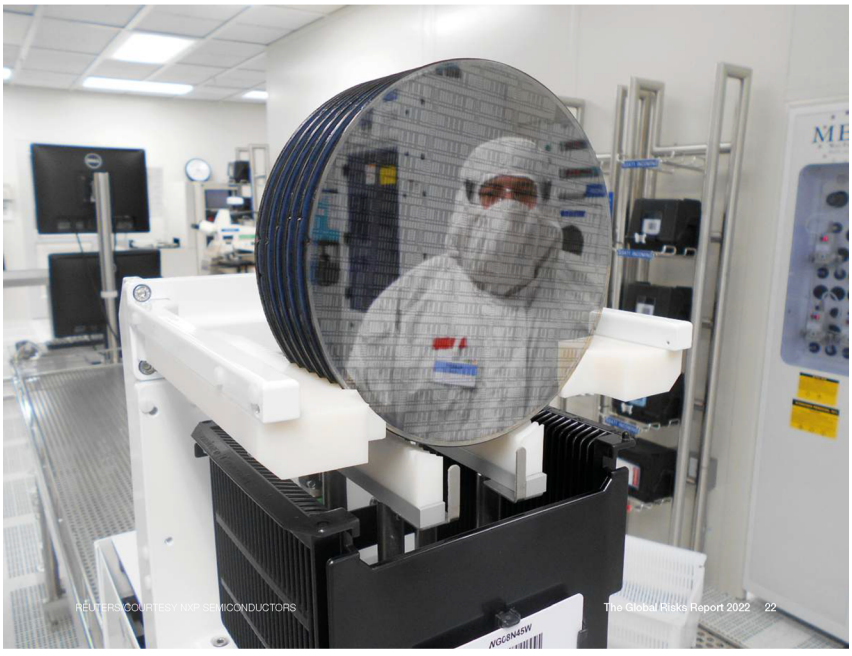
Appreciating this challenge, the final chapter of the report reflects on how governments can hedge against the prevailing limitations of multilateralism by pursuing a whole-of-society approach to bolstering national resilience (see Chapter 6).

Reflecting on the future

Crises prompt unexpected paths. Different blind spots, triggers and shocks can have a wide range of outcomes, all with varying likelihoods and impacts. As readers consider the results of the GRPS survey, review the emerging global context and read the deep dives, this report invites them to consider the behaviours and actions of specific stakeholders and to consider the consequences for a range of risk outcomes, from probable to improbable and manageable to severe.

Among the most notable areas of socio-economic concern are the divergent recovery, economic hardship and growing inequality, along with their interaction with ideological polarization and the sense of disenfranchisement of large sections of the global population. Governments' struggles to contain the pandemic and a lack of global collaboration on COVID-19 offer a sobering view of prospects for managing future global risks such as extreme weather and for pursuing bolder climate action. When it comes to business and industry, even enterprises with the financial room to manoeuvre sometimes struggle to deliver on environmental, social and governance (ESG) commitments while also strengthening the resilience of their supply chains, adapting to social and technological change and remaining vigilant to threats such as cyberattacks.

Two years on from the start of this unprecedented crisis, the actions and behaviours of all stakeholders will determine how quickly the world recovers and embeds the resilience needed to prepare for the next major shock.



REUTERS/COURTESY NXP SEMICONDUCTORS

Global Risks Perception Survey 2021-2022 Results

Scars of COVID-19

"Social cohesion erosion", "livelihood crises" and "mental health deterioration" are three of the five risks that have deteriorated the most globally through the crisis, according to the GRPS. These three risks—and the pandemic itself ("infectious diseases")—are also seen as being among the most imminent threats to the world. This societal scarring compounds the challenges of effective national policy-making and reduces the attention and focus needed on international cooperation for global challenges.

Looming debt crises

"Debt crises" were identified as an imminent threat to the world for the next two years, but GRPS respondents believe they will reach their most critical point in three to five years. Government stimulus was vital to protect incomes, preserve jobs and keep businesses afloat, but debt burdens are now high and public budgets will continue to be stretched after the pandemic, even as they are needed for financing just and green transitions.

The planet cannot wait

"Extreme weather" and "climate action failure" are among the top five short-term risks to the world, but the five most menacing long-term threats are all environmental. "Climate action failure", "extreme weather" and "biodiversity loss" also rank as the three most potentially severe risks for the next decade. While GRPS respondents' concern about environmental degradation predates the pandemic, increasing concern with climate action failure reveals respondents' lack of faith in the world's ability to contain climate change, not least because of the societal fractures and economic risks that have deepened.

Connectivity blind spots

"Digital inequality" is seen as an imminent threat to the world as 3 billion people remain offline. However, it is also the case that many countries and industries were able to quickly access and seamlessly adapt to new forms of human interaction and remote work. This digital leap came with increased vulnerability. GRPS respondents believe "cybersecurity failure" will continue to test the world's digital systems over the next two years and, to a lesser extent, in three to five years. No technological risk appears among the most potentially severe for the next decade. This suggests lower relevance to respondents—or a blind spot in perceptions given the potential damage of cyber-risks—compared to economic, societal and environmental concerns.

Growing rivalries

GRPS respondents believe "geoeconomic confrontations" will emerge as a critical threat to the world in the medium to long term and as one of the most potentially severe risks over the next decade. While pressing domestic challenges require immediate attention, the pandemic and its economic consequences have proven once again that global risks do not respect political frontiers. Humanity faces the shared and compounding threats of economic fragmentation and planetary degradation, which will require a coordinated global response.

To see the full results of the GRPS 2021-2022 see: https://www.weforum.org/reports/global-risks-report-2022/data-on-global-risks-perceptions#report-nav

FIGURE I

COVID-19 Hindsight

Risks that worsened the most since the start of the COVID-19 crisis

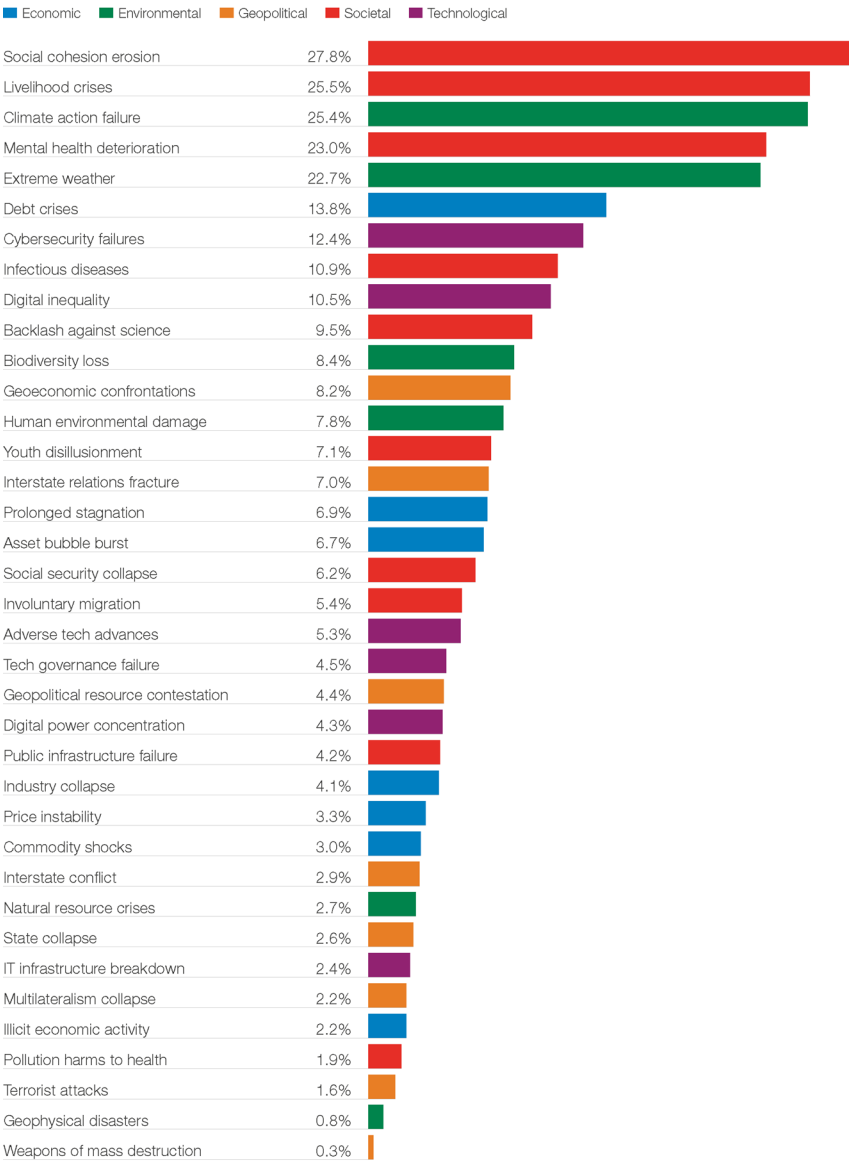


FIGURE II

Global Risks Horizon

When will risks become a critical threat to the world?

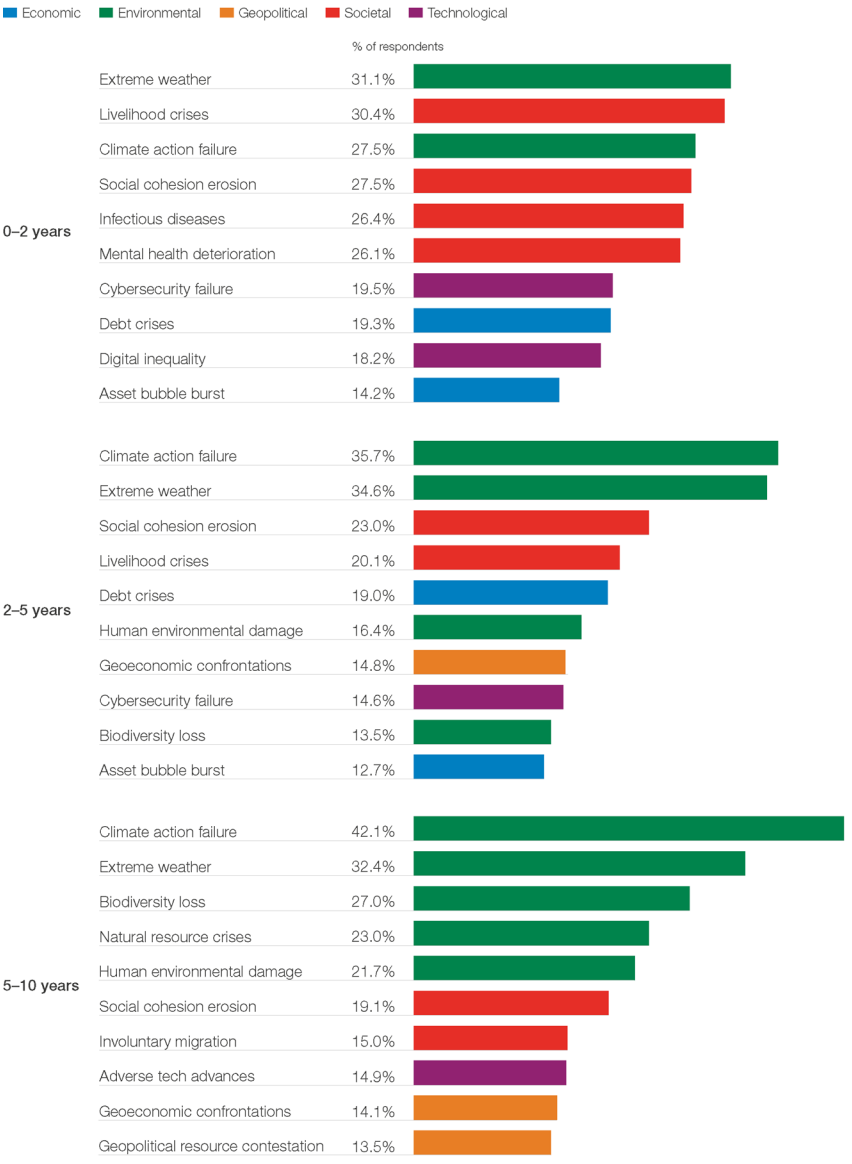
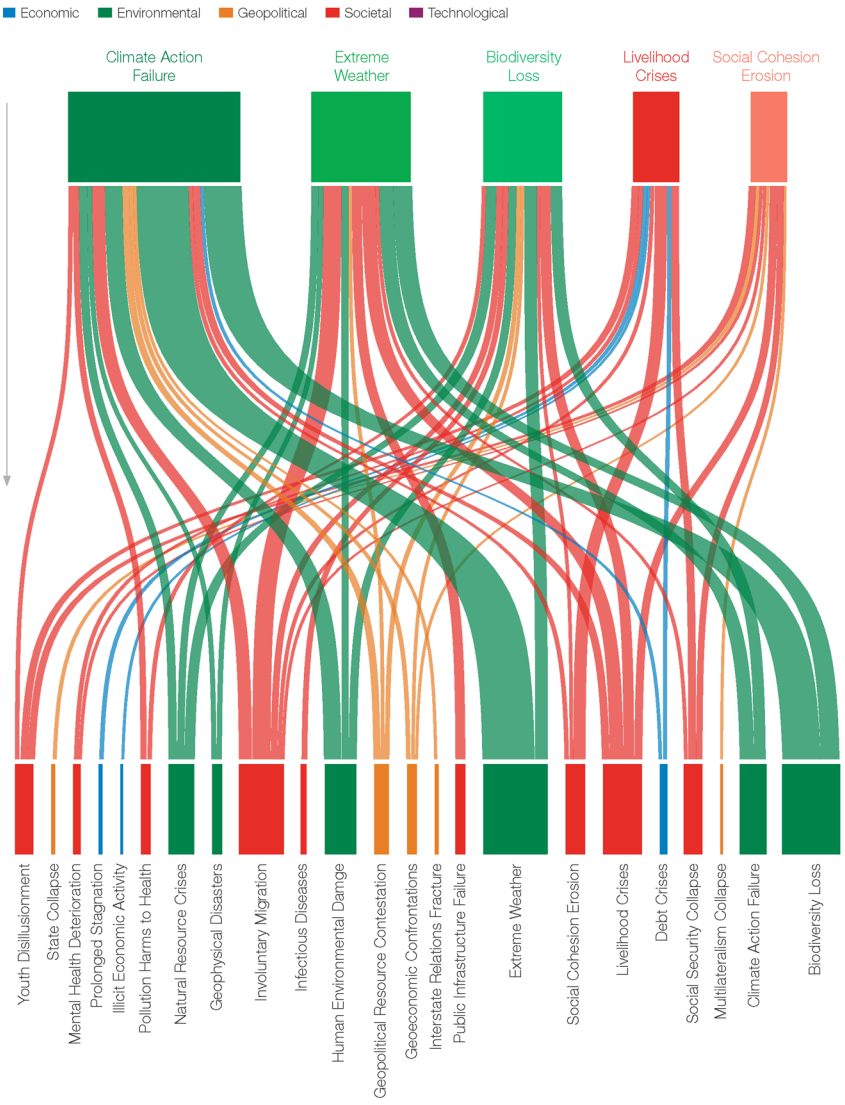


FIGURE III

Global Risks Effects

Most potentially damaging risks (top row) and risks they will aggravate (bottom row)*

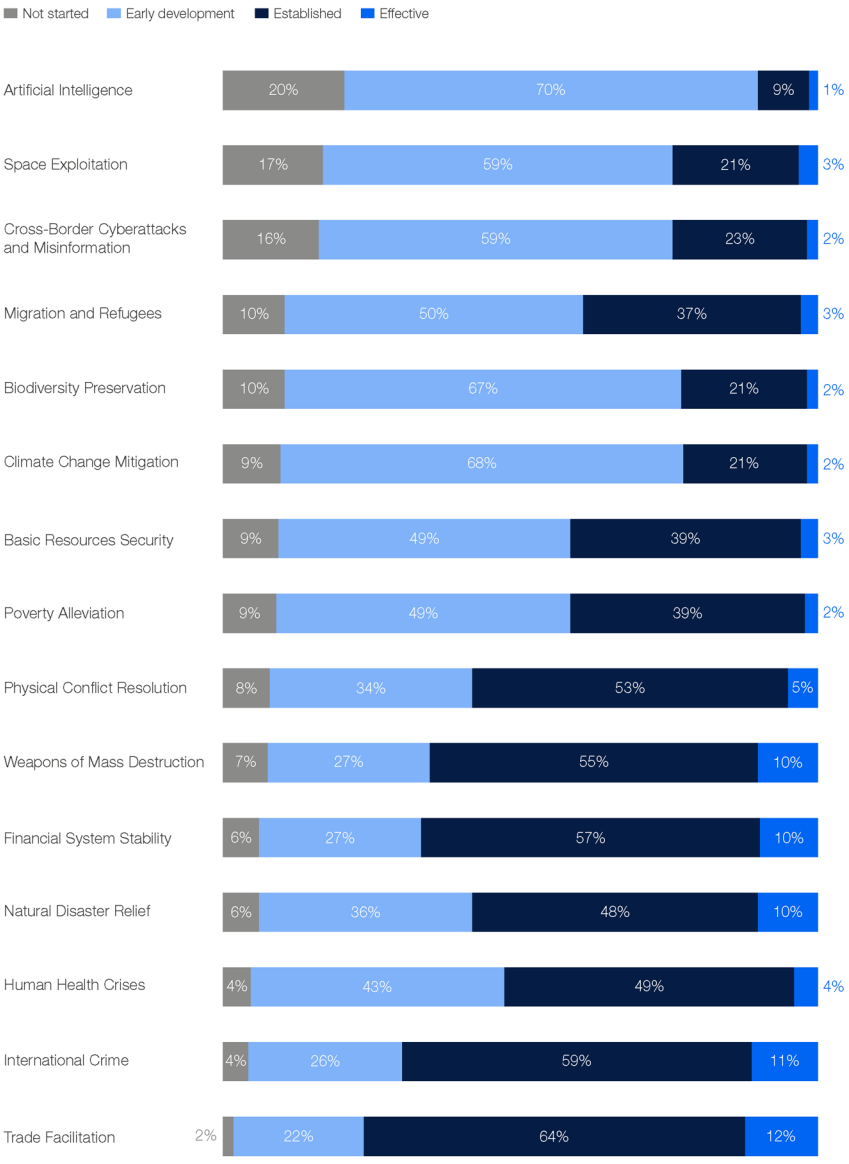


*Line thickness scaled according to tally of links (see Appendix C: Technical Notes).

FIGURE IV

International Risk Mitigation Efforts

Current state of international risk mitigation efforts in each area



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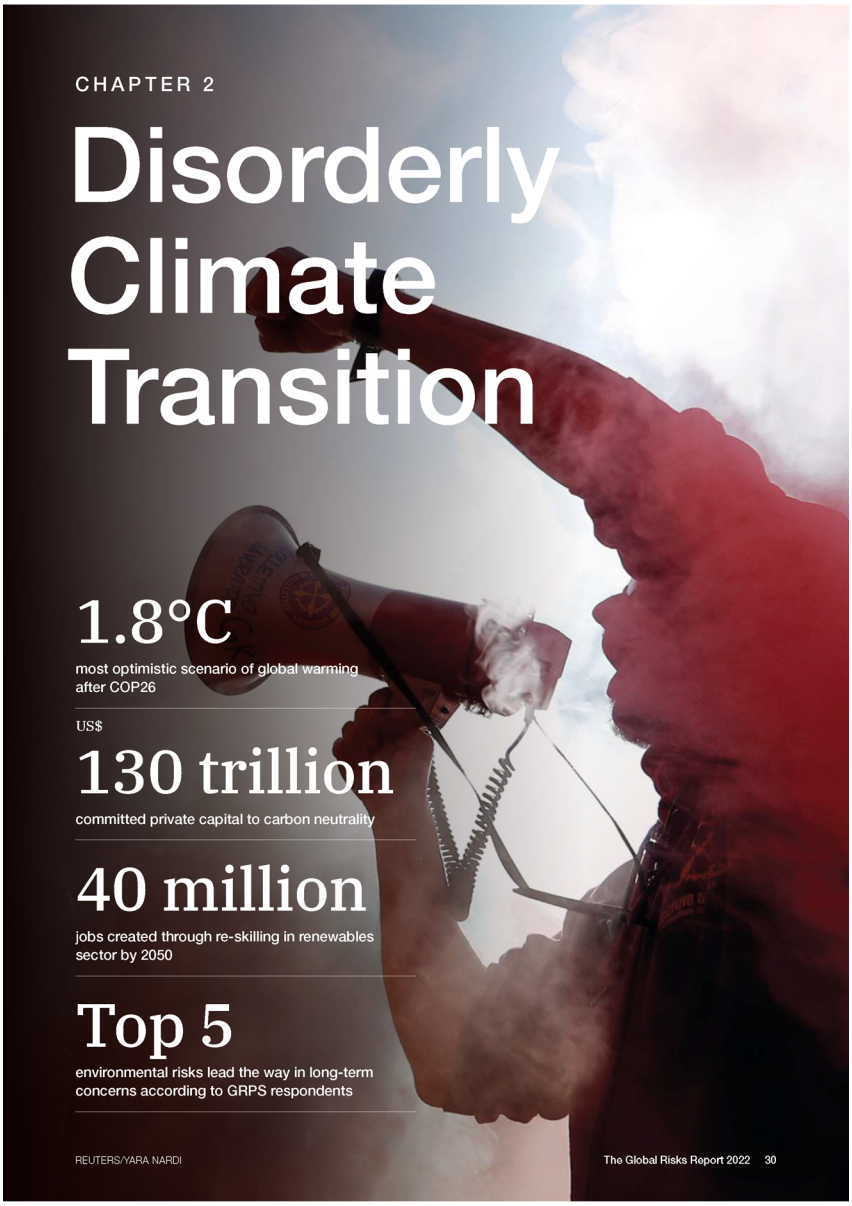
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CHAPTER 2

Disorderly Climate Transition

1.8°C

most optimistic scenario of global warming after COP26

US$

130 trillion

committed private capital to carbon neutrality

40 million

jobs created through re-skilling in renewables sector by 2050

Top 5

environmental risks lead the way in long-term concerns according to GRPS respondents

REUTERS/YARA NARDI

Climate (in-)action

Accelerating and widespread climate change manifests itself in irreversible consequences.[1] The overwhelming weight of scientific analysis points to environmental adjustments and cataclysmic feedback loops that will push ecosystems beyond tipping points.[2] At that moment, decarbonization efforts would be rendered mute.

The latest nationally determined contributions (NDCs) to decarbonization made at the 2021 United Nations Climate Change Conference of the Parties (COP26) still fall short of the 1.5°C goal set out in the Paris Climate Agreement (for an extensive summary of COP26 outcomes, see Chapter 1, Box 1.1).[3] The current trajectory is expected to steer the world towards a 2.4°C warming,[4] with only the most optimistic of scenarios holding it to 1.8°C (see Figure 2.1).

