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Nature-Based Solutions & Risk Management: Recommendations for Integrating Nature into Risk Science & Insurance

Authors

Kelso, Megan A.
Stovall, Austen E.
Reguero, Borja G.
et al.

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Recommendations for Integrating Nature into Risk Science & Insurance

Center for Coastal Climate Resilience
UC SANTA CRUZ

GuyCarpenter

EWN
Engineering With Nature

AXA Research Fund

US Army Corps of Engineers

Kelso, Stovall, Reguero, Franco, & Beck

A report by
the Center for Coastal Climate Resilience at the University of California Santa Cruz,
the U.S. Army Corps of Engineers,
and Guy Carpenter
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Executive Summary

Risks from natural hazards are growing due to climate change and habitat loss. Both insurance and nature-based solutions (NBS) can play important roles in reducing risks. Practitioners in the fields of risk management, insurance, and environmental management have many common goals for assessing risks and developing practical tools for risk reduction. Risk reduction is the core goal of risk managers such as the U.S. Army Corps of Engineers (USACE) and the U.S. Federal Emergency Management Agency (FEMA), along with state and local risk managers. Insurers and re-insurers also have significant incentives to reduce risks, including to decrease payouts and ensure the affordability of insurance. Environmental managers can leverage the risk reduction benefits from NBS to scale up conservation and restoration efforts. This report identifies tangible opportunities for practical science and action at the intersection of NBS and insurance to support more effective environmental and risk management solutions. Our recommendations are based on insights gathered through extensive interviews with leaders in risk science, insurance, risk management, and conservation; literature review; and our practical experience working across these fields. This work was principally supported by and conducted in partnership with the USACE Engineering With Nature (EWN) program, and we pay attention to where recommendations on NBS and insurance may be relevant to USACE and other federal risk managers.

Recently, some connections have been made between NBS, risk science, and insurance – for example, through assessments of habitat benefits in industry risk models and the insurance of coral reefs as natural assets – but integration across these fields is still nascent. Risk industry firms do work on NBS, but usually through sustainability initiatives and only infrequently as part of core business operations. Federal risk management agencies have some dedicated units on insurance and NBS, but these rarely overlap. Few environmental

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groups have expertise in insurance, and it is not common for academics to work across these fields. While interest in these integrated solutions is high and growing, progress towards on-the-ground implementation has remained limited. **We identify 15 recommendations to further integrate NBS into risk science and insurance.** These recommendations are grouped into the 4 key categories of **Risk Models, Insurance Coverages, Public-Private Partnerships, and Financing Opportunities.**

Risk models are at the core of the risk industry and are critical for integrating nature-based solutions into insurance tools and risk management projects. We find that many industry and agency risk models have shortcomings in their inclusion of habitats, waves, climate change, and habitat fragility. These limitations reduce the effectiveness of risk models for risk assessment in general and for evaluating habitats and their benefits for consideration in management and business decisions. We recommend ways to advance risk assessment and better include nature, such as improving the inclusion of waves, nearshore bathymetry, and reefs in risk models. These changes are especially important on the many coastlines where waves are a major driver of flood risk, such as many Small Island Developing States and the west coasts of the Americas, Europe, and the United Kingdom. We also recommend advancing the science and inclusion of fragility curves for wetlands and reefs, which describe the relationship between hazard intensity and habitat damage (e.g., when reefs and their protective benefits are lost during storms).

Insurance coverages can be designed that support nature and protect people and property, yet innovations in this space are new and could be greatly expanded. For example, the National Flood Insurance Program (NFIP) at FEMA offers insurance premium reductions for open space preservation through the Community Rating System program. This is an important advancement, and it could be expanded to explicitly consider risk reduction benefits from *habitats*, rather than simply open space, to more strongly incentivize investments in NBS. This report shares ways to promote the consideration of habitat benefits in the pricing of insurance premiums (both through NFIP and private insurances) as well as other ways that insurance can support nature, such as by de-risking investments in NBS (e.g., with catastrophe wrappers), incentivizing restoration of habitats damaged during a disaster (e.g., through reef and mangrove insurance), and incentivizing building back better and greener after a disaster (e.g., through insurance policy enhancements that could, for example, pay for restoring wetlands instead of rebuilding bulkheads).