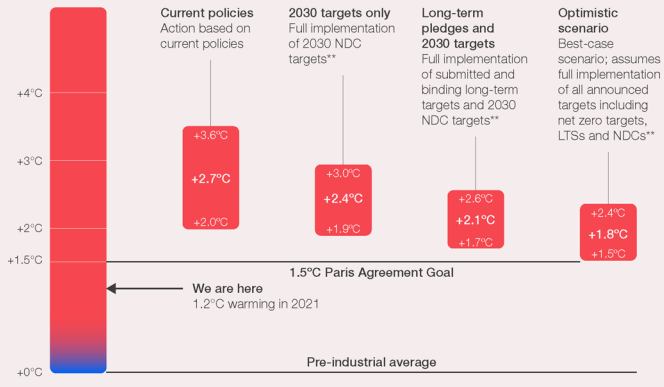
Without stronger action, global capacity to mitigate and adapt will be diminished, eventually leading to a "too little, too late" situation and ultimately a "hot house world scenario" with runaway climate change that makes the world all but uninhabitable.[5] The world will face high costs if we collectively fail to achieve the net zero goal by 2050.[6] Complete climate inaction will lead to losses projected to be between 4% and 18% of global GDP[7] with different impacts across regions.[8]

The transition to net zero—the state in which greenhouse gases (GHG) emitted into the atmosphere are balanced by their removal from the atmosphere*—could be as transformative for economies and societies as past industrial revolutions. However, the complexities of the technological, economic and societal

* Net zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period. Net zero CO_2 emissions are also referred to as "carbon neutrality." This definition of "net zero" is from the IPCC (Intergovernmental Panel on Climate Change). 2018: Annex I Glossary. https://www.ipcc.ch/sr15/chapter/glossary/

FIGURE 2.1

Global Temperature Scenarios by 2100



** Nationally determined contributions (NDCs) are non-binding national plans for climate action, including targets for GHG emissions reductions. Long-term strategies (LTSs) are national mid-century development plans for confronting climate change. If 2030 NDC targets are weaker than projected emissions levels under current policies, then current policies are used here.

Source: Based on the Climate Action Tracker. https://climateactiontracker.org/

changes needed for decarbonization, coupled with the slow and insufficient nature of current commitments, will inevitably lead to varying degrees of disorderliness.

As climate change intensifies and some economies recover more quickly than others from COVID-19, a disorderly transition could bifurcate societies and drive countries further apart, and a too-slow transition will only beget damage and disruption across multiple dimensions over the longer term (see Box 2.1). Within countries, the disruptive potential of the transition could be amplified by disconnects between governments, businesses and households with respect to policy commitments, financial incentives, regulations and immediate needs. A sustained lack of coordination between countries would likely have profound geopolitical implications, with rising friction between strong decarbonization advocates and those who oppose quick strong action by using tactics such as stalling climate action or greenwashing— the practice of making people believe that a company or authority is more environmentally friendly than it actually is.

Tailwinds for a fast, but disorderly, transition

Clear evidence of rising physical risks, such as melting land ice, rising sea levels and prolonged periods of extreme heat and cold,[9] as well as their associated consequences for human and economic systems,[10] are intensifying momentum for the transition. And while COVID-19 lockdowns saw a global dip in GHG emissions, upward trajectories soon resumed:[11] GHG emissions rates rose faster in 2020 than their average over the last decade,[12] illustrating how the global economy is still heavily dependent on fossil fuels.

COVID-19 lockdowns saw a global dip in GHG emissions. However, upward trajectories soon resumed

Governments, businesses, investors and communities are increasingly converging on the need for a quicker transition—each group setting higher expectations of the other. Green parties and green policies—such as a carbon border adjustment tax[13]—have gained traction in many countries, regions and industries, as have multilateral ideas like climate clubs.[14] A plethora of climate risk disclosure frameworks and measurement standards are now being combined within a new International Sustainability Standards Board (ISSB) by the International Financial Reporting Standards (IFRS). This will help clarify what needs to be done, and by whom, to highlight and prevent greenwashing and stalling on climate action.

The rise of stakeholder capitalism, shareholder activism and increased appetite from companies to use environmental,

BOX 2.1

Global Risks Perception Survey Ranks "Climate Action Failure" as Top Risk

Respondents to the Global Risks Perception Survey (GRPS) 2021–2022 rank "climate action failure" as the most critical threat to the world in both the medium term (2–5 years) and long term (5–10 years), with the highest potential to severely damage societies, economies and the planet. Most also believe too little is being done: 77% said international efforts to mitigate climate change have "not started" or are in "early development". (The survey was conducted before COP26. See Appendix C, Technical Notes).



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social and governance (ESG) targets and metrics,[15] coupled with ESG-based investments, is re-shaping the financial and economic landscape,[16] and an increasing number of organizations are committing to decarbonize their operations. As banks, insurers and institutional investors are steering capital towards net zero, financial systems are rapidly emerging as critical enablers of the transition. A growing share of the US$100 trillion bond market is mobilized for climate change solutions, and it is expected to reach the milestone of US$1 trillion in annual issuances by 2022.[17] Moreover, during COP26, the Glasgow Financial Alliance for Net Zero (GFANZ) announced that over US$130 trillion in private capital has been committed to carbon neutrality—enough to achieve net zero by 2050.[18] Similarly, parties at COP26 agreed on the framework for Article 6 of the Paris Agreement, enabling the immediate operationalizing of global carbon markets, ending uncertainty about the Clean Development Mechanism (CDM) and further establishing a new central UN supervisory body to trade carbon credits on specific projects.

These commitments by both businesses and governments are being closely monitored by civil society organizations and investors,[19] which fear untenable populist promises are being made for short-term political or financial gain.[20]

Headwinds slowing the transition

The risk of a disorderly transition is aggravated by the interdependencies and distributed nature of economic and financial systems, the historic shielding of climate change externalities from citizens and businesses, decarbonization costs, and the many divergent interests at play that will complicate the transition. In the short term, these complexities are likely to prompt many actors to avoid or defer action.

Some national and business actors are still deliberately manoeuvring to stall or scale back the green transition. Governments need to balance the needs of populations dependent on carbon-intensive industries with international commitments. Yet some

of these commitments are lofty and lacking scientific credibility,[21] legislatures are pre-emptively blocking new climate laws,[22] and regulations are being contested in courts by both proponents who push for more climate action and those who advocate for less.[23] Geopolitical tensions and rising competition over climate-friendly raw materials also further threaten to undermine international cooperation on green transition progress.[24] Some actors show little interest in the multilateral platforms on which climate action is taking place;[25] others continue to prioritize nationally important industries and could, in the wake of increased global tensions, shift to national security concerns over action on the transitions.

With government finances under pressure, regulatory obligations are not going far or fast enough, and there is an assumption that market forces will come to the rescue. In many countries there are insufficient incentives for households and businesses to invest in net zero technologies and few penalties for failing to do so. Slow uptake of new technologies such as low-carbon energy generation and carbon capture and storage, continued household overconsumption of carbon-intensive products and services,[26] and a failure to grasp the seriousness of climate threats all point to a slower transition that preserves "order" in the near term.[27] New innovations that require high amounts of energy during production and use, such as crypto-mining or crypto-trading,[28] often coming from fossil fuel energy sources, can also offset efforts to reduce ecological footprints.

Post-COVID-19 recovery measures mostly neglect the green transition in favour of short-term stability

Post-COVID-19 recovery measures mostly neglect the green transition in favour of short-term stability,[29] while loose monetary policies further distort green, market-based solutions or investments;[30] they also exacerbate the problem of zombie companies.[31] Carbon-intensive technologies continue to receive public subsidies,[32] with over 50 developed and emerging economies committing US$345 billion to fossil fuels in 2020—a figure lower than in previous years largely because of depressed consumption and prices during the pandemic.[33] At the time of writing, the economic rebound following the impact of COVID-19 has seen (fossil) energy demand outstrip supply,[34] resulting in sharply increased energy prices, even as the world turns against fossil fuels.[35] Moreover, some business actors continue their efforts to slow the transition. Climate-sceptic lobbying,[36] greenwashing and sowing misinformation and distrust about climate science remain pervasive in many countries.[37]



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Some economic incentives also complicate attempts to coordinate measures that could internalize costs in high-emission industries and countries, minimize market disruptions and more fairly redistribute burdens and rewards. Instead of fostering decarbonization, the lack of global emission prices and reporting requirements continues to shield consumers and producers from the cost of inaction.[38] This incentivizes countries and businesses not to curb emissions, but instead to game the system and avoid liability by offshoring carbon-intense activities or trading their emissions to countries with less stringent regulations.[39] Developing countries attracted to emissions in-shoring schemes by short-term financial gain squander the opportunity to use carbon allowances for their own development and risk undermining their future access to trade flows and the finance needed for mitigation and adaptation.[40]

Businesses may be unprepared for transition risks such as rapid shifts in policies and regulations, the need to develop low-carbon technologies and changes in consumer behaviour and investor preferences.[41] These risks have the potential to destabilize the financial system,[42] as in aggregate they can increase default rates and asset volatility. They are further amplified in economies with low investment capability, high reliance on fossil fuels and less-inclusive political systems.[43]

Consequences

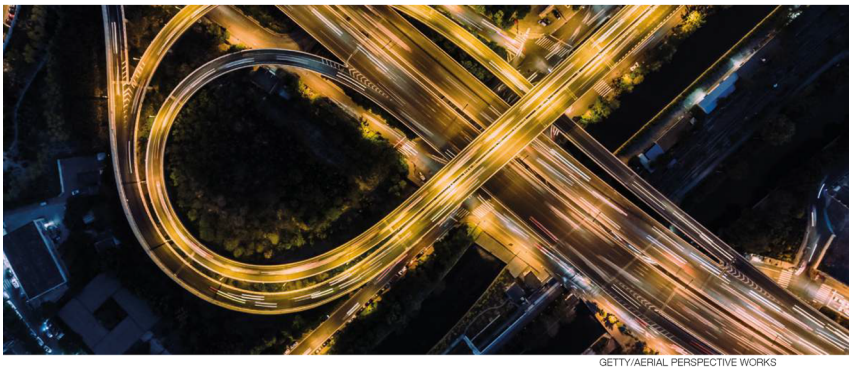
The consequences and repercussions of the transition will necessarily reflect the speed at which it takes place; the efforts that go into it; and whether it is slow or aggressive, concerted or entrenched, and focused more on mitigation or adaptation. The goal of 1.5°C is so fundamental that societies need to be prepared to assume negative consequences of policies taken by governments today to avoid the worst consequences tomorrow. This includes job losses, increased costs and geopolitical insecurity associated with a disorderly transition. Only a socially just transition will make the consequences bearable for large parts of societies with governments needing to create policies and social-protection systems that help reduce the impacts for those affected. A rapid decarbonization would increase economic and societal disruption in the short term, while a slower pace with fewer short-term impacts would entail much larger costs and greater disorderliness in the long-term.

GRPS respondents drew attention to the societal consequences of environmental degradation at a global scale. They identify "climate action failure" and "extreme weather" as strong aggravators of "involuntary migration", "livelihood crises" and "social cohesion erosion". In contrast, respondents to the Executive Opinion Survey (EOS) see the impacts from "climate action failure" as top risks in the short-term at a country level: "human environmental damage" and "extreme weather" are considered top-10 risks in 90 economies and 60 countries, respectively. All countries ranking these risks highly are particularly prone to wildfires, droughts, floods, deforestation and pollution.

Varying speeds

A hasty pace

Concerted, aggressive action now will, because of the scale of the endeavour, bring discontinuities and thus disruptions, as efforts within and between industries, businesses and governments fail to align. It would alleviate long-term environmental consequences but could have severe short-term economic and societal impacts. Missteps will likely threaten national energy security, for example, and result in volatile energy prices. Over the longer term, countries will face questions regarding the viability of vehicle fuel and gas supply arrangements when much of the population has shifted away from combustion engines, gas boilers and heating.



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As carbon-intense industries employ millions of workers, their rapid termination could trigger economic volatility and increase societal and geopolitical tensions. Up to 8.5 million jobs in the energy sector (almost 30%) could be lost in fossil fuels and nuclear energy by 2050, although with re-skilling up to 40 million new jobs could be created, mostly in renewables.[44] Earlier or current investments in carbon-intensive technologies could result in stranded assets. These—even if they are the result of wilfully made investments in carbon-intensive technologies for short-term gain instead of long-term investments in clean technologies[45]—could impact the financial sector,[46] as well as the transition, when they are trapped in industries such as those that extract resources required for low-carbon technologies.[47] Despite these short-term disruptions, the social and economic consequences of unmitigated global warming and entire nations being flooded or disappearing would be even more cataclysmic: countries' complete economies and assets would be left stranded.

Non-holistic government approaches also pose risks. Adopting low-carbon and more sustainable technologies too hastily, in a way that neglects systemic interdependencies—such as transitioning one system before another linked or dependent one is ready—could lead to production shortages and disrupt secondary economic cycles if redundant systems are not in place to prevent energy supplies from collapsing. Poor regulation of new green markets could create unwanted monopolies in geopolitically contested industries such as rare earth elements extraction.

Some approaches to the green transition reflect blind spots that risk damaging outcomes for workers and the environment.[48] These include focusing solely on carbon dioxide (CO_2) emissions and ignoring methane,[49] or the increased use of resources for low-carbon technologies. They also risk setting regulatory requirements to phase out technologies before substitutes exist or, in other words, a focus on supply constraint of fossil fuels rather than an equal emphasis on demand-destruction in the most carbon-intensive industries.

Slow transition

In contrast, a slower but more orderly transition might be more manageable in the short term but would result in the need for deeper and faster changes by 2050. This would lead to more pronounced long-term disorder, amplified at the same time by more damaging economic activity such as the closing off of opportunities, damaging impacts through environmental degradation impacting societal well-being and infrastructural fragilities.

The long-term financial impacts would disproportionately affect large and/or developing countries.[50] Some of these countries face political and financial barriers to swiftly reducing their reliance on fossil fuel energy production such as cutting coal use;[51] others rely on natural gas to

reach a higher level of industrialization before decarbonizing,[52] even though these policies further aggravate the destruction of ecosystems. Consequently, the loss of (arable) land would increase migration pressure and the number of climate refugees (see Chapter 4). This slow pathway may lead countries to prioritize adaptation over mitigation efforts. Yet, once carbon prices increase and demand destruction ends up making fossil energy investment a losing bet, leapfrogging to renewables sooner than later could prove to be a more effective long-term investment for such developing countries.

Divergent paces

It is most likely that national transition programmes will move at different paces as a result of differences in political will (decarbonization ambitions and political interest), economic structure (service versus manufacturing) and capabilities (technological know-how and financial wherewithal). Countries that move faster will be able to consolidate their own national capabilities and clean tech industries; those that move more slowly will lack competitiveness in this area but be able to leverage the best that has been developed elsewhere. Initiatives that pay closer attention to scope 3* emissions will shine a spotlight on global value chains and will increasingly disadvantage exports from laggard countries. Furthermore, the heterogeneity of climate action worldwide will be a risk for trade flows in the future, especially for the less-developed economies. By facing narrower access to trade finance, they risk exclusion from the opportunities for orderly climate mitigation and adaption.[53]

Reputational damage and liability issues for governments and businesses seen as complicit in, if not responsible for, climate change could lead to breakdowns in trust between nations, higher global tensions and the possibility of sanctions being introduced against laggard nations, or fines/trade tariffs against relapsing businesses.

Transition policies risk losing public support if they neglect the impacts—on land use, resources, nature—of large-scale water and wind energy installations,[54] or emanate from failure to create just pricing schemes for communities willing to invest in green energy, such as a shift of fossil fuel to renewable energy subsidies or equal feed-in tariffs for individuals and large-scale providers.[55] Poor grid stability through the intermittency of renewable energy sources, shortages in storage capacity and the phasing out of existing baseload energy technologies that have a low carbon intensity yet are politically highly controversial, such as nuclear energy,[56] could also dwindle public support for cleaner energy sources.

Especially at risk are unskilled workers unable to transition their skill sets

Biotechnical and geoengineering solutions

While negative emission technologies are an essential component of all IPCC 1.5°C scenarios, geoengineering solutions could be silver-bullet solutions, but they may not adequately explore systemic interdependencies and implications.[57] Moreover, the deployment of such untested technologies carries unknown risks. Some geoengineering approaches—such as weather modification or solar radiation management (SRM)—could spiral out of control or create friction if they are used for geopolitical advantage in the absence of any governance framework,[58] as the effectiveness could vary regionally.[59] They could exacerbate geopolitical tensions between countries where the local climate is improving and those that are suffering from the unintended consequences.[60]

On the other side, biotechnical solutions such as carbon dioxide removal (CDR)

* Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions. This definition of "Scope 3 emissions" is from the Greenhouse Gas Protocol. 2021. https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf

from the atmosphere need to be scaled up to come close to keeping the 1.5°C scenario within reach under all IPCC scenarios.[61] The robustness of any net zero strategy that relies on CDR depends both on the effectiveness of the underlying projects that drive the CO_2 removal and, especially, on the permanence of the stored carbon.[62] Other solutions, such as carbon capture, utilization and storage (CCUS), are already heavily subsidized,[63] but they risk being used for greenwashing as carbon-heavy industries eventually fail to structural change their value chains to reduce their emissions.[64] Similarly, Bio-energy Carbon Capture and Storage (BECCS) solutions could create unintended geopolitical consequences or prove to be counterproductive.[65]

Stakeholder consequences

Loss of agency: Consequences for individuals

The type of transition will have far-reaching socio-economic implications for individuals. Where policies, incentives and innovations fail to stimulate effective market solutions, households will see increases in their cost of living due to rising decarbonization requirements for homes, rising fossil fuel prices and physical climate impacts, among other issues. They may also face increased service disruption from utilities where system dependencies and discontinuities have not been adequately anticipated by participants. Especially at risk are unskilled workers, those unable to transition their skill sets and those currently employed in carbon-intensive industries that undergo radical transformation.[66] Many of these workers are already facing challenges related to automation and the hyper-globalization of the pre-COVID-19 era, when key heavy industries such as coal and steel were offshored to emerging markets.[67] Middle-class households could also be left behind if aggressive transition measures impact their finances and their purchasing power diminishes substantially.

Loss of income would inhibit people's access to new technologies and upward mobility, entrenching inequalities for generations. Unequal transition speeds could widen inequalities between economies and create pressure on workers to migrate to countries where their skills are still in demand (see Chapter 4). Failed or slow climate action could worsen gender inequalities as, in many low-income economies, women are responsible for gathering and producing



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REUTERS/OCTAVIO JONES

food, securing water and collecting bioenergy sources such as firewood and crop waste. Together, these consequences could trigger disillusionment with climate action and lead to the radicalization of marginalized socio-economic groups across the political spectrum.

Loss of control: Consequences for governments

Governments will face backlash whether climate action is slow or aggressive. Steeper transition costs such as high and quick increase in the price of carbon and fossil fuels could weaken public support for fast action; conversely, slow action could trigger further radicalization from those who feel authorities at all levels do not act fast enough, with a potential increase in inter-generational friction and more fiscal drain due to increased recovery funding. Investing in a net zero economy could create unsustainable levels of debt for economies lacking the means of such large-scale investment, or the loss of rent/tax revenue for economies heavily dependent on carbon intensive resource production, which would cripple public finances already vulnerable from the economic impacts of COVID-19 fallouts (see Chapter 1). Especially at risk are more climate-vulnerable countries; such green investment could be seen as a diversion from pandemic-related recovery programmes and the enhancement of core public infrastructure and services. Unequal access to low- or zero-carbon innovations could undermine support for governments in some countries.[68]

A socially unjust transition would exacerbate geopolitical and economic friction and inequalities between countries and regions. Laggard economies—especially those reliant on carbon-intensive sectors and that fail to keep up with technological innovation—risk losing competitive advantage and leverage in trade agreements, civil unrest, regime change and massive economic and societal disruption. Unequal access to materials and funding to enable the transition could increase tensions, as could unintended consequences—such as the destruction of ecosystems in developing countries to extract resources for next-level electrification of mobility in developed economies.[69]

Failed or delayed financial promises by advanced economies—such as a decline in promised foreign direct investment (FDI),[70] or shortcomings to the globally agreed annual $100 billion for emerging and developing countries to finance their transition to lower emissions and adaption measures to the physical consequences of climate change[71]—could leave developing countries stranded with costly, aggressive transition plans, unable to provide for vulnerable populations.

A zero-sum political game, with a first-come, first-served mentality, compounded by a lack of solidarity and combined with the absence of clear climate governance or enforceable accountability measures would increase tensions between economies transitioning quickly and those preferring or needing a slower transition.

Loss of market share: Consequences for businesses
Policies triggering the premature termination of large-scale industries would disrupt markets, affect financing mechanisms and limit investment opportunities.[72]

Inconsistent policy signals, choices crippling competitiveness, and conflicting rhetoric, regulations and incentives would generate discontent among businesses. The transition could lead to stranded assets in carbon-intensive industries,[73] while devaluations could potentially affect the financial system,[74] leading to loss of liquidity and increasing liability, credit and market risks.[75] Businesses perceived as lagging, or as complicit in slowing down climate action,[76] could lose consumer and investor confidence and face additional state intervention and liability risk through judicial action.[77] Overall, businesses could also lose out on opportunities to invest in net zero technologies and the skilled professionals of the future,[78] impacting their long-term viability.

A disorderly transition could see more frequent and severe supply chain disruptions due to labour and product shortages, especially as sectors and companies switch operating models or simply go out of business. These disruptions present challenges to the resilience of business models across all industries.

Loss of nature
How the speed and degree of transition impacts natural ecosystems will, in turn, help or hinder its effectiveness. Some actions taken to mitigate climate change will incur costs for nature. In the rush to increase biomass use for BECCS, to use more agricultural land to create biofuels for industries such as aviation, and to extract minerals needed for the decarbonization of the world's economy,[79] additional negative impacts on ecosystems and indigenous societies in emerging economies are difficult to avoid. Solutions used for carbon offsetting, such as restoring or reforesting land—so-called offset forests—could be destroyed if that land is damaged by more severe weather such as wildfires or floods, eventually unleashing the stored carbon. Poorly sited windfarms or hydroelectric dams can affect ecosystems and wildlife at a large scale, and they also present societal risks (such as forced relocation of local residents) and political risks (such as by controlling downstream water-access to neighbouring countries). The continued degradation of nature will add to stress on local residents, public health, businesses and ultimately the stability of society, while regional population growth will further impact the use of land and resources such as water and food.

Shocks to Reflect Upon



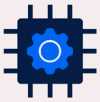
Green Market Crash

What if the boom in sustainable investments becomes a bubble, followed by a crash that cripples innovation and progress?



Fusion Power at Last

What if a new transformative technology emerges but cannot be mass-produced at low cost, disadvantaging developing economies and impacting climate action dynamics?



Collateral Geo-Damage

What if unilateral implementation of large-scale geoengineering solutions creates unexpected knock-on effects that developing economies are ill-equipped to handle?

Towards a more sequenced transition

Beyond the sheer scale, complexity and interdependency of the needed changes, the climate transition will be disorderly because decades of inaction and hesitant implementation of transition measures on local and global levels have steered the planet onto a path that will be difficult to change.

In a recovering yet diverging global economy, countries will need to transition at varying paces to prevent short-term disruptions from offsetting long-term gains, but the consequences of disparate transitions will be felt worldwide. The least disruptive climate transition measures will be those that holistically integrate the needs of individuals, societies, businesses and planet. Domestic and international collaboration should focus on educating the public about the value and need of climate action, including a change in consumer behaviour and demand-destruction for carbon intensive goods. Businesses of all sizes need to be incentivised to proactively factor in transition risks and move to circular economy models, while governments should be encouraged to take bold and immediate steps towards implementing robust legal frameworks that ensure a just transition.

Any transition of this scale will be disruptive. All stakeholders need to focus on actions that will drive an innovative, determined and inclusive transition in order to minimize the impacts of disorder, facilitate adaptation and maximize opportunities.



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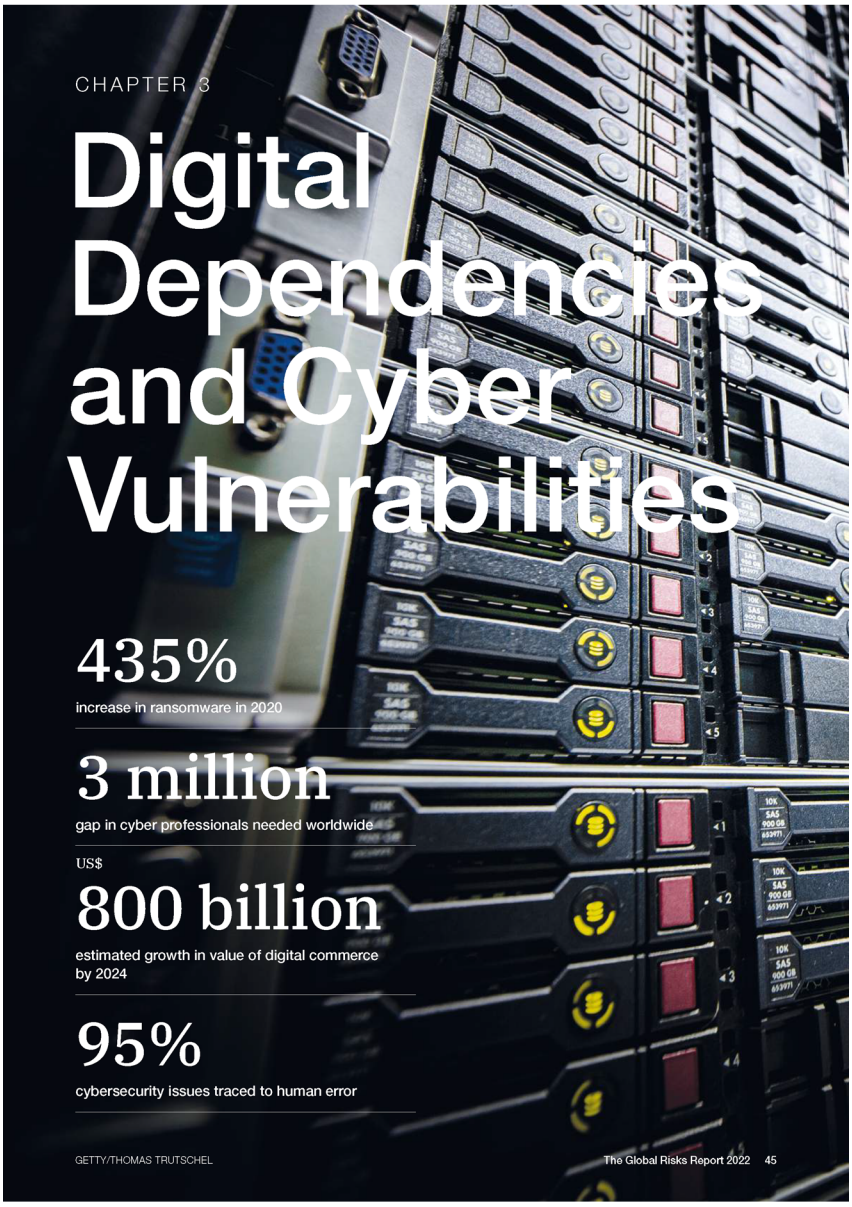
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CHAPTER 3

Digital Dependencies and Cyber Vulnerabilities

435%

increase in ransomware in 2020

3 million

gap in cyber professionals needed worldwide

US$ 800 billion

estimated growth in value of digital commerce by 2024

95%

cybersecurity issues traced to human error

GETTY/THOMAS TRUTSCHEL

Digital distress

Governments, societies and companies increasingly rely on technology to manage everything from public services to business processes, even routine grocery shopping.[1] Converging technological platforms, tools and interfaces connected via an internet that is rapidly shifting to a more decentralized version 3.0 are at once creating a more complex cyberthreat landscape and a growing number of critical failure points. As society continues to migrate into the digital world, the threat of cybercrime looms large, routinely costing organizations tens—even hundreds—of millions of dollars. The costs are not just financial: critical infrastructure, societal cohesion and mental well-being are also in jeopardy.

Digital everything

Growing dependency on digital systems over the last 20 years has drastically shifted how many societies function.[2] The COVID-19-induced shift to remote work has accelerated the adoption of platforms and devices that allow sensitive data to be shared with third parties—cloud service providers, data aggregators, application programming interfaces (APIs) and other technology-related intermediaries.[3] These systems, while powerful tools for data and processing, attach an additional layer of dependency on service providers. Remote work has also moved digital exchanges from office networks to residential ones, which have a greater variety of connected devices with less protection against cyber intrusion. In parallel, the appetite for capabilities predicated upon using multiple technologies working in concert—including artificial intelligence (AI), Internet of Things (IoT)/ Internet of Robotic Things–enabled devices, edge computing, blockchain and 5G—is only growing.[4] While these capabilities afford tremendous opportunities for businesses and societies to use technology in ways that can dramatically improve efficiency, quality and productivity, these same capabilities also expose users to elevated and more pernicious forms of digital and cyber risk.

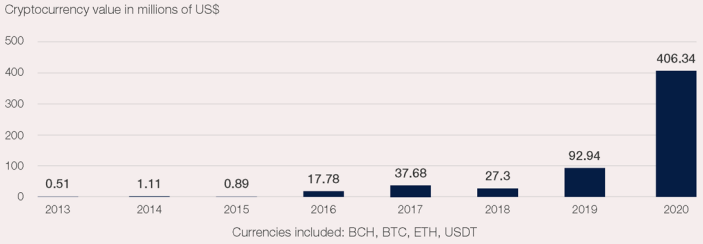
In the future, the interconnectedness and convergence of these digital tools will continue to increase as society embraces the next version of the internet built upon blockchain technology. One manifestation of this migration will be the metaverse: a network of 3D virtual spaces, enabled by cryptocurrencies and non-fungible tokens (NFTs) among other technologies, with unprecedented socio-economic interoperability and immersive virtual reality experiences.[5] Users will be required to navigate security vulnerabilities inherent in both increased dependency on and growing fragmentation in these types of complex technologies often characterized by decentralization and lack of structured guardrails or sophisticated onboarding infrastructure.



GETTY/FILIPPOBACCI

FIGURE 3.1

Total Cryptocurrency Value Received by Ransomware Addresses, 2013-2020



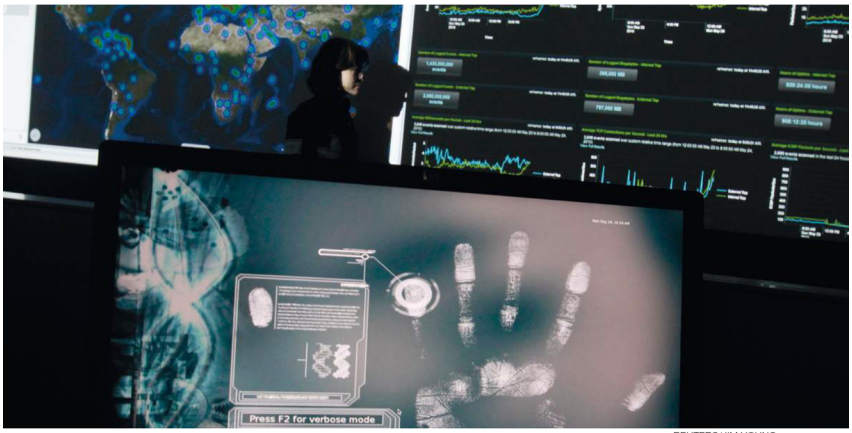
Source: Based on Chainanalysis. Ransomware 2021: Critical Mid-Year Update. Insights blog. https://blog.chainalysis.com/reports/ransomware-update-may-2021

Cyber vulnerabilities

In the context of widespread dependency on increasingly complex digital systems, growing cyberthreats are outpacing societies' ability to effectively prevent and manage them. For example, the digitalization of physical supply chains creates new vulnerabilities because those supply chains rely on technology providers and other third parties, which are also exposed to similar, potentially contagious, threats.[8] In December 2021, just one week after discovering a critical security flaw in a widely used software library (Log4j), more than 100 attempts at exploiting the vulnerability were detected every minute, illustrating how free access coding can spread vulnerabilities widely.[7] Information technology (IT) monitoring and management software also illustrate the potential for contagious exposure, which can break through the defences of critical cybersecurity supply chains, as shown by the Solar Winds Orion attack that occurred in late 2020.[8] While a state-based institution with highly sophisticated capabilities probably lodged this attack, other criminal organizations will certainly attempt to replicate this approach.[9] At the same time, older vulnerabilities persist with many organizations still relying on outdated systems or technologies.

Malicious activity is proliferating, in part because of the growing vulnerabilities—but also because there are few barriers to entry for participants in the ransomware industry and little risk of extradition, prosecution or sanction.[10] Malware increased by 358% in 2020, while ransomware increased by 435%,[11] with a four-fold rise in the total cryptocurrency value received by ransomware addresses (see Figure 3.1).[12] "Ransomware as a service" allows even non-technical criminals to execute attacks, a trend that might intensify with the advent of artificial intelligence (AI)-powered malware.[13] In fact, profit-seeking groups of cyber mercenaries stand ready to provide access to sophisticated cyber-intrusion tools to facilitate such attacks. Furthermore, cryptocurrencies have also allowed cybercriminals to collect payments with an only modest risk of detection or monetary clawback.[14]

Attacks themselves are also becoming more aggressive and widespread.[15] Cyberthreat actors using ransomware are leveraging tougher pressure tactics as well as going after more vulnerable targets, impacting public utilities, healthcare systems and data-rich companies.[16] For example, before it disbanded, DarkSide—the group accused of being responsible for the Colonial Pipeline attack—offered a suite of services ("triple" or "quadruple" extortion)



REUTERS/JIM YOUNG

to clients beyond simply encrypting files; these included data leaks and distributed denial-of-service (DDoS) attacks. Hacker groups will also contact victims' clients or partners to get them to urge the victims to pay ransoms. Among the services offered is the collection of top executive information for blackmail.[17]

Sophisticated cyber tools are also allowing cyberthreat actors to attack targets of choice more efficiently, rather than settling for targets of opportunity, highlighting the potential to carry out more goal-oriented attacks that could lead to even higher financial, societal and reputational damage in the future. Increasingly sophisticated use of spyware technologies, for example, has allowed for targeted attacks against journalists and civil rights activists across geographies—spurring a wave of political and industrial blowback in the form of government sanctions and lawsuits.[18] The ability to tailor attacks at will includes timing them for when cybersecurity teams and leadership could be distracted by other priorities, such as during peak COVID-19 outbreaks or a natural disaster. Cyberthreat actors are also accessing higher-quality and more sensitive information from victims. And deepfake technology is allowing cyberthreat actors to improve social engineering ploys, proliferate disinformation and wreak societal havoc, especially at times of high volatility.[19]

Global Risks Perception Survey (GRPS) respondents reflect these trends, ranking "cybersecurity failure" among the top-10 risks that have worsened most since the start of the COVID-19 crisis. Moreover, 85% of the Cybersecurity Leadership Community of the World Economic Forum have stressed that ransomware is becoming a dangerously growing threat and presents a major concern for public safety.[20] At a regional level, "cybersecurity failure" ranks as a top-five risk in East Asia and the Pacific as well as in Europe, while four countries—Australia, Great Britain, Ireland and New Zealand—ranked it as the number one risk. Many small, highly digitalized economies—such as Denmark, Israel, Japan, Taiwan (China), Singapore and the United Arab Emirates—also ranked the risk as a top-five concern.

Already-stretched IT and cybersecurity professionals are under an increasing burden, not only because of the expansion of remote work but also because of the growing complexity of regulations for data and privacy, even though such regulations are critical to ensuring public trust in digital systems.[21] There is an undersupply of

"Cybersecurity failure" is one of the risks that worsened the most through COVID-19

cyber professionals—a gap of more than 3 million worldwide[22]—who can provide cyber leadership, test and secure systems, and train people in digital hygiene.[23] As with other key commodities, a continued lack of cybersecurity professionals could ultimately hamper economic growth,[24] although new initiatives to "democratize" cybersecurity, for example, by providing free cybersecurity risk management tools, could help fill some of the gaps for small businesses or other institutions.[25]

There are concerns that quantum computing could be powerful enough to break encryption keys—which poses a significant security risk because of the sensitivity and criticality of the financial, personal and other data protected by these keys. The emergence of the metaverse could also expand the attack surface for malicious actors by creating more entry points for malware and data breaches.[26] As the value of digital commerce in the metaverse grows in scope and scale—by some estimates projected to be over US$800 billion by 2024—these types of attacks will grow in frequency and aggression.[27] The myriad forms of digital property such as NFT art collections and digital real estate could further entice criminal activity.

For governments attempting to prevent cybersecurity failures, patchwork enforcement mechanisms across jurisdictions continue to hamper efforts to control cybercrime.[28] Geopolitical rifts hinder potential cross-border collaboration, with some governments unwilling or unable to regulate cyber intrusions that originate inside and impact outside their borders. Unsurprisingly, given the geopolitical tensions around digital sovereignty, according to GRPS respondents, "cross-border cyberattacks and misinformation" and "artificial intelligence" were among the areas with the least "established" or "effective" international risk mitigation efforts.

Companies must also act ahead of new regulatory shifts, as the political undercurrents/geopolitical tensions between various countries might impact cross-border data flows. This might mean moving data processing to jurisdictions that might allow for better customer protection around data privacy issues.[29]

Consequences

Often-repeated examples of past cyber intrusions are worth re-examination, as these cases demonstrate how damaging attacks on large and strategically significant systems—such as banking, hospital, Global Positioning System (GPS) or air traffic control systems—could be.[30] As resources are increasingly digitized, notable as well is the heightened risk of cyber espionage attacks that typically target intellectual property and result in high developmental and reputational costs to both private and public sector organizations.[31]

The interaction between digitalization and growing cyberthreats carries intangible consequences as well. The growth of deepfakes and "disinformation-for-hire" is likely to deepen mistrust between societies, business and government.[32] For example, deepfakes could be used to sway elections or political outcomes.[33] More concretely, in one recent case, cybercriminals cloned the voice of a company director to authorize the transfer of US$35 million to fraudulent accounts.[34] There is also a booming market for services designed to manipulate public opinion in favour of clients, public or private, or to damage rivals.[35] Fraud, too, will become easier and therefore more frequent with banking, health and civic processes going remote.

Patchwork enforcement mechanisms continue to hamper efforts to control cybercrime

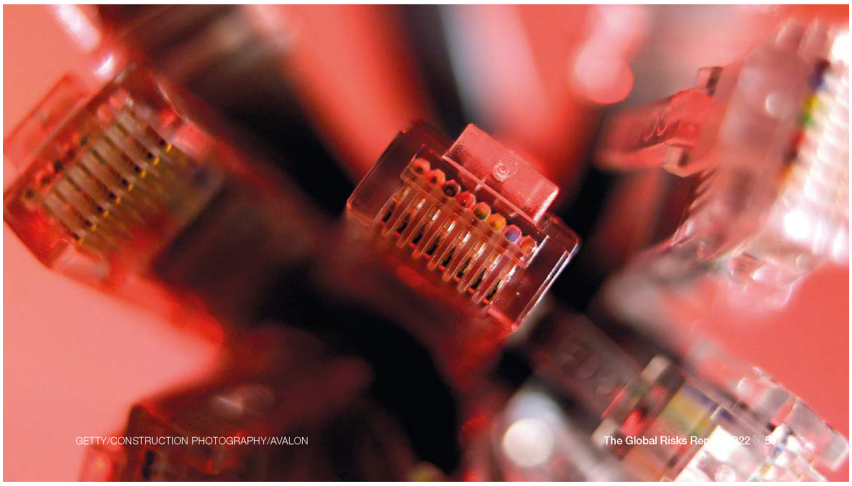
In 2021, UK internet banking fraud rose by 117% in volume and 43% in value compared with 2020 levels, as people spent more time shopping online.[36] Digital safety overall—from health misinformation and extremism to child exploitation—faces new challenges with unexperienced and more vulnerable populations coming online.[37]

Even in the best-case scenario of aggressive digital threat defences, there will be significant increases in the cost of operations for all stakeholders. This could be particularly challenging for small- or medium-sized businesses that might spend 4% or more of their operational budget on security, compared to larger organizations that might spend closer to 1–2%.[38] Indeed, amid the rising frequency and severity of ransomware claims, cyber insurance pricing in the United States rose by 96% in the third quarter of 2021, marking the most significant increase since 2015 and a 204% year-over-year increase.[39] Respondents to the GRPS indicate a long-term concern with these developments, with "adverse tech advances" appearing as a top-10 risk over a 5-to-10-year horizon.

Cyberthreats also continue to drive states apart, with governments following increasingly unilateral paths to control risks. As attacks become more severe and broadly impactful, already-sharp tensions between governments impacted by cybercrime and governments complicit in their commission will rise as cybersecurity becomes another wedge for divergence, rather than cooperation, among nation states.[40] Particularly in an era of rising tensions between superpowers, cyberattacks are another battlefront in which escalation is a key risk (see Chapter 1).[41] If cyberthreats continue without mitigation, governments will continue to retaliate against perpetrators (actual or perceived), leading to open cyberwarfare, further disruption for societies and loss of trust in governments' ability to act as digital stewards.

Digital security divides: Consequences for people

Among the most vulnerable are those who are only now coming online or will soon do so. Around 40% of the world's population is not yet connected to the internet.[42] These individuals are already facing inequalities in digital security, which will only widen with the advent of internet 3.0 and the metaverse.[43] Within digitally advanced societies, vulnerable populations are also often more digitally at risk: for example, a recent study finds that low-income residents of San Francisco—

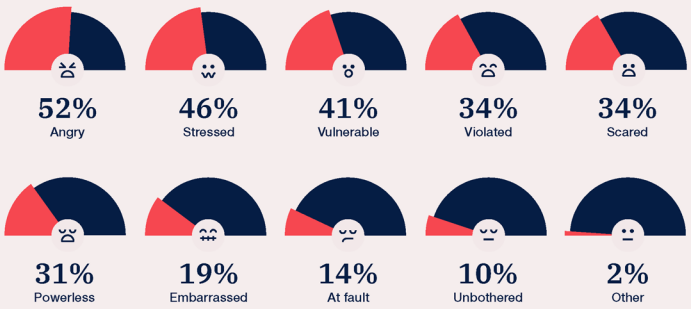


GETTY/CONSTRUCTION PHOTOGRAPHY/AVALON

FIGURE 3.2

Emotions Experienced after Detecting Unauthorized Access

Global total of those who detected unauthorized access in past 12 months



Source: NortonLifeLock Inc. 2021. "2021 Norton Cyber Safety Insights Report: Global Results". Norton and The Harris Poll. May 2021. https://now.symassets.com/content/dam/norton/campaign/NortonReport/2021/2021_NortonLifeLock_Cyber_Safety_Insights_Report_Global_Results.pdf

the cultural heart of Silicon Valley—are more likely than wealthier residents to be cybercrime victims.[44] In other situations, obligatory digital identity markers could introduce new risks for citizens, particularly evident in the growing risk that deepfakes could compromise biometric authentication.[45]

Individuals will increasingly experience anxiety as control over their data becomes more precarious and they are subjected to personal attacks, fraud, cyberbullying and stalking (see Figure 3.2).[46] A perceived lack of agency could also lead to apathy in taking responsibility for securing one's own digital footprint, as evinced by the continued market dominance of instant messenger applications plagued by privacy controversies.[47] Even with more widespread "reject all" options on websites intended to simplify personal data privacy, there are drawbacks and caveats—such as limiting functionality and other options. Importantly, these features are just a tiny part of the larger privacy equation. Websites are still littered with tracking pixels and third-party scripts that remain powerful ways to fingerprint online behaviours.[48]

Overreaching or underdelivering: Consequences for governments

Government at all levels faces mounting responsibilities and many are struggling to uphold their end of the digital social contract: securing critical infrastructure; addressing threats to "epistemic security" from disinformation; protecting the integrity of civic processes and public services; legislating against cybercrime; training and educating populaces around cyber literacy; regulating digital service providers; and ensuring the availability of resources, such as rare-earth minerals, for the digital economy. The necessary oversight could lead to overreach as governments move to shut down systems, erect higher digital barriers or embark on digital colonization (by monopolizing digital systems) for geopolitical ends.[49] While such actions might carry the ostensible goal of reducing

attacks and disruption, these policies could quickly become a vehicle for oppression. Already suffering from a loss in public trust as a result of the COVID-19 crisis, governments may face further societal anger if they are unable to both keep up with the shifting threat landscape and responsibly manage these challenges.

Pay, protect or perish: Consequences for businesses

As cyberthreats continue to grow, insuring against such risks will become increasingly precarious, with insurers themselves facing retaliatory attacks for attempting to curb ransomware payments.[50] Thus, when an attack occurs, businesses will either be forced to pay increasingly high ransoms or suffer the reputational, financial, regulatory and legal consequences of cyberattacks. As previous incursions (like SolarWinds) have demonstrated, exposure to vendors and supply chain partners must also be assessed and managed. The impact of disruptive cyberattacks could be financially devastating for businesses that fail to invest in protections for their digital infrastructure, particularly in a scenario in which governments begin prohibiting ransom payments or penalizing poor cybersecurity practices.[51] Furthermore, as environmental, social and governance (ESG) concerns come increasingly into focus (see Chapter 2), businesses that fail to demonstrate strong corporate governance around cybersecurity—such as by implementing robust systems and process oversight protocols, and by practicing accountability and transparency in the event of a breach—could suffer reputational harm in the eyes of ESG-focused investors.

Businesses also operate in a world in which 95% of cybersecurity issues can be traced to human error,[52] and where insider threats (intentional or accidental) represent 43% of all breaches.[53] Some companies will inevitably move to greater segmentation of digital systems to better account for insider risk. Companies could begin or continue to lock up key data as a result of the cybersecurity issues. Workforce efficiency, too, could suffer if accessing data and information is less seamless.

Shocks to reflect upon



NotPetya 2.0

What if an attack that is even more wide-ranging and costly than NotPetya—with the ability to self-propagate and even mutate to avoid preventative controls—created cascading lockups of systemically important businesses, bankrupting organizations, disrupting services and unwinding the digital transformation efforts made over the past years?



Sovereignty slips

What if the shifts towards privately held IT infrastructure as well as cryptocurrency and decentralized finance undermine governments' control over data, processes and financial systems?

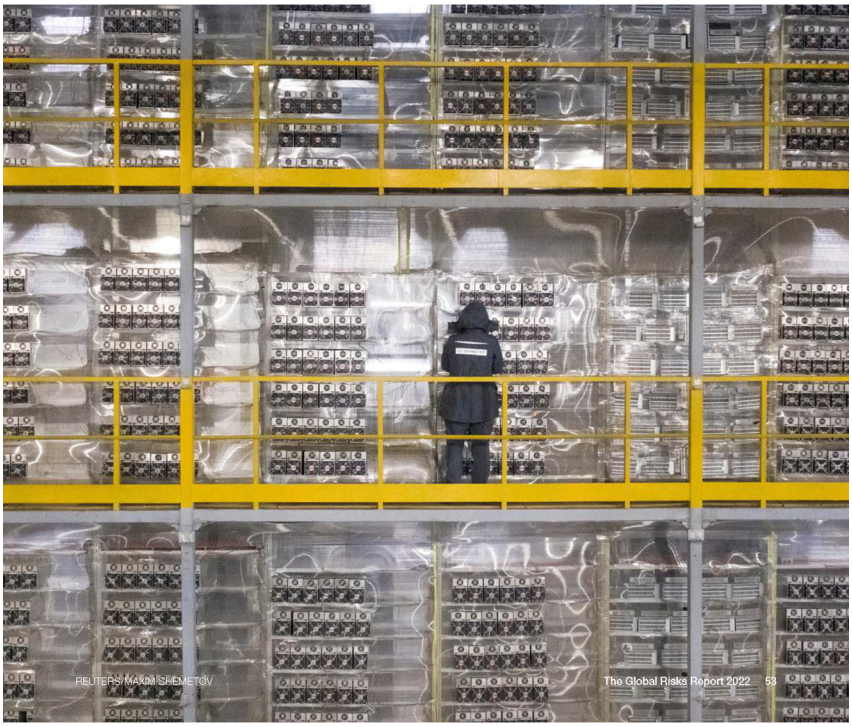


Undetected disruption

What if subtle changes in health, banking or other data go undetected for years, but carry significant consequences for premature death, loss of funds or other significant consequences over time? How can cyber espionage compromise return on R&D investment and competitiveness in the future?

Towards greater cyber resilience

As our reliance on digital technologies grows and Internet 3.0 becomes reality, efforts aimed at building norms and defining rules of behaviour for all stakeholders in cyberspace are intensifying. While multistakeholder international dialogues can help strengthen links between actors operating in the digital security realm, cooperation between organizations could unlock best practices that can be replicated across industries and economies. Initiatives should focus on emerging technologies, such as blockchain, quantum and artificial intelligence, as well as the modes of digital exchange they facilitate, like the metaverse. Leaders must remain attentive to perennial concerns like cybercrime and ransomware attacks as well. At the organizational level, upskilling leaders on cybersecurity issues and elevating emerging cyber risks to board-level conversations will strengthen cyber-resilience. In a deeply connected society, digital trust is the currency that facilitates future innovation and prosperity. Trustworthy technologies, in turn, represent the foundation on which the scaffolding of a fair and cohesive society is built. Unless we act to improve digital trust with intentional and persistent trust-building initiatives, the digital world will continue to drift towards fragmentation and the promise of one of the most dynamic eras of human progress may be lost.



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CHAPTER 4
Barriers to Migration
200 million
projected climate refugees by 2050
~25%
remittances-to-GDP in El Salvador and Honduras
9%
decline in FDI to low-income countries in 2021
4,800
estimated migrants perished or missing in 2021
REUTERS/YARA NARDI
The Global Risks Report 2022 57

Nowhere to go

Large parts of the global population face an increasingly insecure outlook (see Chapter 1). Global Risks Perception Survey (GRPS) respondents perceive "livelihood crises" as one of the most potentially severe risks over the next decade. Millions of people are already seeking to cross borders in search of better economic opportunities.

Over the last decade, the number of international migrants has grown consistently, from 221 million people in 2010 to 281 million in 2020.[1] Economic hardship, climate change, conflict and political instability are forcing millions more people to leave their homes. These trends are reflected in the GRPS, where "involuntary migration" is ranked as a top long-term concern.

Better international collaboration is required to manage these flows to ensure that economic migrants are not exposed to exploitation and that involuntary migrants—refugees—crossing into other countries receive the assistance and shelter that they need. The scale of the challenge has put significant pressure on existing frameworks for migration and refugee protection, such as the 1951 Refugee Convention and 1967 Protocol;[2] this pressure is compounded by fractures within the international community and national interest postures that risk limiting global capacity to address this challenge. Some 60% of GRPS respondents believe "migration and refugees" is an area where international mitigation efforts are falling short (that is, they have either "not started" or are in "early development").

Economic migration often has considerable benefits for both origin and destination countries. It is "the most effective way to reduce poverty and share prosperity", according to a World Bank report,[3] and can support economic growth by helping address labour shortages in destination countries. While most cross-border migration takes place between low- and middle-income countries, 83% of non-migrant residents in the 22 richest Organisation for Economic Co-operation and Development (OECD) countries have experienced net economic gains from the influx of migrants.[4] On the other hand, some project-based migration undertakings to enhance cross-border infrastructure have had negative impacts in destination countries, where the



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tendency to employ workers from origin countries has reduced opportunities for income and skills transfer for native, destination-country workers.[5]

Refugees can also ultimately make a positive contribution to the economies of destination countries, depending partly on a balanced intake across countries that have the capacity to take them in. Their ability to contribute often depends on whether they receive support to deal with the aftereffects of forced displacement—for example, counselling for post-traumatic stress, which is not normally afforded to economic migrants. Instead, millions of refugees remain crowded in camps on the fringes of society—often in countries in the Global South that do not have the economic capacity to absorb them.

However, national-level barriers to the movement of people are increasing. Disillusionment with globalization has fuelled nativist discourses and national interest policies in many destination countries in recent years, and COVID-19 has accelerated this trend. An IPSOS–World Economic Forum Survey from April 2021 found that positive views towards globalization fell during the pandemic by an average of 10 percentage points across 25 countries.[6] Many governments, reflecting popular attitudes, have expressed concern about pressures on education and healthcare services, housing capacity and local employment; for others, integration concerns have been a priority.

Higher barriers to both orderly and disorderly migration elevate the risk of forgoing potential pathways to restoring livelihoods, closing income and labour gaps and maintaining political stability. Instead, the clash between heightened insecurity in origin countries and migration barriers in destination countries will exacerbate global divergence (see Chapter 1), aggravating tensions within and between countries that could complicate an equitable recovery and lead to ever more desperate measures by those who feel compelled to move.

Growing insecurity in origin countries

Movement restrictions related to COVID-19 interrupted some migration flows;[7] as these restrictions are lifted, divergent economic recoveries will likely amplify pressures to migrate that have been restrained through the pandemic.[8] Many origin countries—mostly less advanced and less vaccinated



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ones (see Chapter 1)—face highly insecure economic outlooks as growth stagnates, public finances continue to be stretched and pandemic-related stimuli—on which vulnerable groups have depended—are scaled back.[9] Employment in these countries may also decline if the pandemic persists, exacerbated by a worldwide trend for workplace automation, re-shoring business operations and shortening supply chains that may affect foreign direct investment (FDI) inflows, exports and growth.[10] In many lower-income countries, where informal work is prevalent, informal migrant workers are particularly exposed to the pandemic's economic fallout because of their low income and lack of access to state support.[11]

Climate change is a key driver of migration. It displaces people directly because of natural disasters and it can displace them indirectly by encouraging economic migration from weakening economies vulnerable to the adverse impacts of climate change. The inability to adapt to

Climate change, conflict and political instability will force millions to leave their homes

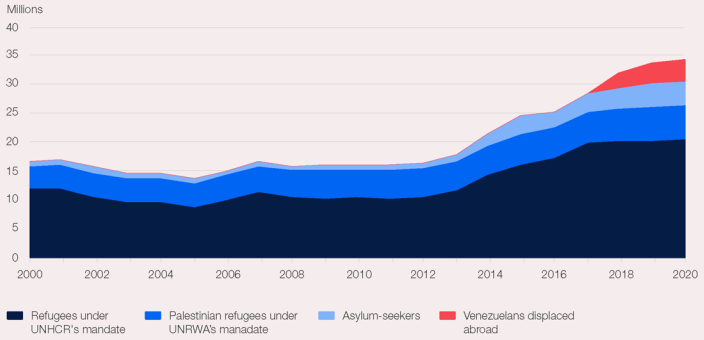
or mitigate the impacts of climate change threaten to make certain densely populated parts of the world uninhabitable.[12] More frequent and extreme weather events—including fires, floods and droughts—could displace more than 200 million people by 2050.[13] Water scarcity is a key driver of migration because of its impact on health and livelihoods as well as the conflicts it risks triggering.[14] GRPS respondents rated "extreme weather" and "climate action failure" as strong aggravators of "involuntary migration". Densely populated countries that are highly dependent on agriculture—such as India, Nigeria, Pakistan and the Philippines[15]—are especially vulnerable to climate insecurity. Worsening extreme weather will trigger large-scale migration and displacement, but the



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FIGURE 4.1

Refugees, Asylum-Seekers and Venezuelans Displaced Abroad, 2000–2020 (Millions)



Source: Data from UNHCR, "Refugee Data Finder", https://www.unhcr.org/refugee-statistics/download/?url=rVpdj6, accessed 1 December 2021.

Note: UNHCR = United Nations High Commissioner for Refugees; UNRWA = United Nations Relief and Works Agency.

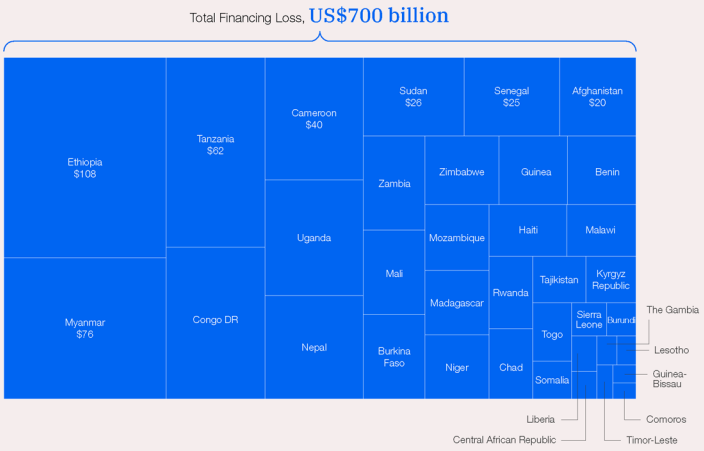
international community's reluctance to recognize "climate refugees" and "environmental migrants" is widening their legal protection gap.[16] Legislative and governance frameworks remain ill-equipped to protect millions at risk of displacement who do not qualify as traditional refugees.[17] These governance voids could leave governments blindsided in the event of a sudden, high-impact environmental shock. Moreover, the failure to achieve inclusive transitions to net zero economies (see Chapter 2) could worsen economic insecurity for businesses and households in those origin countries left behind.

Conflict and political insecurity are also major drivers of involuntary migration. In 2020, there were over 34 million people displaced abroad globally from conflict alone—a historical high (see Figure 4.1)—mostly due to long-standing conflicts and political turmoil in Afghanistan, Myanmar, South Sudan, Syria and Venezuela,[18] and to expanding conflicts within and beyond the borders of Ethiopia.[19] According to the Executive Opinion Survey (EOS), "involuntary migration" is a top short-term threat in Armenia, Ukraine and Venezuela, which have experienced conflict and political instability.[20] Political turmoil may well worsen in the aftermath of the COVID-19 pandemic, compounded by the reduction of international security forces from conflict zones such as Afghanistan and the Sahel region of Africa. Moreover, some political leaders have reacted to economic crises and social unrest with authoritarianism, discriminatory policies, or extremist discourses that put ethnic or religious minorities at risk of marginalization or violence.

National-level barriers to the movement of people are increasing

FIGURE 4.2

Developing Countries' Financing Loss versus GDP, 2020 (US$ billions)



Source: Data from OECD. Global Outlook on Financing for Sustainable Development 2021. https://www.oecd.org/development/global-outlook-on-financing-for-sustainable-development-2021-e3c30a9a-en.htm; World Bank Open Data, "GDP (current US$)" and "GDP per capita (current US$)". https://data.worldbank.org/indicator/NY.GDP.MKTP.CD, accessed 1 December 2021.

Global cooperation to resolve or mitigate ongoing humanitarian crises is being challenged by financial pressures in advanced economies, greater focus on domestic priorities and a more tense geopolitical context (see Chapter 1). Already, the pandemic has diminished external financing to developing countries by US$700 billion—equivalent to the combined GDPs of 36 of the world's poorest economies (see Figure 4.2).[21]

Mobility barriers in destination countries

There are three potential barriers to cross-border migration: post-pandemic effects on international mobility, future employment trends and increased national interest postures of many countries.

The COVID-19 pandemic and its economic ramifications have emboldened some groups and political leaders to adopt more hostile postures against migration, foreigners or communities with foreign roots. Restrictions on international movement as a result of the pandemic remained in place in 32 countries at the time of writing.[22] These include critical destination and corridor countries such as China, India, Russia, the United Arab Emirates and the United States. Future easing of restrictions will depend on the progress of vaccination and the evolution of COVID-19, but persistent vaccination gaps globally, and particularly within origin countries, means international mobility will continue to be restricted for many.

The pandemic may also narrow future employment opportunities for migrant workers in destination countries, both

because of the economic disruption it created and because of the accelerating automation and digitalization of tasks and services. The World Economic Forum's *Future of Jobs Report* found that 50% of employers globally planned to automate tasks in response to COVID-19, often in sectors that have relied on migrant workers.[23] The report also estimates that 85 million jobs will be destroyed by automation by 2025, and although 97 million new jobs will emerge, these jobs may not necessarily match the skillsets of many migrants.[24] The short-term economic rebound from the pandemic has resulted in a surge in hiring in some key sectors for migrants such as hospitality and healthcare, but in the long-term, new consumption patterns in destination countries—such as more e-commerce and less business travel—are expected to shrink demand for jobs in migrant-intensive industries such as agriculture, food services and warehousing.[25]

National interest postures have also become more entrenched across both developing and advanced economies. For example, Chile and Peru have reframed their migration governance mechanisms, which complicates access for migrant and refugee populations to essential financial and healthcare services.[26] Meanwhile, restrictive policies originally grounded in public health concerns have not been rolled back, as indicated by sustained declines in issued visas for the United Kingdom and the perpetuation of Title 42 expulsions at the US border.[27] Other destination countries have sought to harden borders to prevent the arrival of involuntary migrants, as evidenced in fresh ambitions to build walls in Europe and Turkey.[28]

Consequences

Barriers to orderly migration could have negative global consequences, such as widening labour gaps and income disparity, triggering or worsening humanitarian crises and increasing societal polarization.

Economic consequences. The economic rebound from COVID-19 has created labour shortages in specific industries—albeit some may be temporary—by disrupting market dynamics and supply chains and prompting workers to re-evaluate their personal and career choices. At the time of writing, the United States faced over 11 million unfilled jobs in general and the European Union had a deficit of 400,000 drivers just in the trucking industry.[29] The hospitality sector, one of the most severely affected by the pandemic, is especially vulnerable to long-term labour shortages that migration could close. In the United States, a survey found that over 50% of former hospitality employees would not return to their previous jobs, and 60% of workers seeking employment would not consider the hospitality sector.[30]

A decrease in migrant employment could weaken the global flow of remittances such that growth in income fails to keep pace with inflation, thereby limiting social mobility in origin countries. Remittances also support private consumption, savings and investment in origin countries and can equate to a significant proportion of GDP (from nearly one-fourth of GDP in El Salvador and Honduras to over one-third in Somalia).[31] They proved to be resilient through the pandemic, falling by 2% annually in low- and middle-income countries in 2020[32]—far less than the 30% drop in FDI[33]—and quickly recovering to rise by 7.3% in 2021.[34] Combined with stagnant tourism and pressures on exports,[35] a fall in remittances would weaken another important source of financing for many developing countries.

Businesses risk worker deficits and demand shocks from constrained migration



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Humanitarian consequences. Humanitarian crises could worsen where barriers to exit prevent vulnerable groups from escaping persecution or violence. In some fragile states, governments could block their citizens' departure to halt depopulation as well as capital flight. In Afghanistan and Myanmar, governments have reportedly impeded citizens from leaving the country.[36] Blocking emigration prevents people from seeking more secure livelihoods and diasporas from reuniting with families. It can exacerbate societal fractures by closing a mechanism to reduce poverty and narrow inequality, fuelling citizens' animosity towards government and potentially empowering criminal or even terrorist groups that offer hope to disaffected individuals.

More limited international mobility opportunities will push migrants to embark on more perilous journeys and risk worsening or triggering humanitarian crises in neighbouring and corridor countries. One such case is the Syrian crisis, which by 2021 had already displaced nearly 6 million Syrians abroad—mostly to Turkey, Lebanon and Jordan—but could further deteriorate.[37] An estimated 700,000 Central American migrants transited through Mexico in 2021—a rapid return to pre-pandemic levels[38]—and those unable to enter the United States are unlikely to return to their origin countries.[39] At one point, 15,000 Central American refugees were stranded for days in precarious conditions under a bridge on the Mexico-US border.[40] According to the EOS, "involuntary migration" is a top short-term threat in El Salvador, Guatemala, Honduras and Nicaragua.

These perilous journeys can also lead to tragic loss of life, such as when people become lost at sea or face harsh weather while stuck in borderlands.[41] At the time of writing, nearly 4,800 migrants were estimated to have perished or gone missing in 2021, most of them trying to reach Europe from Africa.[42] Although there is worldwide consensus on the urgent need to combat human trafficking, the International Organization for Migration estimates that organized human-trafficking groups operate in every country.[43]

Geopolitical consequences. Migration pressures could exacerbate geopolitical tensions and even fuel cross-border conflicts. For example, in the Middle East, half a million Afghans are expected

to take increasingly drastic measures to circumvent migration restrictions and flee to neighbouring countries[44]—including Iran, which has enlarged its military presence along the border to deter a potential Taliban incursion.[45] Management of migration flows has become a tense issue between Turkey, which hosts some 3.6 million Syrian refugees,[46] and the European Union.

Geopolitical rifts could also worsen—and new ones emerge—if origin country migration is increasingly used as a geopolitical instrument. The crossing of migrants from Morocco into the Spanish enclave of Ceuta aggravated tensions that originated in the European Union's lack of support for Morocco's claims over the Western Sahara.[47] Political tensions between Belarus and the European Union escalated considerably as Belarus encouraged travel from the Middle East, moved migrants to camps along its border with Poland and pushed them to cross over, prompting Poland to deploy troops in response.[48] In such cases, destination-country governments seeking to comply with international laws on the treatment of refugees—thereby preserving their reputation among the global community in the spheres of global development and human rights—will have to carefully manage diplomatic relationships with neighbours to arrive at a way forward while responding to immigrant scepticism among a significant proportion of their populations.

Geopolitical rifts could worsen if migration is used as a geopolitical instrument

Consequences for stakeholders

People, governments and businesses in origin and destination countries face distinct challenges from divergent perspectives on migration. But stakeholders in both geographies also face common challenges: social unrest if migration is used to discriminate against and marginalize certain groups; hardening political contexts if governments exploit migration challenges to justify more control over citizens and markets; and some negative economic



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consequences if legitimate diaspora networks in destination countries created by migration are undermined.

Left alone: Consequences for people
By 2020, there were more than 4 million stateless persons in the world, the highest number in a decade;[49] but this number risks increasing due to heightened social polarization and strained government capacity. Limited options for migrants to gain admittance to destination countries upon entry—even temporarily—could be compounded by corridor countries refusing to allow them to remain within their borders. People in this situation—who are unwilling or unable to return home and whose governments do not take responsibility for their welfare—are at risk of being stranded in irregular settlements or facilities with minimal access to basic goods and services, financial support or diplomatic assistance. Others unable to escape insecurity are at risk of violence or falling prey to extremist ideologies and organizations. Refugees would face poor conditions and even violence in transit and in camps if international cooperation to manage involuntary migration is lacking. Even more economic migrants could resort to desperate measures and become vulnerable to exploitation by human-smuggling cartels.

In destination countries, growing extremism could create greater challenges for migrants trying to assimilate.[50] Citizens could also see their civil liberties violated by governments using migration management to justify widespread population surveillance and intrusions on personal information.

Last resort: Consequences for governments
Remittances improve living standards in origin countries and provide an important source of financing.[51] Without them, governments in origin countries whose economic stability hinges on remittances may face severe complications in their ability to govern—some could be at risk of degenerating into failed states. Destination-country governments also face risks domestically from failing to address citizens' concerns with migration. Adopting stricter migration measures could encounter some popular backlash as pro-migration advocates make their voices heard on the streets and online, while failing to effectively manage inflows risks stoking the growth of populism.

Shocks to Reflect Upon



Not in My Country

What if xenophobic political parties in federal democracies start winning more elections and securing leadership positions in destination-country border or sanctuary towns? What if they ignore federal law and start taking border protection or mobility policies into their own hands, facilitating vigilante behaviour?



Show Me the Money

What if stricter migration policies lead to more burdensome regulation, reduced competition and higher fees in remittance services? What if traditional remittance channels are choked off and cryptocurrencies become the prevalent method for sending remittances, exposing digitally insecure migrants to cybertheft?



Too Little, Too Late

What if stalled or delayed climate action means that ecosystems reach their tipping points suddenly and unexpectedly, accelerating climate migration into neighbouring countries as droughts, floods and resource scarcity worsen?



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Little room: Consequences for businesses

Businesses in destination countries are at risk from a global worker deficit and demand-side shocks that could result from constrained migration. Migrant workers comprise an attractive consumer group that can contribute to developing domestic markets and support international expansion by boosting brand awareness in their home countries. But businesses perceived to favour stricter foreign labour requirements, or that are seen as not making enough effort to support their migrant staff, could face a public backlash from migrant communities and their supporters. On the other hand, businesses that welcome migrant workers with a view to low-cost labour may expose themselves to union pushback.

Towards two-way bridges

At a time of global divergence, migration could foster economic integration. International mobility could narrow inequality within and between countries by matching job seekers in origin countries with unfulfilled vacancies abroad in growth industries—such as healthcare, renewable energy and transportation.[52]

More efficient and orderly channels for migration—including coherent legal and policy frameworks, cross-border cooperation and alignment and better enforcement against smuggling operations—could prompt closer political ties between countries and encourage collaboration on issues of mutual concern such as shared infrastructure for cross-border financial flows. The global community could also build goodwill across geopolitical divisions by strengthening collaboration mechanisms for refugee intake.

Migration offers opportunities but also entails challenges for origin, corridor and destination countries. Leaders have the chance to jointly identify where new bridges can be built for mutual benefit.

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CHAPTER 5

Crowding and Competition in Space

5

number of new government-developed space stations by 2030

70,000

estimated number of satellites to launch in coming decades

28

nations with domestic space regulation

1 million

estimated number of debris pieces 1 centimetre and larger

REUTERS/ROSCOSMOS

Space is getting busier

Humans have been inspired by space exploration for decades but growing commercial and geopolitical interests are increasingly influencing this frontier. While early space activity was conducted or funded by the public sector, the last decade has seen growing private investment. New commercial entrants are disrupting traditional incumbents' control in delivering satellite services, especially in internet-related communications or launch services. Some governments are encouraging private space activity to further national "territorial" claims or to foster the development of high-value jobs, especially in the zone of Low Earth Orbit (LEO) or Medium Earth Orbit (MEO), as well as enhancing their military or defence-oriented presence.* Increased exploitation of these orbits carries the risk of congestion, an increase in debris and the possibility of collisions in a realm with few governance structures to mitigate new threats.

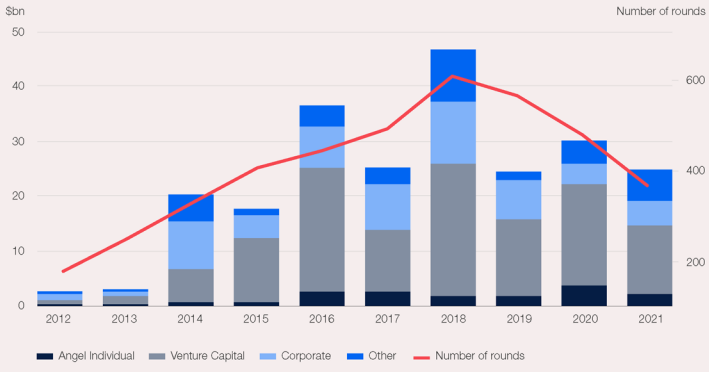
A LEO/MEO space race

The traditional Geostationary Orbit (GEO) commercial satellite market, which has dominated the communications sector for decades, is now losing commercial value because of competition from new players seeking to provide services from LEO or MEO. More recently, in the last decade, the financing of new applications for space-based initiatives has grown fast: businesses, start-ups and research entities are proliferating, raising money in the billions, and thereby driving down the cost of launch systems, particularly in LEO (see Figure 5.1).[1] Lower costs bring more opportunity for a greater diversity of actors to launch constellations of smaller satellites. With this more cost-effective access to space, attention is increasingly shifting to new opportunities in areas such as hyperspectral remote sensing, energy

* Low Earth Orbit (LEO) is generally considered to encompass Earth-centred orbits with an altitude of 2,000 kilometres (1,200 miles) or less. The Geostationary Orbit (GEO) encompasses a higher-altitude orbit, typically at an altitude of 35,000 kilometres above the Earth's equator while Medium Earth Orbit (MEO) comprises a range of orbits between LEO and GEO.

FIGURE 5.1

Space Investment: Equity Capital by Investor Type (US$ Billions)



Source: Space Capital. Q3 2021. https://app.powerbi.com/view?r=eyJrIjoiNGY4MWI4OWEtMjNmZS00OTM5LWE5M2QtYTgxZTdjODk3YTIlIiwidCI6IjYzMDZkMTJjLTEwODMtNGNhOS04Yjk2LTdjYzM3ODcwMWIzMilsImMiOjN9

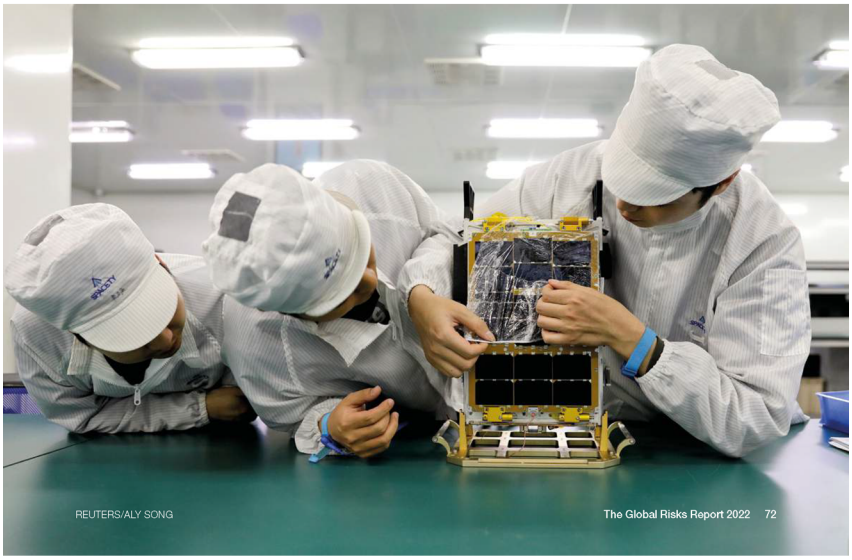
generation, manufacturing, mining and tourism.[2] However, the largest growth is still expected to come from industries that are already expanding digital connectivity on Earth, such as direct-to-consumer broadband access.[3]

National ambitions

Space programmes are still widely seen as a sign of national prestige, as they project geopolitical and military power as well as have scientific and commercial significance. Powers such as China, Europe (EU and ESA), France, Germany, India, Japan, NATO, Russia, the United Kingdom and the United States have publicly announced space forces and continue to build space infrastructure, with plans for at least five new space stations by 2030 in the works.[4] The first commercial space station is also slated for completion in the next decade.[5] Next-step deep space exploration projects are under development, such as the United States–led Artemis programme—which aims to reopen exploration of the Moon and eventually develop outposts on Mars and asteroids.[6] In addition, new space-faring powers will emerge as more economies begin to see opportunities to expand both geopolitical and commercial influence in this arena. Among countries that have expressed interest are Argentina, Brazil, and Mexico in Latin America; Egypt, Iran, Turkey, Saudi Arabia, South Africa and the United Arab Emirates in Africa and the Middle East; and Australia, Indonesia, Malaysia, New Zealand, South Korea and Vietnam in the Asia-Pacific region.[7]

Businesses, start-ups and research entities are proliferating

Alongside new programme development, the critical infrastructure on which many civil and commercial entities rely must be maintained and secured.[8] Satellites in LEO as well as in MEO and GEO are used for multiple purposes that include climate and natural resource monitoring, broadband internet, and radio and television broadcasting, as well as position,



REUTERS/ALY SONG

navigation and timing services.[9] While this infrastructure will continue to remain vital for governments, businesses and societies, it is also creating opportunities for nations with an advanced space industry, supported by national-level regulation, to stake claims to specific orbital sectors by virtue of first-mover advantage.[10] Finally, space will continue to be of critical military importance: armed forces have long relied on space-based or space-supported technologies—including Global Positioning System (GPS) for navigation, dedicated military satellite-based communications for secure digital connectivity and spy satellites for intelligence—making such systems tempting military targets and spurring the need for enhanced defensive measures.[11]

Consequences

A greater number and diversity of actors operating in space could generate new or exacerbate old frictions if not responsibly managed. The trend in commercial, civil and military sectors is to replace traditionally large and expensive single geostationary satellite systems with a more distributed system of multiple smaller satellites in LEO. Approximately 11,000 satellites have been launched since Sputnik 1 in 1957, but 70,000 more could enter orbit in the coming decades if proposed plans play out.[12] The vast majority of these new planned and approved satellites will be launched by a handful of operators that will have increasing influence over the regulatory landscape.

Once in orbit, and unless actively decommissioned, many of these satellites could remain in space for hundreds of years.[13] Smaller, low-cost satellites are also proliferating because of lower costs and fewer barriers to entry.[14] While the risk is still relatively low, an increase in the number of satellites also increases the opportunity for collisions, or, at the least, a need to engage in emergency manoeuvres to avoid contact.

Collisions could hinder future space development or aggravate international tensions. This is because when objects in space collide, they may break up and produce debris that—even at sizes of 1 to 5 centimetres in diameter—could cause severe damage.[15] For example, the International Space Station (ISS) was damaged in May 2021 when a piece of debris penetrated its robotic arm.[16] Such strikes have been documented for decades, but they may become more frequent. One theory, known as the "Kessler Effect" (see Box 5.1), posits the potential consequences of a cascading effect.[17] Estimates put the current number of smaller pieces of debris (larger than 1 centimetre in size) at nearly a million,[18] while larger objects over 10 centimetres number in the thousands (see Figure 5.2). Providing orbital servicing and debris removal could, however, help alleviate some of the worst consequences.[19] Tracking debris is a critical tool in preventing collision or damage, but it will need to become increasingly sophisticated to maintain reliability in a more congested realm.

With such possibilities becoming likelier in a congested space, the lack of updated international rules around space activity increases the risk of potential clashes. The most relevant of space agreements, the Outer Space Treaty, was concluded in 1967 and still, through the UN Office for

BOX 5.1

The Kessler Effect

First identified by NASA scientist Donald Kessler in 1978, this describes a scenario where the density of objects (satellites and debris) in LEO is high enough that collisions between objects could cause a cascade in which each collision generates space debris that increases the likelihood of further collisions and an exponential growth of debris. One implication is that the distribution of debris in orbit could render space activities and the use of satellites in specific orbital ranges difficult for many generations.



REUTERS/JOE SKIPPER

Outer Space Affairs (UNOOSA), governs much of the activity taking place in space. However, few effective governance tools have emerged in recent years to reflect new realities, such as the pressing need for an authority to govern satellite launches and servicing, space traffic control and common enforcement principles.[20]

As an exemplar challenge, the 1972 Space Liability Convention—which governs international responsibility for space objects launched from Earth—lacks precision around hybrid aircraft and rocket transport systems. For example, different legal authorities may govern depending on whether a vehicle is deemed to have launched when an aircraft takes off with a rocket attached or when the rocket detaches from the aircraft—and whether the hybrid vehicle is an aircraft or spacecraft while both pieces are attached. New addenda may be needed to clarify when space law should supersede aviation law.[21] Even the most robust governance realm, electromagnetic spectrum management, which is governed by the International Telecommunication Union (ITU), faces serious crowding pressures with new satellite systems and increased competition in the terrestrial spectrum usage of emerging 5G technologies.[22]

Respondents to the Global Risks Perception Survey (GRPS) reflect these gaps: 76% of respondents characterized the current state of international risk mitigation efforts in space as either "not started" or in "early development".

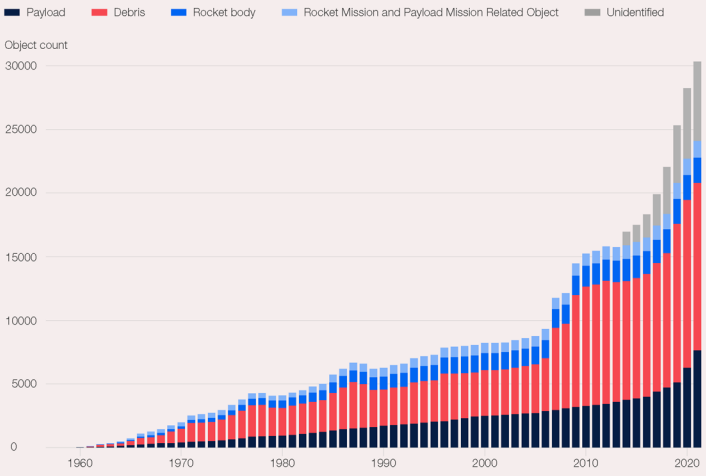
Governments, too, have developed their own national space policies,[23] with commercial interests as a key pillar of their national strategies, alongside national security and civil space policy. Although many governments have cooperated behind the scenes historically and still do today,[24] there is significant policy divergence among the 28 nations with space regulation,[25] and countries now operate at different scales and with different levels of ambition.[26] Such fragmentation compromises the further development of beneficial commercial space activities, which require shared norms across states to be able to function.[27]

National space ambitions also bring a growing risk of the militarization of space. The US military created a Space Force as a separate branch of its armed services in 2019, while Japan's Space Operations Squadron and the United Kingdom's

National space ambitions bring a growing risk of militarization of space

FIGURE 5.2

Evolution of the Number of Objects in All Orbits, 1960–2020



Source: European Space Agency. 2021. ESA's Annual Space Environment Report. 27 May 2021. https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf

Space Command were both created in the last two years. Other leading armed forces also now typically include a space component—for instance, in 2021, the French Air Force became the Air and Space Force (Armée de l'Air & de l'Espace). In November of 2021, an anti-satellite weapons test conducted by Russia created significant debris and threatened astronauts on the ISS.[28] Other countries have conducted similar testing, raising the spectre of repeat occurrences from other nations, which would add considerably to the problem of space debris (see Figure 5.2).[29] A hypersonic weapons arms race also risks contributing to the militarization of space—China, Russia and the United States are all developing such weapons and each tested them in the second half of 2021.[30] And with expanding geospatial intelligence, all of Earth is observable by satellites, which could spur some nations to blind, jam or otherwise interfere with satellite Earth observation.[31] As technology advances, space mineral exploitation—already heralded as part of some deep-space exploration programmes—could also be viewed as another competitive wedge over a more distant horizon.[32]

Gaps in space governance render arms races even more likely. For example, the Outer Space Treaty prohibits nuclear weapons in space but does not address conventional weapons, which is particularly worrisome in today's context of conventional weapons development and testing in space. New rules are unlikely in the near future, as there is little agreement over key issues such as

boundaries, control over space objects, or dual-use systems.[33] Any further decline in cooperation on space governance will only exacerbate risks.[34]

Service disruption and environmental unknowns: Consequences for people
Societies are dependent on space infrastructure in myriad everyday ways. GPS satellites not only allow for safe navigation in the air, land and sea, but they also underpin financial transactions, data transmissions and energy control systems. Threats—such as a massive solar storm or jamming or spoofing of GPS satellites—could cause the internet to slow, navigation systems to fail, and controls for energy grids, water or transportation to crash. Ripple effects across societies could be extensive, even for a few seconds of disruption.[35]

There are also significant unknowns about the impacts of rapid space development on Earth's environment—including damage to the ozone layer, butterfly effects from black carbon (soot) emissions, and possible alterations of the polar jet stream.[36] Of course, technological advances, such as developments in space-based solar power, could offset many of the potential negative environmental impacts of growing space exploration and exploitation.[37]

Gravitational push and pull: Consequences for governments
Notwithstanding high levels of private sector investment, increased commercialization and growing geopolitical competition will demand higher government spending on space programmes and defence at a time when public finances are under greater pressure due to the economic overhang of COVID-19 (see Chapter 1). For example, governments will increasingly need to compete for talent, with private sector entities offering more lucrative employment packages. Defence agencies will need to continue to expend resources to defend against more-sophisticated space-based weaponry and increasingly effective space-based tools of statecraft, such as enhanced surveillance or espionage.

Yet, for a large majority of governments, space technology and access will remain out of reach altogether at a time when reliance on space technologies is growing for all. Forty-one nations have registered space agencies with UNOOSA,[38] yet the many governments not represented will continue to struggle to develop their capacities or earn a seat at the table in key decision-making processes. Without concerted effort to facilitate inclusive growth in the space realm, inequalities in the commercial and geopolitical benefits accruing from space development will only grow.

Shocks to Reflect Upon



Kessler Collapse

What if a cascading chain of collisions between near-Earth objects and space debris result in a saturated Low Earth Orbit that renders space practically unusable for further commercial development?



Solar Disruption

What if a massive solar event or geomagnetic storm disrupts satellite-based services and functions, causing massive, cascading economic and societal consequences on Earth?[39]



Property in Space

What if violations of the Outer Space Treaty—such as mineral resources being claimed in a Moon "gold rush"—are carried out without meaningful consequences?

Opportunity blocks: Consequences for businesses
Venture financing flooded into the space industry following the successful launches of commercial space flights. As commercial activity in space grows, more companies could crop up seeking entry while investor interest is high. However, if manufacturing, tourism or other space ventures fail to take flight, speculators and space industry companies could see their bubble burst. Similarly, grassroots campaigns to ban space pollution and prevent privatization of important science data could give investors pause, stifling the unmitigated venture financing in the field. [40]

Towards cooperation in space

Although space represents yet another realm in which geopolitical and commercial tensions will play out, important traditions of cooperation in this arena should not be forgotten. Norms of behaviour established through voluntary measures that are not legally binding with the goal of building trust and establishing mutual understanding have helped mitigate escalating tensions in the past. While this trend could continue, more robust formal governance will be required in a more crowded and competitive space. Specific and functional bilateral or multilateral agreements between major space powers could help create norms and influence broader global behaviours.

Space situational awareness, space traffic management and debris mitigation are areas in which norms-based and eventually formal international agreements would benefit all actors. Critically, and like other realms where technology is developing at a faster pace than its regulation, bringing private sector actors into the agreement processes will help ensure that such pacts reflect both commercial and technical realities. Taking advantage of these opportunities to achieve widely accepted norms could then help facilitate discussions around more challenging issues in space, such as limits on weaponization, ownership and appropriate venues from which to govern the realm.



REUTERS/ROSCOSMOS

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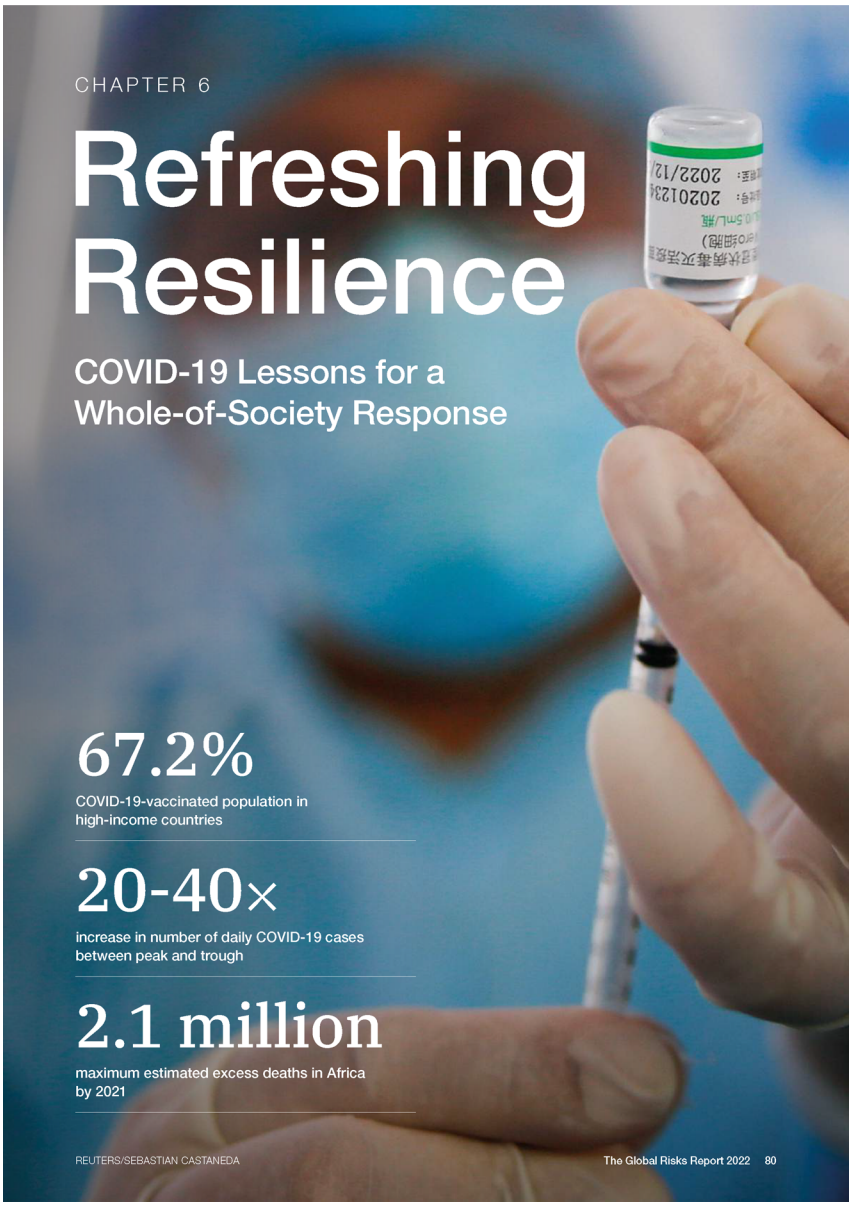
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CHAPTER 6

Refreshing Resilience

COVID-19 Lessons for a Whole-of-Society Response

67.2%

COVID-19-vaccinated population in high-income countries

20-40×

increase in number of daily COVID-19 cases between peak and trough

2.1 million

maximum estimated excess deaths in Africa by 2021

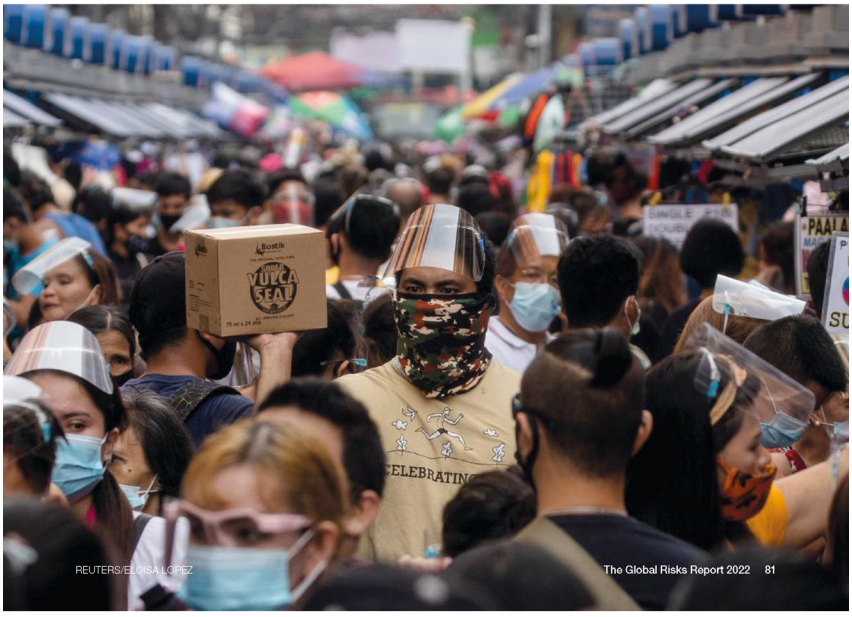
REUTERS/SEBASTIAN CASTANEDA

Adaptive resilience to the pandemic at the national level

The 2021 *Global Risks Report* closed with a reflection on the extent to which shortcomings in the pandemic response could be attributed to long-standing complacencies, the novel and specific complexities of COVID-19, the volatile and divisive (geo)political environment or simple mismanagement. This chapter takes stock of national response strategies implemented in the second year of the pandemic, and then reflects on collaborative opportunities within countries to improve preparedness for future crises and organizational resilience.

During 2020, national governments sought to protect lives and livelihoods against a novel virus that was resulting in a significant mortality rate—with the backdrop of significant shortcomings in national and global preparedness. In 2021, as the virus evolved more contagious variants, governments sought to deploy new responses, in alignment with measures developed the previous year, to return to societal and economic normalcy. Most countries experienced several surges during the year, with the number of daily cases characterized by exponential growth and a 20- to 40-fold increase between peak and trough (see Figure 6.1). By this measure, most countries presented both success stories and cautionary tales at different times.

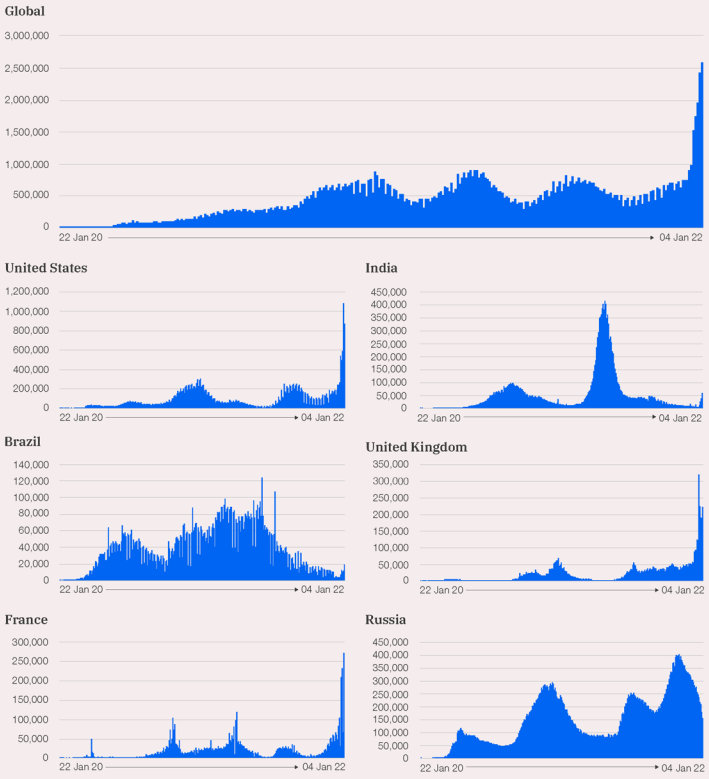
Most countries saw both success stories and cautionary tales at different times



REUTERS/ELOISA LOPEZ

FIGURE 6.1

COVID-19 Daily New Cases: Global and Top Six Countries by Infections



Source: Worldometer. Covid-19 Coronavirus Pandemic – "Daily new cases". https://www.worldometers.info/coronavirus/, accessed 5 January 2022.

Two interlinked factors have proved critical for the effective national management of the pandemic: first, governments' readiness to adjust response strategies according to changing circumstances; and second, their ability to maintain societal trust and compliance through principles-based decisions and effective communications.

Flexible response strategies

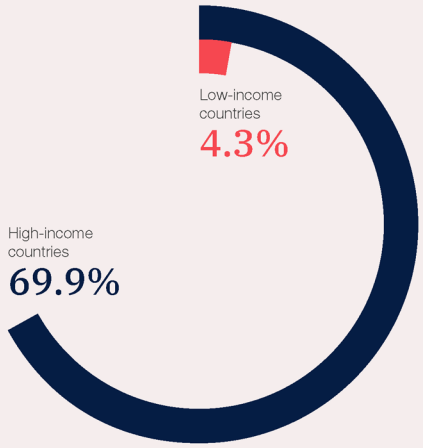
In general, effective national responses were characterized by a holistic view of societal well-being, multi-pronged approaches to transmission control and health system protection, robust coordination of policy and process, reliable logistics and the deployment of new interventions and increasingly granular and real-time data where available. Countries such as Chile and Finland were better able to manage peak periods than those with less well-rounded approaches.[1] They achieved this via cross-departmental policy agendas; expanded networks of community health workers; key health worker protections; a range of individually imperfect but collectively effective transmission control measures such as testing, tracing, and isolating; digital healthcare technologies; and early investment in anticipation of future needs.

Critical for many countries was the establishment of well-judged policy transitions between enabling social interaction and economic activity when possible and returning, when needed, to the kind of mobility constraints that were default strategies in the early stages of the crisis. Rapid and wholesale easing of constraints on social and economic activity often resulted in a steep rise in case numbers, although the impact on health systems and mortality was often mitigated by high vaccination rates. Some countries that had prided themselves on very low case numbers for a long time found it hard to acknowledge or pivot when that was no longer the best indicator to measure the state of the pandemic.[2] The Omicron variant, with its higher infectiousness, will moreover force governments to revisit the balance between sustaining economic activity and limiting spread. Some are choosing to minimize disruptions in light of the virus' evidently milder threat, although they must be prepared to reinstate restrictions as necessary given that healthcare systems remain at risk of collapse.[3]

The arrival of effective vaccines and antiviral treatments changed the game in terms of managing the impact of the virus on citizens' health and national health systems, enabling greater latitude in other policies.[4] Mass deployment of affordable rapid tests also helped people move and mingle again while mitigating transmission risk. However, although a range of vaccines was technically available from early in the year, differing negotiating powers, contracting approaches and approval regimes had a strong impact on programme rollout timetables. Many high-income countries had privileged access to vaccines: by early December 2021, all but three Organisation for Economic Co-operation and Development (OECD) countries had double-vaccinated at least 50% of their populations.[5] Some middle-income countries had also achieved high levels of vaccination: for example, the 79% vaccination rate in Malaysia was largely due to effective distribution,[6] while Brazil's 65% was attributed to strong vaccine enthusiasm.[7]

FIGURE 6.2

Percentage of the Population Who Are Fully Vaccinated



Source: ONE. 2021. "Data dive: The astoundingly unequal vaccine rollout". January 2022.



REUTERS/ELOISA LOPEZ

The lowest vaccination rates were mostly found in low-income countries (see Figure 6.2), especially in Africa, that had to rely on "vaccine diplomacy" initiatives from individual countries and multilateral agreements such as the Covid-19 Vaccines Global Access (COVAX) programme. The latter suffered from low contributions from high-income countries, high levels of bureaucracy, unpredictable supplies, and storage and distribution challenges.[8] Relatively younger populations and "a favorable climate may have blunted the mortality of the virus in these countries, though excess deaths were estimated at between 0–2.1 million in Africa by May 2021,[9] and long Covid may emerge as a longer-term challenge given the large number of non-fatal cases.

In general, successful vaccine rollout programmes struck a balance between speed and robustness, recognizing that perfect was sometimes the enemy of good. Vaccine effectiveness was found to improve following a second dose but waned over time, leading advanced economies to introduce booster jab programmes in which take-up and speed were key priorities.[10] By the latter part of the year, analysis showed that fully vaccinated individuals were less likely to transmit the virus, experience severe or long-haul symptoms, occupy hospital beds or die.[11]

Although global eradication of COVID-19 is no longer a viable option, persistent transmission of SARS-Cov-2 allows the emergence of new variants that are more contagious and may be more virulent and escape immunity conferred by infection or existing vaccines. Hence, the relatively slower vaccine rollouts in middle- and low-income countries, as well as vaccine hesitancy wherever present, remain a continued pandemic risk for all countries and require anticipation of further policy transitions. As and when new variants arise, governments will need to reimpose an appropriate set of control measures.

Maintaining societal trust

Maintaining societal trust involved galvanizing compliance and cooperation across citizens and the business community through frequent changes of government policy over an extended period. This often proved

Mass and affordable testing helped people move and mingle while mitigating transmission

challenging as, during 2021, many citizens became even more weary of lockdowns and obligations such as mask-wearing. In late November, several European countries and Australia experienced riots when governments tightened regimes in the face of ballooning case numbers.[12]

Moreover, in advanced economies with widespread access to vaccines, significant percentages of the adult population remained unvaccinated at the end of 2021 due to misplaced concerns about the risk of the vaccines relative to that of catching the virus, over-confidence in their own natural immunity and adherence to a range of theories that lack scientific basis.[13] In other countries, general distrust of the government has resulted in widespread vaccine hesitancy, with alternative sources of authority, including local opinion and religious leaders, not sufficiently able to help allay fears.[14]

The trust component of managing this crisis has often depended on a balance between imposing constraints or coercions based on science and policies that encourage good behaviour. Communication has needed to steer a narrow course between individual freedoms and collective resilience; indeed, nearly 50% of the World Economic Forum global risk experts identified this tension as one of the most critical for societies to manage.[15] The challenge will only intensify as the pandemic extends into its third year and the public grows increasingly weary, especially during festive seasons as expectations for unfettered social activity increase.

The faster distribution of testing kits, along with easier self-administration and greater reliability of results, were helpful for enabling social interactions and international mobility. Widespread availability of affordable testing will be crucial as restrictions are increasingly lifted and greater social activity causes demand to outstrip supply, as has already been seen in some countries. However, regarding vaccines, some governments have become concerned that voluntary measures have reached their limits, especially with the arrival of the Omicron variant.[16] Plans for vaccination requirements, with sanctions on employment or mobility for those who continue to resist, will test societal goodwill and compliance as well as government determination in light of divisive politics.[17] Additionally, national resilience strategies for future pandemics may require anticipation of some level of distrust and defiance of restrictions and interventions aimed at protecting vulnerable population segments.



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Preparing national resilience ecosystems for future crises

The COVID-19 crisis repeatedly surprised those charged with anticipating its trajectory and will likely leave further complex problems in its wake. Nor is the pandemic and its response the only challenge that governments, societies and businesses are facing. As the *Global Risks Report* sets out, new crises may lie just over the horizon.

Many critical risks demand a whole-of-society response. This involves not only the engagement of different sectors leading to multiple individual actions, but also more effective interaction between different sectors in ways that are accretive to well-being and prosperity.[18]

Countries must distinguish between different resilience goals to harness their collective capabilities more effectively and navigate the many inevitable trade-offs, as failure to appreciate where agendas are misaligned will limit the traction any solutions can gain. One such goal might be community resilience to potential disasters; another might be reliable critical economic and societal infrastructure; a third might be long-term strategic imperatives such as industrial transformation.[19] Each of these goals requires different strategies, providing a frame for different cross-sectoral interactions.

Government lens

National risk assessments and resilience strategy reviews should be used to reveal where momentum is insufficient and greater government intervention is needed. It is not desirable or feasible for governments to seek to fill all gaps themselves: instead, they should look to harness the capabilities and energies of other sectors to complement enhanced competencies that ought to lie in the public realm.[20] Strategies should set out what is needed and examine all available levers with fresh eyes. They should identify where governments may need to compel action by others, and where they can exercise power as a client, stimulate new initiatives, facilitate collaboration or simply act as cheerleader for good practices.

In their interactions with the private sector, governments that are more dirigiste might want to adjust their approaches to models for stockpiling critical goods, requisitioning and procurement in a crisis.[21] All might also seek tougher cybersecurity mandates and set out stronger expectations of stress testing for critical infrastructure.[22] They might seek to bring about a research and development ecosystem for resilience, coordinate crisis management exercises involving public and private sectors and provide a level of backstop for pooled insurance schemes targeted at catastrophic risks.[23]

On three issues, finding a balanced path is critical. First, it is essential to allocate risk in a way that means the taxpayer does not ultimately pay up in every crisis nor do governments sweep risks off the public balance sheet onto the private sector. More transparent, analysis-led discussions about risks and tolerances should spur more equitable, creative solutions about the cost and pricing of risk as well as fiscal and market buffers that might mitigate fallout in the event of crisis.

Second, regulating for resilience must factor in rapid changes in assets, industries and systems; conflicting priorities in regulatory mandates; and enforcement challenges. Arguably, systemically important assets, firms and sub-sectors ought to experience greater oversight to prevent "hidden" assets in digital ecosystems, dominant firms in niche but critical industries and growing segments of certain sectors

Government should harness capabilities in other sectors to enhance public competencies

where the plausible near-simultaneous failure of several providers could have negative far-reaching consequences.[24] For regulatory regimes that primarily look out for present-day consumers, long-term resilience should be a central tenet and capability underpinning the development and implementation of major critical infrastructure capital investment plans.[25] Stronger cross-sector regulatory hubs could sharpen debate and help reconcile differing agendas of bodies with separate statutory powers.[26]

Third, data-sharing arrangements must be adjusted in a way that enables both pre-emptive resilience building and sharper crisis management. There are good reasons for constraining some flows of data and intelligence, including national security, commercial confidentiality, antitrust constraints and personal privacy. Acknowledging this, governments may seek to identify crisis circumstances—such as a cybersecurity lapse—in which they should compel critical infrastructure operators to provide data to government bodies. In other situations, such as an earthquake, they might permit, or even encourage, competing firms to share data with each other to ensure strategic supplies for the nation. Prior to crises, governments should consider how to develop more collaborative approaches to scenario and impact analyses, build semi-accessible and proprietary data into resilience analytics and crisis decision-making, and better facilitate pre-competitive data sharing by companies for innovations that will benefit both participants and the national good.[27]

Business lens

Many companies have sought to understand how they can contribute to the resilience of the countries in which they operate. They recognize that better national-level preparedness leads to shock events having smaller impacts on the economy and stability of government policy, creating a better environment in which to plan, invest and execute.

Opportunities fall into four groups. First, large firms already look intensively at business interruption risks across supply chains, managed service providers, utilities and customers with a view to softening the impact of bottlenecks and outages; smaller firms could do the same with a lighter touch.[28] Second, nationally important companies worked with each other where permitted during the pandemic; more broadly scoped codes of conduct could set out best-practice behaviours per industry for future crises.[29] Third, the pandemic spurred companies to look harder at the resilience of their workforces and the communities in which they are located; large employers could build a resilience dimension into health and benefits offerings.[30] Fourth, some firms have been seeking to take a more



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active role in addressing large-scale public policy challenges that affect their business but cannot be resolved by government alone; more of that effort could be directly positioned in support of public goods.[31]

While public funds have traditionally directed resilience efforts, there is a growing imperative for businesses to take up the mantle of driving innovation in order to reduce blind spots and counter stovepiping tendencies within government. Greater private sector participation in strategic forums can allow experts and practitioners to contribute to and challenge government agendas. Dynamic cross-sectoral interactions around priorities, policies and operating practices can also help uncover efficient and efficacious solutions as well as generate broader traction for fresh initiatives.[32]

Community lens

Both the pandemic and extreme weather events have highlighted areas where central governments and local bodies can combine more effectively. Failure to join up policy agendas across national government departments can have devastating impacts at the local level, where crises play out and disconnects are exposed. Similarly, "air gaps" between central and local governments—often due to struggles for authority or weaknesses in liaison networks—have compromised data flows, the effectiveness of initiatives and local trust.[33] Improved communication processes, better devolution of decision-making authorities, stronger coordination of on-the-ground efforts between central government specialist agencies and local administrations and better capacity-building at local and national levels would go a long way in supporting resilience.

Better national preparedness creates a better environment to invest

There is scope for central and local governments to do more to support resilience efforts at the community level, often in partnership with non-governmental organizations and businesses. Local resilience forums can galvanize communities to provide detailed intelligence on situational vulnerabilities and likely impacts of key risks, helping to prioritize resilience measures. Enhancing awareness and participation, empowering local actors and building capabilities are vital for the cultural shift that is essential for sustaining resilience programmes over the long term.

There are multiple opportunities to enrich interfaces between academic communities and government agendas at local, national and international levels, especially for the provision of expertise and evidence on matters of science and technology.[34] Collaborative exploration of risk and resilience issues—before, during and after a crisis—would benefit from stronger, more flexible communication channels and higher levels of trust (see Box 6.1).

BOX 6.1

From Insights to Practice

Based on the challenges of the past year, the World Economic Forum has worked with two of its principal risk communities, the Chief Risk Officers Community and the Global Future Council on Frontier Risks, to identify five practical lessons to improve organizational practice for resilience:

1. **Ground analyses in delivery requirements.**	It is often useful to start not with specific risks but with the types of failure, damage and attrition that could compromise core business goals. Working back from these undesirable outcomes makes for a more open assessment of current practices and a better appreciation of the capabilities, levers, tools and processes that might need to be introduced, deployed, redesigned or enhanced.
2. **Appreciate vulnerabilities within the broader ecosystem.**	As well as examining the critical assets and operations they control, organizations should look at the broader ecosystem in which they operate. They should examine their resilience to shortfalls, outages and delays of the third-party assets and services on which they depend, and the tolerances of those who depend on them.
3. **Embrace a diversity of resilience strategies.**	Some possible crises can be mitigated by placing more emphasis on just-in-case reliability than on just-in-time efficiency. Others may be best served by implementing back-ups and redundancies, adjusting operational processes, or ensuring that the organization can move quickly and adapt in order to maintain business continuity. Supportive employee behaviours are as vital as structural measures, especially when empowered by good leadership and effective communication.
4. **Connect resilience efforts with other goals.**	Many organizational environmental, social and governance (ESG) goals are shared with a broad-based resilience platform and would benefit from improved alignment. For example, shortening supply chains can advance net zero strategies as well as reduce exposure to adverse geoeconomic developments, while strong community relations may help recovery initiatives in the event of a disaster.
5. **Consider resilience to be a journey not a destination.**	Organizations with leading resilience programmes learn from stress-testing exercises and actual crises to emerge stronger, more supple and better prepared. They are alert to changing circumstances that may demonstrate elevated risks, vigilant in challenging themselves about blind spots and shortcomings that require additional action and eager to adapt response strategies to better achieve critical goals.

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Appendices

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APPENDIX A

Descriptions of Global Risks 2022

Global Risks

A "global risk" is the possibility of the occurrence of an event or condition that, if it occurs, could cause significant negative impact for several countries or industries. For the purposes of this report, the scope is over the next 10 years.

To ensure legibility, the names of the global risks have been abbreviated in the figures. The portion of the full name used in the abbreviation is in bold.

	Global Risk	Description
Economic	**Asset bubble bursts** in large economies	Prices for housing, investment funds, shares and other assets in a large economy increasingly disconnect from the real economy
	Collapse of a systemically important **industry**	Collapse of a systemically important global industry or firm with an impact on the global economy, financial markets and/or society
	Debt crises in large economies	Corporate and/or public finances overwhelmed by debt accumulation and/or debt servicing in large economies, resulting in mass bankruptcies, defaults, insolvency, liquidity crises or sovereign debt crises
	Failure to **stabilize price** trajectories	Inability to control an unmanageable increase (inflation) or decrease (deflation) in the general price level of goods and services
	Proliferation of **illicit economic activity**	Global proliferation of informal and/or illegal activities that undermine economic advancement and growth: counterfeiting, illicit financial flows, illicit trade, tax evasion, human trafficking, organized crime etc.
	Prolonged economic **stagnation**	Near-zero or slow global growth lasting for many years
	Severe **commodity shocks**	Abrupt shocks to the supply and demand of systemically important commodities at a global scale that strain corporate, public and/or household budgets: chemicals, emissions, energy, foods, metals, minerals etc.
Environmental	**Biodiversity loss** and ecosystem collapse	Irreversible consequences for the environment, humankind, and economic activity, and a permanent destruction of natural capital, as a result of species extinction and/or reduction
	Climate action failure	Failure of governments and businesses to enforce, enact or invest in effective climate-change adaptation and mitigation measures, preserve ecosystems, protect populations and transition to a carbon-neutral economy
	Extreme weather events	Loss of human life, damage to ecosystems, destruction of property and/or financial loss at a global scale as a result of extreme weather events: cold fronts, fires, floods, heat waves, windstorms etc.
	Human-made **environmental damage**	Loss of human life, financial loss and/or damage to ecosystems as a result of human activity and/or failure to co-exist with animal ecosystems: deregulation of protected areas, industrial accidents, oil spills, radioactive contamination, wildlife trade etc.
	Major **geophysical disasters**	Loss of human life, financial loss and/or damage to ecosystems as a result of geophysical disasters: earthquakes, landslides, geomagnetic storms, tsunamis, volcanic activity etc.
	Natural resource crises	Chemical, food, mineral, water or other natural resource crises at a global scale as a result of human overexploitation and/or mismanagement of critical natural resources

Geopolitical	Collapse of a multilateral institution	Dissolution of a global multilateral institution established to resolve economic, environmental, geopolitical and/or humanitarian crises with regional or global implications: border disputes, environmental commitments, migration crises, health emergencies, trade disputes etc.
	Fracture of interstate relations	Economic, political and/or technological rivalries between geopolitical powers resulting in a fracture of bilateral relations and/or growing tensions
	Geoeconomic confrontations	Deployment of economic levers, including investment controls, trade controls, non-tariff barriers and/or currency measures, by global or regional powers to decouple economic interactions between nations and consolidate spheres of influence
	Geopolitical contestation of strategic resources	Concentration, exploitation and/or mobility restriction by a state of goods, knowledge, services or technology critical to human development with the intent of gaining geopolitical advantage
	Interstate conflict	Belligerent bilateral or multilateral conflict between states with global consequences: biological, chemical, cyber and/or physical attacks, military interventions, proxy wars etc.
	State collapse	Collapse of a state with global geopolitical importance as a result of internal conflict, breakdown of rule of law, erosion of institutions, military coup, regional or global instability
	Terrorist attacks	Large-scale, scattered or isolated terrorist attacks carried out by individuals or non-state groups with ideological, political or religious goals, resulting in loss of life, severe injury and/or material damage
	Weapons of mass destruction	Deployment of biological, chemical, cyber, nuclear or radiological weapons, resulting in loss of life, destruction and/or international crises
Societal	Collapse or lack of social security systems	Non-existence or widespread bankruptcy of social security systems and/or erosion of social security benefits: disability, elderly, family, injury, maternity, medical care, sickness, survivor, unemployment etc.
	Employment and livelihood crises	Structural deterioration of work prospects and/or standards for the working-age population: unemployment, underemployment, lower wages, fragile contracts, erosion of worker rights etc.
	Erosion of social cohesion	Loss of social capital and a fracture of social networks negatively impacting social stability, individual well-being and economic productivity as a result of persistent public anger, distrust, divisiveness, lack of empathy, marginalization of minorities, political polarization etc.
	Failure of public infrastructure	Unequitable and/or insufficient public infrastructure and services as a result of mismanaged urban sprawl, poor planning and/or under-investment, negatively impacting economic advancement, education, housing, public health, social inclusion and the environment
	Infectious diseases	Massive and rapid spread of viruses, parasites, fungi or bacteria that cause an uncontrolled contagion of infectious diseases, resulting in an epidemic or pandemic with loss of life and economic disruption
	Large-scale involuntary migration	Large-scale involuntary migration induced by climate change, discrimination, lack of economic advancement opportunities, persecution, natural or human-made disasters, violent conflict etc.
	Pervasive backlash against science	Censure, denial and/or scepticism towards scientific evidence and the scientific community at a global scale, resulting in a regression or stalling of progress on climate action, human health and/or technological innovation
	Pollution-driven harms to human health	Physical and mental health impacts from harmful chemical or other particulates in the air, water or food, which may stem from energy generation, industrial and agricultural practices, waste management failures, natural disasters, human behaviour and other sources
	Severe mental health deterioration	Pervasiveness of mental health ailments and/or disorders globally and across multiple demographics, negatively impacting well-being, social cohesion and productivity: anxiety, dementia, depression, loneliness, stress etc.
	Widespread youth disillusionment	Youth disengagement, lack of confidence and/or loss of trust of existing economic, political and social structures at a global scale, negatively impacting social stability, individual well-being and economic productivity

Technological	**Adverse** outcomes of **tech**nological **advances**	Intended or unintended negative consequences of technological advances on individuals, businesses, ecosystems and/or economies: AI, brain-computer interfaces, biotechnology, geo-engineering, quantum computing etc.
	Breakdown of critical information **infrastructure**	Deterioration, saturation or shutdown of critical physical and digital infrastructure or services as a result of a systemic dependency on cyber networks and/or technology: AI-intensive systems, internet, hand-held devices, public utilities, satellites etc.
	Digital inequality	Fractured and/or unequal access to critical digital networks and technology, between and within countries, as a result of unequal investment capabilities, lack of necessary skills in the workforce, insufficient purchase power, government restrictions and/or cultural differences
	Digital power concentration	Concentration of critical digital assets, capabilities and/or knowledge by a reduced number of individuals, businesses or states, resulting in discretionary pricing mechanisms, lack of impartial oversight, unequal private and/or public access etc.
	Failure of **cybersecurity** measures	Business, government and household cybersecurity infrastructure and/or measures are outstripped or rendered obsolete by increasingly sophisticated and frequent cybercrimes, resulting in economic disruption, financial loss, geopolitical tensions and/or social instability
	Failure of **technology governance**	Lack of globally accepted frameworks, institutions or regulations for the use of critical digital networks and technology, as a result of different states or groups of states adopting incompatible digital infrastructure, protocols and/or standards

APPENDIX B

Executive Opinion Survey: National Risk Perceptions

Table B.1 presents the top five risks for each of the 124 economies surveyed by the World Economic Forum's Executive Opinion Survey (EOS) between May and September 2021. Over 12,000 leaders answered the following question: "What five risks will pose a critical threat to your country in the next two years?" and were asked to select these from a list of 35 risks, with no particular order. "Risk 1" indicates the most frequently selected risk in each economy. Where there is a tie, the tied risks are presented alphabetically in the same cell, separated by a dotted line ("---") and the next cell in the row contains an ellipsis ("…"). For example, in Armenia, two risks ("human-made environmental damage" and "large-scale involuntary migration") are tied for third place and there is therefore no risk in fourth place.

The question posed to EOS respondents is comparable to the following question asked to GRPS respondents: "Please identify your top five global risks of concern [that will become a critical threat to the world] over the next 0–2 years". The list of 35 risks to select from in the EOS is also comparable to the list of risks in the Global Risks Perception Survey (GRPS), except for two new risks that were added to the GRPS after the EOS was conducted—"geoeconomic confrontations" and "pollution-driven harms to human health"—and one risk that changed name from "geopolitization of strategic resources" in the EOS to "geopolitical contestation of strategic resources" in the GRPS (see Appendix C, Global Risks Perception Survey Technical Notes).

TABLE B.1

Top Five Risks Identified by the Executive Opinion Survey

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Albania	Fracture of interstate relations	Human-made environmental damage	Failure of cybersecurity measures	Debt crises in large economies	Infectious diseases
Angola	Employment and livelihood crises	Prolonged economic stagnation	Human-made environmental damage	State collapse	Widespread youth disillusionment
Argentina	Prolonged economic stagnation	Employment and livelihood crises	State collapse	Failure to stabilize price trajectories	Digital inequality
Armenia	Interstate conflict	Prolonged economic stagnation	Human-made environmental damage --- Large-scale involuntary migration	…	Failure of cybersecurity measures --- Fracture of interstate relations
Australia	Failure of cybersecurity measures	Extreme weather events	Climate action failure	Infectious diseases	Debt crises in large economies

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Austria	Climate action failure	Erosion of social cohesion	Debt crises in large economies	Digital power concentration	Prolonged economic stagnation Extreme weather events
Azerbaijan	Natural resource crises	Asset bubble bursts in large economies	Debt crises in large economies	Climate action failure Collapse of a multilateral institution Human-made environmental damage Infectious diseases	...
Bahrain	Prolonged economic stagnation	Debt crises in large economies Failure of cybersecurity measures	...	Infectious diseases	Employment and livelihood crises
Bangladesh	Employment and livelihood crises	Digital inequality Geopolitization of strategic resources	...	Human-made environmental damage	Climate action failure Failure of cybersecurity measures
Barbados	Extreme weather events	Prolonged economic stagnation	Employment and livelihood crises	Collapse of a systemically important industry	Climate action failure Infectious diseases
Belgium	Climate action failure	Debt crises in large economies	Extreme weather events	Asset bubble bursts in large economies Fracture of interstate relations	...
Benin	Proliferation of illicit economic activity	Failure to stabilize price trajectories	Severe commodity shocks	Pervasive backlash against science	Erosion of social cohesion
Bolivia	Employment and livelihood crises	Proliferation of illicit economic activity	Digital inequality Human-made environmental damage	...	State collapse

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Bosnia and Herzegovina	Human-made environmental damage Prolonged economic stagnation	...	Employment and livelihood crises	Digital inequality Widespread youth disillusionment	...
Botswana	Employment and livelihood crises	Collapse or lack of social security systems	Prolonged economic stagnation	Widespread youth disillusionment	Debt crises in large economies
Brazil	Prolonged economic stagnation	Employment and livelihood crises	Digital inequality	Human-made environmental damage	Geopolitization of strategic resources
Brunei Darussalam	Employment and livelihood crises	Prolonged economic stagnation	Failure of technology governance	Human-made environmental damage	Failure of cybersecurity measures
Bulgaria	Human-made environmental damage	Infectious diseases	Interstate conflict	Debt crises in large economies Employment and livelihood crises	...
Cambodia	Human-made environmental damage	Prolonged economic stagnation	Adverse outcomes of technological advances Infectious diseases	...	Biodiversity loss and ecosystem collapse Debt crises in large economies
Cameroon	Employment and livelihood crises	Terrorist attacks	Debt crises in large economies	Human-made environmental damage	Natural resource crises
Canada	Debt crises in large economies	Climate action failure	Extreme weather events	Employment and livelihood crises	Infectious diseases
Cape Verde	Employment and livelihood crises	Prolonged economic stagnation	Human-made environmental damage	Debt crises in large economies	Biodiversity loss and ecosystem collapse Failure of cybersecurity measures
Chad	Debt crises in large economies	Employment and livelihood crises	Breakdown of critical information infrastructure	Terrorist attacks	Human-made environmental damage
Chile	Prolonged economic stagnation	Erosion of social cohesion	Collapse or lack of social security systems	State collapse	Extreme weather events

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
China	Extreme weather events	Asset bubble bursts in large economies	Infectious diseases	Collapse or lack of social security systems	Geopolitization of strategic resources
Colombia	Employment and livelihood crises	Human-made environmental damage	Prolonged economic stagnation	State collapse	Proliferation of illicit economic activity
Congo	Employment and livelihood crises Human-made environmental damage	…	Biodiversity loss and ecosystem collapse Digital inequality	…	Interstate conflict State collapse
Costa Rica	Prolonged economic stagnation	Employment and livelihood crises	Digital inequality	State collapse	Debt crises in large economies Extreme weather events
Côte d'Ivoire	Terrorist attacks	Debt crises in large economies	Failure to stabilize price trajectories	Employment and livelihood crises	Human-made environmental damage
Croatia	Prolonged economic stagnation	Geopolitization of strategic resources	Digital inequality	Human-made environmental damage	Widespread youth disillusionment
Cyprus	Climate action failure	Debt crises in large economies	Geopolitization of strategic resources	Asset bubble bursts in large economies Infectious diseases Prolonged economic stagnation	…
Czech Republic	Debt crises in large economies	Collapse of a systemically important industry	Asset bubble bursts in large economies	Infectious diseases	Failure to stabilize price trajectories
Denmark	Climate action failure	Asset bubble bursts in large economies Infectious diseases	…	Failure of cybersecurity measures	Debt crises in large economies
Dominican Republic	Extreme weather events	Employment and livelihood crises	Debt crises in large economies	Digital inequality Failure of cybersecurity measures	…

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Ecuador	Collapse or lack of social security systems	Prolonged economic stagnation	Employment and livelihood crises	Proliferation of illicit economic activity	Digital inequality
Egypt	Natural resource crises	Infectious diseases	Debt crises in large economies	Failure to stabilize price trajectories	Employment and livelihood crises
El Salvador	Prolonged economic stagnation	State collapse	Extreme weather events	Employment and livelihood crises	Collapse or lack of social security systems Digital inequality
Estonia	Interstate conflict	Debt crises in large economies	Asset bubble bursts in large economies Fracture of interstate relations	…	Human-made environmental damage
Finland	Prolonged economic stagnation	Debt crises in large economies	Climate action failure	Asset bubble bursts in large economies	Infectious diseases
France	Erosion of social cohesion	Debt crises in large economies Geopolitization of strategic resources	…	Climate action failure	Failure of cybersecurity measures
Georgia	Interstate conflict	Digital inequality	Failure to stabilize price trajectories	Debt crises in large economies	Employment and livelihood crises
Germany	Climate action failure	Erosion of social cohesion	Digital power concentration	Debt crises in large economies	Fracture of interstate relations Geopolitization of strategic resources
Ghana	Employment and livelihood crises Human-made environmental damage	…	Geopolitization of strategic resources	Failure of cybersecurity measures	Collapse of a systemically important industry
Greece	Prolonged economic stagnation	Extreme weather events	Debt crises in large economies	Interstate conflict	Digital inequality

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Guatemala	Proliferation of illicit economic activity	State collapse	Extreme weather events	Failure of public infrastructure	Erosion of social cohesion Human-made environmental damage
Honduras	State collapse	Employment and livelihood crises	Extreme weather events	Proliferation of illicit economic activity	Prolonged economic stagnation
Hong Kong SAR, China	Asset bubble bursts in large economies	Prolonged economic stagnation	Infectious diseases	Interstate conflict	Erosion of social cohesion
Hungary	Failure to stabilize price trajectories	Extreme weather events	Climate action failure	Infectious diseases	Fracture of interstate relations
Iceland	Asset bubble bursts in large economies Climate action failure	…	Collapse of a systemically important industry	Failure of cybersecurity measures Infectious diseases	…
India	Fracture of interstate relations	Debt crises in large economies	Widespread youth disillusionment	Failure of technology governance	Digital inequality
Indonesia	Debt crises in large economies Human-made environmental damage	…	Employment and livelihood crises	Geopolitization of strategic resources	Failure of cybersecurity measures
Iran	Employment and livelihood crises	Widespread youth disillusionment	Prolonged economic stagnation	Natural resource crises	Biodiversity loss and ecosystem collapse
Ireland	Climate action failure Failure of cybersecurity measures	…	Fracture of interstate relations	Debt crises in large economies Prolonged economic stagnation	…
Israel	Terrorist attacks	Asset bubble bursts in large economies Interstate conflict	…	Failure of cybersecurity measures	Weapons of mass destruction
Italy	Climate action failure Debt crises in large economies	…	Extreme weather events	Geopolitization of strategic resources	Digital inequality

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Japan	Prolonged economic stagnation	Extreme weather events	Interstate conflict	Failure of cybersecurity measures	Asset bubble bursts in large economies Infectious diseases
Jordan	Debt crises in large economies	Employment and livelihood crises	Natural resource crises	Prolonged economic stagnation	Failure to stabilize price trajectories
Kazakhstan	Employment and livelihood crises Failure to stabilize price trajectories	…	Severe commodity shocks	Interstate conflict	Geopolitization of strategic resources
Kenya	Employment and livelihood crises	Debt crises in large economies	Human-made environmental damage	Prolonged economic stagnation Terrorist attacks	…
Republic of Korea	Asset bubble bursts in large economies	Employment and livelihood crises Infectious diseases	…	Debt crises in large economies	Human-made environmental damage
Kuwait	Asset bubble bursts in large economies Collapse or lack of social security systems	…	Failure of technology governance Geopolitization of strategic resources	…	Human-made environmental damage Infectious diseases
Kyrgyzstan	Employment and livelihood crises	Interstate conflict	Failure of technology governance	Climate action failure	Failure to stabilize price trajectories
Lao PDR	Failure to stabilize price trajectories	Employment and livelihood crises	Human-made environmental damage	Biodiversity loss and ecosystem collapse	Breakdown of critical information infrastructure Infectious diseases
Latvia	Interstate conflict	Asset bubble bursts in large economies	Digital inequality	Debt crises in large economies Prolonged economic stagnation	…

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Lebanon	State collapse	Human-made environmental damage	Collapse or lack of social security systems	Debt crises in large economies Prolonged economic stagnation	…
Lesotho	Digital inequality	Infectious diseases	Climate action failure	Extreme weather events	Debt crises in large economies
Lithuania	Interstate conflict	Severe commodity shocks	Asset bubble bursts in large economies Failure of cybersecurity measures	…	Human-made environmental damage
Luxembourg	Asset bubble bursts in large economies	Climate action failure Debt crises in large economies	…	Digital inequality Fracture of interstate relations	…
Malawi	Failure to stabilize price trajectories	Human-made environmental damage Prolonged economic stagnation	…	Proliferation of illicit economic activity	Debt crises in large economies Employment and livelihood crises
Malaysia	Human-made environmental damage	Employment and livelihood crises	Prolonged economic stagnation	Geopolitization of strategic resources	Debt crises in large economies
Mali	Employment and livelihood crises Terrorist attacks	…	Debt crises in large economies	Collapse or lack of social security systems	Failure of technology governance
Malta	Human-made environmental damage	Collapse of a systemically important industry	Proliferation of illicit economic activity	Failure of cybersecurity measures	Asset bubble bursts in large economies
Mauritius	Prolonged economic stagnation	Collapse of a systemically important industry	Employment and livelihood crises	Extreme weather events	Erosion of social cohesion
Mexico	Proliferation of illicit economic activity	Prolonged economic stagnation	State collapse	Employment and livelihood crises	Digital inequality
Moldova	Prolonged economic stagnation	Large-scale involuntary migration	Interstate conflict	Extreme weather events	Proliferation of illicit economic activity

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Mongolia	Human-made environmental damage	Employment and livelihood crises	Prolonged economic stagnation State collapse	…	Geopolitization of strategic resources
Montenegro	Employment and livelihood crises	Fracture of interstate relations	Prolonged economic stagnation	Digital inequality	Human-made environmental damage
Morocco	Natural resource crises	Employment and livelihood crises	Prolonged economic stagnation	Digital inequality	Extreme weather events Interstate conflict
Namibia	Employment and livelihood crises	Digital inequality	Prolonged economic stagnation	Extreme weather events	Debt crises in large economies
Nepal	Employment and livelihood crises	Human-made environmental damage	Geopolitization of strategic resources	Infectious diseases	Digital inequality Prolonged economic stagnation
Netherlands	Climate action failure	Erosion of social cohesion	Failure of cybersecurity measures	Asset bubble bursts in large economies	Debt crises in large economies
New Zealand	Failure of cybersecurity measures	Asset bubble bursts in large economies Infectious diseases Prolonged economic stagnation	…	…	Climate action failure Extreme weather events
Nicaragua	State collapse	Prolonged economic stagnation	Employment and livelihood crises Extreme weather events	…	Collapse or lack of social security systems
Nigeria	Terrorist attacks	Prolonged economic stagnation	Widespread youth disillusionment	Employment and livelihood crises	Human-made environmental damage
North Macedonia	Human-made environmental damage	Failure of public infrastructure	Debt crises in large economies	Prolonged economic stagnation	Digital inequality
Pakistan	Debt crises in large economies	Extreme weather events	Failure to stabilize price trajectories	Failure of cybersecurity measures	Human-made environmental damage

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Panama	Collapse or lack of social security systems	Prolonged economic stagnation	Employment and livelihood crises	Digital inequality	Human-made environmental damage
Paraguay	Proliferation of illicit economic activity	Collapse or lack of social security systems	Digital inequality	Human-made environmental damage	Employment and livelihood crises State collapse
Peru	State collapse	Prolonged economic stagnation	Employment and livelihood crises	Digital inequality	Human-made environmental damage Proliferation of illicit economic activity
Philippines	Prolonged economic stagnation	Digital inequality	Extreme weather events	Employment and livelihood crises	Failure of public infrastructure
Poland	Human-made environmental damage	Infectious diseases	Interstate conflict	Fracture of interstate relations Prolonged economic stagnation	...
Portugal	Prolonged economic stagnation	Debt crises in large economies	Employment and livelihood crises	Digital inequality	Collapse or lack of social security systems
Qatar	Climate action failure	Digital inequality	Collapse of a systemically important industry Fracture of interstate relations Infectious diseases Natural resource crises	...	...
Romania	Human-made environmental damage	Employment and livelihood crises	Debt crises in large economies Geopolitization of strategic resources	...	Large-scale involuntary migration
Russian Federation	Interstate conflict	Failure to stabilize price trajectories	Infectious diseases	Employment and livelihood crises	Severe commodity shocks

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Rwanda	Employment and livelihood crises	Prolonged economic stagnation	Extreme weather events	Digital inequality	Failure of cybersecurity measures
Saudi Arabia	Failure to stabilize price trajectories	Human-made environmental damage Infectious diseases	…	Interstate conflict	Fracture of interstate relations Prolonged economic stagnation
Senegal	Employment and livelihood crises	Debt crises in large economies	Terrorist attacks	Human-made environmental damage	Digital inequality Natural resource crises
Serbia	Human-made environmental damage	Debt crises in large economies	Employment and livelihood crises	Digital inequality	Geopolitization of strategic resources
Sierra Leone	Employment and livelihood crises	Human-made environmental damage	Prolonged economic stagnation	Failure to stabilize price trajectories	Widespread youth disillusionment
Singapore	Prolonged economic stagnation	Infectious diseases	Asset bubble bursts in large economies	Failure of cybersecurity measures	Climate action failure
Slovakia	Collapse of a systemically important industry	Collapse or lack of social security systems	Debt crises in large economies Human-made environmental damage	…	Digital inequality
Slovenia	Severe commodity shocks	Geopolitization of strategic resources	Asset bubble bursts in large economies	Extreme weather events Human-made environmental damage	…
South Africa	Prolonged economic stagnation	Employment and livelihood crises	State collapse	Failure of public infrastructure	Proliferation of illicit economic activity
Spain	Employment and livelihood crises	Prolonged economic stagnation	Debt crises in large economies	Climate action failure Fracture of interstate relations	…

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Sri Lanka	Human-made environmental damage	Debt crises in large economies	Employment and livelihood crises Infectious diseases	…	Digital inequality
Sweden	Asset bubble bursts in large economies	Terrorist attacks	Climate action failure	Debt crises in large economies	Human-made environmental damage
Switzerland	Asset bubble bursts in large economies	Prolonged economic stagnation	Debt crises in large economies Fracture of interstate relations Geopolitization of strategic resources Interstate conflict	…	…
Taiwan, China	Infectious diseases	Extreme weather events	Geopolitization of strategic resources	Failure of cybersecurity measures	Asset bubble bursts in large economies
Tajikistan	Interstate conflict	Failure to stabilize price trajectories	Extreme weather events	Employment and livelihood crises Infectious diseases	…
Tanzania	Debt crises in large economies	Employment and livelihood crises	Human-made environmental damage	Climate action failure Infectious diseases	…
Thailand	Debt crises in large economies	Human-made environmental damage	Prolonged economic stagnation	Digital inequality	Employment and livelihood crises
Trinidad and Tobago	Prolonged economic stagnation	Employment and livelihood crises	Digital inequality	Collapse of a systemically important industry	Extreme weather events
Tunisia	State collapse	Debt crises in large economies	Employment and livelihood crises	Prolonged economic stagnation	Proliferation of illicit economic activity
Turkey	Employment and livelihood crises	Prolonged economic stagnation	Fracture of interstate relations	Human-made environmental damage	Failure of technology governance

Economy	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Ukraine	Prolonged economic stagnation	State collapse	Climate action failure Failure to stabilize price trajectories Interstate conflict	…	…
United Arab Emirates	Infectious diseases	Asset bubble bursts in large economies	Debt crises in large economies Failure of cybersecurity measures	…	Climate action failure Employment and livelihood crises
United Kingdom	Failure of cybersecurity measures	Debt crises in large economies	Prolonged economic stagnation	Infectious diseases	Extreme weather events
United States	Asset bubble bursts in large economies	Climate action failure	Extreme weather events	Debt crises in large economies	Employment and livelihood crises
Uruguay	Severe commodity shocks	Prolonged economic stagnation	Employment and livelihood crises	Extreme weather events	Collapse or lack of social security systems
Venezuela	State collapse	Prolonged economic stagnation	Human-made environmental damage	Large-scale involuntary migration	Proliferation of illicit economic activity
Viet Nam	Biodiversity loss and ecosystem collapse	Asset bubble bursts in large economies	Infectious diseases	Extreme weather events Geopolitization of strategic resources	…
Yemen	Failure to stabilize price trajectories	State collapse	Failure of public infrastructure	Employment and livelihood crises Interstate conflict Natural resource crises	…
Zambia	Employment and livelihood crises	Debt crises in large economies	Failure to stabilize price trajectories	Human-made environmental damage	Prolonged economic stagnation

APPENDIX C

Technical Notes: Global Risks Perception Survey 2021–2022

The Global Risks Perception Survey (GRPS) is the World Economic Forum's source of original risks data, harnessing the expertise of the Forum's extensive network of academic, business, government, civil society and thought leaders. Survey responses were collected from 8 September to 12 October 2021 from the World Economic Forum's multistakeholder communities (including the Global Shapers Community), the professional networks of its Advisory Board, and members of the Institute of Risk Management. The results of the GRPS are used to create the graphics depicting the Global Risks COVID-19 Hindsight, Future Outlook, the Global Risks Horizon, Global Risks Severity, Global Risks Effects and International Risk Mitigation Efforts presented at the beginning of the report and to offer insights used throughout.

Both the GRPS and the *Global Risks Report* adopt the following definition: *a global risk is the possibility of the occurrence of an event or condition which, if it occurs, could cause significant negative impact for several countries or industries. For the purposes of this report, the scope is over the next 10 years.*

Updates in the GRPS 2021–2022

New list of risks

The list of 37 global risks included in the survey was updated in 2021.

Two new risks were added in response to observed economic, geopolitical and environmental trends. These new risks are: (1) "Geoeconomic confrontations" and (2) "Pollution harms to human health".

The names and definitions of the remaining 35 risks have been revised and, where applicable, have been modified and/or expanded to reflect new ways in which the risks may materialize and the potential adverse outcomes they may cause. However, to ensure comparability over time, although names and definitions were modified, the fundamental concept of the risk remained consistent with that in previous versions of the survey.

New sections

The GRPS 2021–2022 was extensively reformed this year to gather fresher, broader and more informed risk perceptions and to incorporate new approaches to risk management and analysis. The GRPS 2021–2022 is comprised of six sections:

1. **COVID-19 Hindsight and Future Outlook (new):** asks respondents to form an opinion about how the COVID-19 pandemic aggravated risks, permitting some comparability with GRPS results from previous years. This opinion then facilitates the projection of their views forward beyond the pandemic. This section also captures respondent sentiment on the outlook for the world to inform an analysis of how individual contexts may influence global risk perceptions and the perceived status of mitigation efforts.

2. **Global Risks Horizon**: recognizes that respondents may have varying perceptions on the evolution of global risks within a 10-year horizon. This section asks respondents to take a view on risks in the short term (0–2 years), medium term (2–5 years) and long term (5–10 years), also capturing respondents' sense of urgency about global risks and informing an analysis of choices and trade-offs that may face decision-makers.

3. **Global Risks Severity (new):** asks respondents to rank the potential damage of a global risk over the next 10 years and reminds respondents to consider multiple criteria—including human suffering, societal disruption, economic shock, environmental degradation and political instability. This section

uses ranking rather than a 1–5 rating scale to allow respondents to answer the question with more confidence.

4. **Global Risks Effects (new):** recognizing that risks are not isolated but affect and amplify each other through negative feedback loops, this section incentivizes a holistic view of global risks by asking respondents to consider cascading impacts in conjunction with the severity of the risk itself.

5. **Global Governance – International Risk Mitigation Efforts (new):** recognizing that risk mitigation needs to be a part of the global agenda, this section asks respondents to assess the current state of international mitigation efforts in 15 global governance areas. It identifies achievements and areas of opportunity for global action and cooperation and informs an analysis of how the various stages of effectiveness may influence future preparedness.

6. **Open Questions (new):** complements risk identification with a series of questions to detect blind spots, trends and shocks. This section ensures that the GRPS is a flexible and engaging mechanism to source expert knowledge.

Methodology

COVID-19 Hindsight & Future Outlook

COVID-19 Hindsight:
For each of the 37 global risks listed in Appendix A, respondents were asked to identify three global risks that they believe had worsened since the start of the COVID-19 crisis. A simple tally for each of the 37 global risks was calculated on this basis. The results are illustrated in Figure I.

Future Outlook:
Respondents were asked to express their feeling about the outlook for the world in four sentiments: worried, concerned, positive, optimistic. A simple tally for each of the four sentiments was calculated on this basis. The results are illustrated in Figure 1.2.

Respondents were then asked to characterize their outlook for the world over the next 3 years with the following four answer options: accelerating global recovery; fractured trajectories, separating winners and losers; consistently volatile with multiple surprises; progressive tipping points with increasing catastrophic outcomes. A simple tally for each of the four sentiments was calculated on this basis. The results are illustrated in Figure 1.1.

Global Risks Horizon

For each of the 37 global risks listed in Appendix A, respondents were asked to identify when they believe a risk will become a critical threat to the world, within the following timeframes:

– Short-term threats: 0–2 years

– Medium-term threats: 2–5 years

– Long-term threats: 5–10 years

A simple tally for each of the 37 global risks was calculated on this basis. the results are illustrated in Figure II.

Global Risks Severity

For each of the 37 global risks listed in Appendix A, respondents were asked to choose nine risks and rank order them from 1 to 9 according to their perceived severity of impact—"most severe" was defined as having the potential to yield the most damage on a global scale within the next 10 years. Respondents were asked to value the impact of risks considering multiple criteria, including human suffering, societal disruption, economic shock, environmental degradation and political instability.

The results were aggregated according to the following scoring schedule:

– 9 points each time a risk was selected as the most severe risk

– 8 points each time a risk was selected as the second-most severe risk

– 7 points each time a risk was selected as the third-most severe risk

– 6 points each time a risk was selected as the fourth-most severe risk

- 5 points each time a risk was selected as the fifth-most severe risk
- 4 points each time a risk was selected as the sixth-most severe risk
- 3 points each time a risk was selected as seventh-most severe risk
- 2 points each time a risk was selected as the eighth-most severe risk
- 1 point each time a risk was selected as the ninth-most severe risk

A simple sum of the scores for each of the risks according to the above scoring schedule was calculated on this basis. The results are illustrated in Figure 1.3.

Global Risks Effects

In the Global Risks Severity component, for each of the risks ranked most severe, second-most severe and third-most severe, respondents were then asked to select two risks that will be aggravated by those top severe risks.

A simple tally of the number of times a risk was identified as being aggravated by another for each of the most, second-, third-, fourth- and fifth-most severe risks was calculated on this basis. The results are illustrated in the Global Risks Effects (Figure III).

In the Global Risks Effects graph, the size of each of the most concerning risk nodes is scaled according to the above scoring schedule. The thickness of each of the links between a risk and the risks being aggravated is scaled according to the above tally.

Global Governance – International Risk Mitigation Efforts

From 15 international risk areas listed below, respondents were asked to rate the state each area was with regard to international risk mitigation efforts: "not started", "early development", "established", or "effective".

A simple tally for each of the four possible states was calculated on this basis. The results are illustrated in Figure IV.

The 15 international areas were: Artificial Intelligence (e.g., autonomous weapons, bias); Basic resource security (food and water); Biodiversity preservation; Climate change mitigation; Cross-border cyberattacks and misinformation; Financial system stability; Human health crises; International crime; Migration and refugees; Natural disaster relief; Physical conflict resolution; Poverty alleviation; Space exploitation; Trade facilitation; Weapons of mass destruction.

Completion thresholds

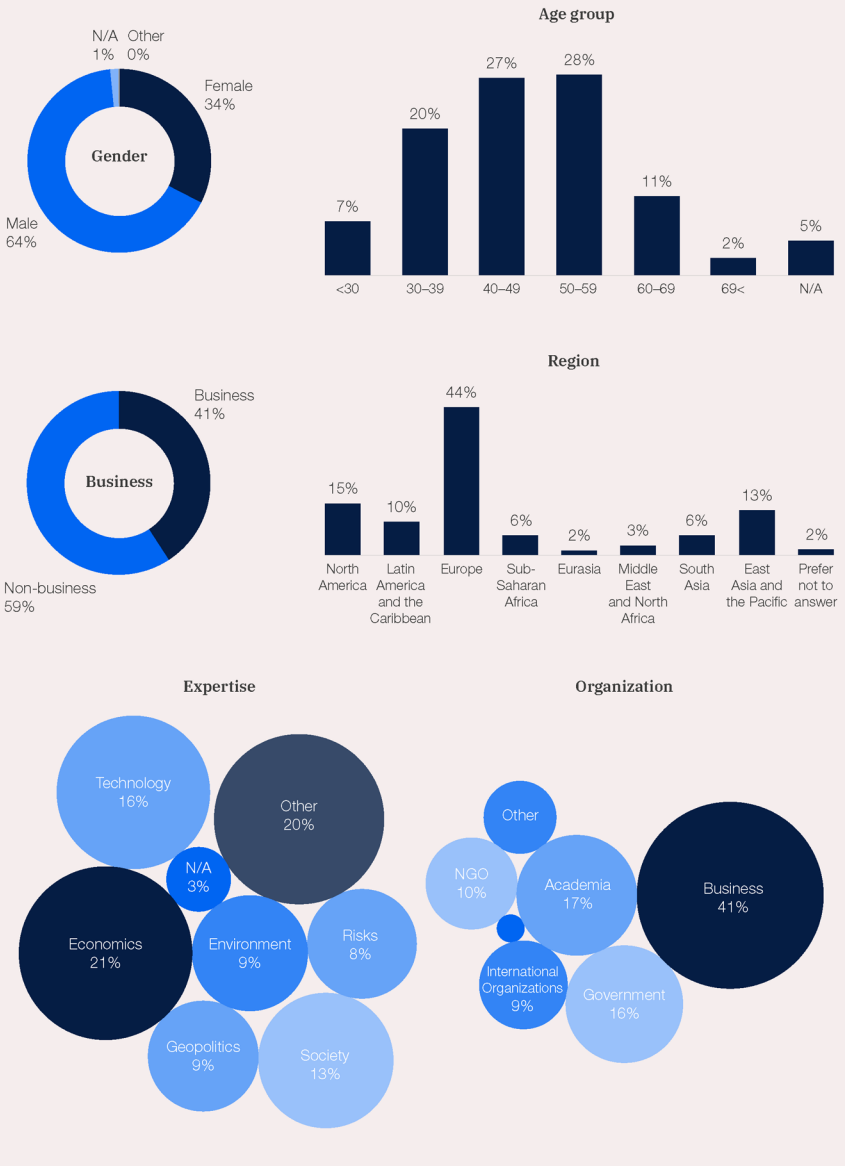
A total of 1,183 responses to the GRPS were received. From these, 959 were kept, using as a threshold at least one non-demographic answer.

- **Section 1 - COVID-19 Hindsight & Future Outlook:** 959 respondents selected the three global risks.
  - **Future Sentiment:** 957
  - **Future Outlook:** 957
- **Section 2 - Global Risks Horizon:** 926 (0–2 years); 912 (2–5 years); 904 (5–10 years) respondents placed at least one risk within a possible timeframe. The results were computed among all respondents of the survey.
- **Section 3 - Global Risks Severity:** 893 respondents; 888 ranked at least one severe risk and assigned at least one driver.
- **Section 4 - Global Risks Effects:** 837 respondents identified at least one risk aggravating another.
- **Section 5 – Global Governance – International Risk Mitigation Efforts:** 829 (climate change) respondents scored at least one level of response, either global or regional. The results were computed among all respondents of each risk area within the section.
- **Sample distribution:** the 959 respondents from Section 1 were used to calculate the sample distribution by place of residence (region), gender, age, area of expertise and institution.

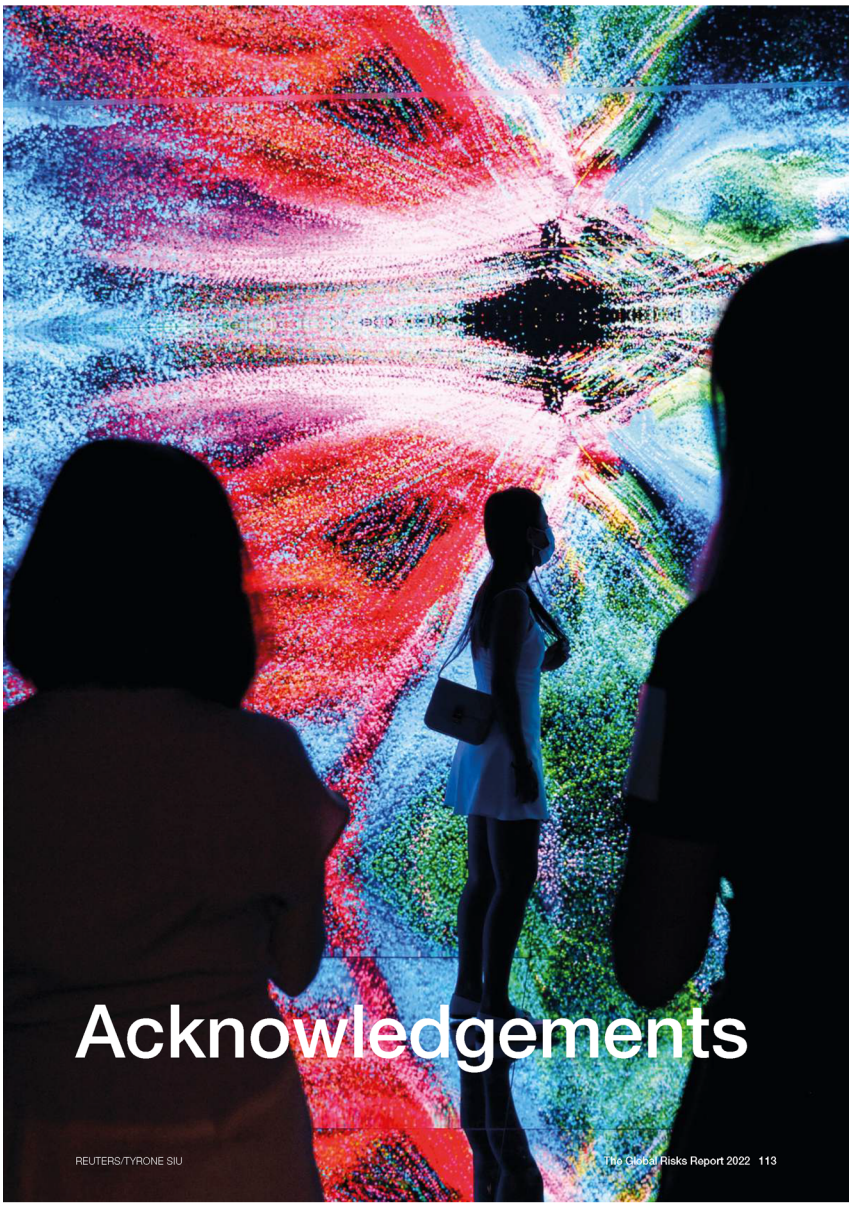
Figure C.1 presents some key descriptive statistics and information about the profiles of the respondents.

TABLE C.1

Survey Sample Composition



Source: World Economic Forum Global Risks Perception Survey 2021–2022



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REUTERS/TYRONE SIU

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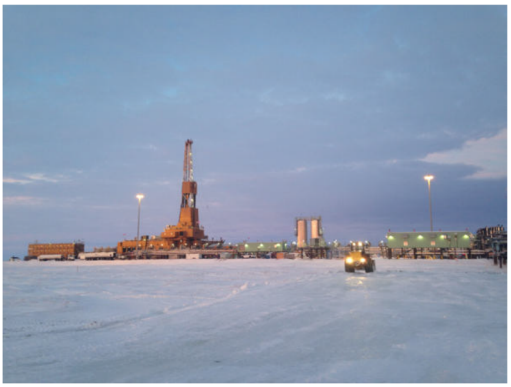
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A new oil boom on Alaska's North Slope is encircling a village, and residents have raised a red flag

By **Nathaniel Herz, Alaska's Energy Desk - Anchorage** - November 19, 2019



ConocoPhillips' CD5 drill site, which is linked to its Alpine development that opened in 2000, is nine miles from the North Slope village of Nuiqsut. (Photo by Elizabeth Harball/Alaska's Energy Desk)

A major proposed North Slope oil project is running into local opposition from residents of the village of Nuiqsut, who are already partially surrounded by development and wary of more.

After hearing residents' concerns at a North Slope Borough planning commission meeting that ran past midnight earlier this month, the commissioners declined to support a rezoning proposed for the Nanushuk project — a development that could produce 120,000 barrels of oil a day at its peak, or about one-fourth the amount that currently flows through the trans-Alaska pipeline.

The 4-2 vote isn't binding, and the borough Assembly will take up the question at a meeting next month. But the decision highlights how the balance between development and subsistence is becoming increasingly fraught in Nuiqsut, a village of 450 that's found itself in the middle of the oil industry's resurgence on the North Slope.

*[**Read more:** How a small, Arctic village found itself in the middle of Alaska's new oil boom]*

Eight miles north of the village is ConocoPhillips' Alpine project, a $1.3 billion development that opened in 2000 and is still expanding, with sites to the south and west. Another big new Conoco project, Willow, proposes to establish a gravel mine seven miles west of Nuiqsut, with as many as 250 wells at the site of the development farther away.

Then there's Nanushuk, pushed by Papua New Guinea-based Oil Search. The company plans to build one of its drill sites seven miles northeast of Nuiqsut, with a processing facility — to separate out oil from natural gas and water — farther away.

Some of Alaska's elected leaders have touted the developments as a major boost to the state's oil-dependent economy. And many Nuiqsut residents support continuing oil development, citing the ample financial benefits and quality-of-life improvements the industry has brought to the village's residents — particularly those who are shareholders in the village's Native corporation.

But Sam Kunaknana, Nuiqsut's representative to the borough and an outspoken critic of oil development's impacts on the village, said that the other commissioners — who represent different North Slope communities — were persuaded to vote against the Nanushak resolution by testimony from Nuiqsut residents.

People are concerned about development's impacts on the fish they're catching and the caribou they're hunting, Kunaknana said in a phone interview. Already, oil development has affected as much as one-third of Nuiqsut's traditional subsistence range, according the local Native village corporation.

"It's not just one project," Kunaknana said. "It's everything that's going on around this area."

Oil Search's Nanushuk project and Conoco's Willow project could, if built, together produce 250,000 daily barrels of oil at their peak, or roughly half the amount of oil that currently flows down the trans-Alaska pipeline. The companies' management would have been watching the planning commission's meeting closely, said Tim Bradner, a former BP employee and journalist who's long followed Alaska's oil industry.

"And they would be very concerned about making sure that their relationships are good with the local people up there," he said. "Because unlike in a lot of places, the North Slope is a place where the local people really do have clout."

Oil Search has been expanding its footprint in Alaska and recently hired Joe Balash, formerly a top official in the U.S. Interior Department; the company recently moved into office space in BP's Midtown Anchorage headquarters. Spokeswoman Amy Jennings Burnett declined to comment.

The planning commission's vote comes as the Trump administration pushes to loosen restrictions on oil and gas development in the area. Later this week, the Bureau of Land Management plans to release an environmental review of a new land-use plan for the National Petroleum Reserve in Alaska, where the Willow project and others are located — and it's expected to revoke some of the environmental safeguards contained in a previous, Obama-era version.

*[**Read more:** Trump administration moves to open environmentally sensitive National Petroleum Reserve land to oil drilling]*

The challenge of balancing resource extraction and subsistence exists across the North Slope, but that tension has escalated in Nuiqsut amid the increasing development nearby.

"I can't think of anywhere in the state where the juxtaposition of these issues comes to roost as it does in Nuiqsut," Bradner said. "You have to feel some sympathy for the people — they're surrounded by all this and they worry about their community kind of becoming a truck stop for the industry. On the other hand, there are people in the community who see a lot of upside to this."

Nuiqsut sits in the biologically-rich delta of the Colville River, just south of where it flows into the Beaufort Sea, and it was founded amid passage of the Alaska Native Claims Settlement Act in the early 1970s. At the time, the oil industry's focus was 50 miles east, where the Prudhoe Bay field had been discovered. But in the decades since, development has crept steadily west.

Since Alpine opened in 2000, Conoco has linked its central facility with several additional sites, with pipelines and roads now stretching nearly 180 degrees around Nuiqsut; a new connected drill site, Greater Mooses Tooth 2, is under construction.

The village of Nuiqsut, pictured last year. (Photo: Elizabeth Harball/Alaska's Energy Desk)

Oil Search's Nanushuk development is proposed northeast of Nuiqsut. And Conoco's new proposed Willow project, to the west, is currently undergoing federal environmental reviews.

Conoco has a "long-term relationship with Nuiqsut, which goes back over 20 years with our Alpine development," spokeswoman Natalie Lowman said in an emailed statement.

"We are actively engaged with the community on our Willow project to identify concerns and seek collaborative solutions," she said. "It is our goal to assist the community and ensure the North Slope Borough and all the NPR-A villages have the opportunity to benefit from our activities in the NPR-A."

In February, Nuiqsut's tribal government sued the federal government over its approval of Conoco's exploratory drilling program for the previous winter.

*[**Read more:** North Slope village tribal government sues over ConocoPhillips drilling plans]*

But Nuiqsut's Native village corporation, Kuukpik Corp., has taken a different approach, often partnering with the oil industry to bring cash and infrastructure improvements to shareholders and residents.

Kuukpik's shareholders receive as much as $30,000 a year in dividends, thanks in part to royalties from oil pumped from some of Kuukpik's lands that are part of the Alpine project. Alpine also is the source of a natural gas line that runs directly to Nuiqsut, allowing residents to heat their homes for a fraction of the cost in other rural Alaska villages.

Kuukpik has fought for, and received, concessions from oil companies to protect the village's subsistence harvests and health. For one project, Conoco agreed to move the location of a proposed bridge away from an area where residents fish; for another, it used lower-emission generators to power a drill rig, reduced noise levels and boosted air and water quality monitoring.

The Nanushuk project also included a list of mitigation measures in the resolution that the planning commission rejected this month.

Oil Search, the company pushing the project, would have been required to hire a "subsistence representative" and conduct an array of studies on fish, caribou and the "cumulative impacts" of development in the area. It also would have been required to host an annual job fair in Nuiqsut, and to the extent possible, involve local students in their studies and hire local boat and snowmachine drivers.

The company has also agreed to build a boat ramp on the Colville River, along with a road to it, to improve residents' access for subsistence.

The North Slope Borough's planning department recommended that the planning commissioners approve it, and Kuukpik's position was similar.

"The corporation still thinks that Oil Search will be a genuine and viable partner in the Colville delta," Lanston Chinn, Kuukpik's chief executive, said in a phone interview this week. "And we'll see where it goes from there."

The North Slope Borough Assembly is scheduled to consider the Nanushuk rezoning at its meeting Dec. 3. The borough's chief administrative officer, Deano Olemaun, said he could

not comment on the project "until all the final processes have been completed."

Bradner, the journalist, said he expects the Assembly to balance the planning commission's position with the project's potential to add to the North Slope's tax base. Most of the borough's $400 million budget is paid for with property taxes on oil infrastructure, and "as the industry matures on the North Slope, its existing tax base is depreciated," he said.

"They need new projects to keep their tax base active and renewed, to maintain all the public services that they support up there," said Bradner. "So there's two sides to this issue, and it's a complicated question."

Nathaniel Herz, Alaska's Energy Desk - Anchorage

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Senator CARPER. Last thing I would add to that, Senators are going to be allowed to submit written questions for the record through the close of business on Wednesday, June 1st of this year. We will compile those questions and send them to you and ask you to reply by Wednesday, June 15th.

With that, we are done. This hearing is adjourned. Thank you so much.

[Whereupon, at 11:37 a.m., the hearing was adjourned.]

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