Stronger **public-private partnerships** could advance NBS by building knowledge and capacity. For example, USACE together with FEMA could help build local community capacity around NBS and insurance, paving the way for community-based risk reduction projects that link insurance and NBS. Additionally, we recommend academics collaborate with industry and agency experts to create a professional development course to build awareness about NBS among risk industry professionals. More broadly, we recommend cultivating deeper working relationships between public risk managers and the private risk industry to foster opportunities to jointly advance NBS and insurance.

Much more funding could be directed to NBS projects, and we recommend specific scientific, policy, and financial innovations that could help achieve this goal. Better scientific guidance for evaluating the risk reduction benefits of NBS and including them in benefit-cost analyses could drive substantial new public and private funding to NBS adaptation projects, e.g., through FEMA's Hazard Mitigation Grant Assistance programs and corporate sustainability commitments. This guidance could also inform the development of databases of shovel-ready NBS projects that could be included, for example, in bonds for infrastructure and adaptation. Other opportunities to drive more funding to NBS include incorporating nature into municipal disaster plans and promoting novel financial tools such as Environmental Impact Bonds. Leveraging **financing opportunities** like these will be critical to scaling up NBS.

The recommendations in this report outline opportunities to integrate risk science, insurance, and nature to drive major gains for conservation, risk reduction, and community resilience. ◆

Table of Contents

Index of Figures, Boxes, & Tables

Figures

Boxes

Tables

Key Terms

For simplicity, we use the following general terms:

Insurance describes the broad industry that advances elements of risk science and risk modeling and is generally devoted to risk transfer.

Nature-based solutions (NBS) are approaches that build, protect, sustainably manage, or restore natural or modified habitats to address societal challenges, and provide benefits to people and nature (WHCEQ et al. 2022).

Natural and nature-based features (NNBF) are landscape features that provide engineering functions relevant to risk management, while producing additional economic, environmental, or social benefits. NNBF are a subset of NBS.

Risk managers are actors and agencies such as USACE with hazard and risk management responsibilities.

Interviewees

Risk Science

- Duncan Bryant – U.S. Army Corps of Engineers
- Chris Thomas – Moody's RMS
- Kechi Nzerem – Moody's RMS
- Charlotte Acton – Moody's RMS
- Çagdas Kafali – Verisk
- Dag Lohmann – KatRisk
- Venkat Kolluru – Environmental Resources Management
- Shwet Prakash – Environmental Resources Management

Insurance

- Daniel Kaniewski – Marsh McLennan
- Jonathan Clark – Guy Carpenter
- Chip Cunliffe – Ocean Risk and Resilience Action Alliance
- Andrew MacFarlane – AXA XL
- Lindsay Judd – AXA XL
- Brett Stewart – AXA XL
- Maryam Golnaraghi – Geneva Association
- Simon Young – WTW

Sustainable Development and Disaster Risk Management

- Juliana Castaño Isaza – World Bank
- Mary Boyer – World Bank
- Janan Reilly – U.S. Federal Emergency Management Agency
- Jeffrey King – U.S. Army Corps of Engineers
- Todd Bridges – University of Georgia

Investing

- Alejandro Litovsky – Earth Security Group
- Antigone Theodorou – Earth Security Group
- Jane "Carter" Ingram – Pollination Group

Conservation

- Rod Braun – Conservation International
- Kim Hum – National Oceanic and Atmospheric Administration

Academia

- Blair Feltmate – Intac Centre on Climate Adaptation

Introduction

Risks and costs from climate hazards are rising globally, especially in coastal zones (Tellman et al. 2021). Flood losses represent the largest costs from natural hazards in the U.S. (Kousky 2018). Globally one billion people are estimated to live less than 10 meters above the high tide line (Kulp and Strauss 2019), including many of the world's most vulnerable people. Climate change has also led to increased risk of wildfire (e.g., Goss et al. 2020, Ellis et al. 2021), drought (Cook et al. 2018, IPCC 2023), and heat waves (Coffel et al. 2017, IPCC 2023), among other risks. There is a pressing need for cost effective strategies for risk reduction, and growing interest in identifying, incentivizing, and investing in strategies that work with nature to help meet hazard mitigation and conservation management objectives. Recent innovations in risk science and insurance can help support these nature-based risk reduction strategies. This report identifies key opportunities to advance solutions at the interface between risk science, nature-based risk management, and insurance, with a particular focus on coastal flood risks and ecosystems.

Nature-based solutions (NBS) can play an important role in reducing risks, yet their benefits are often underestimated by practitioners in the risk industry. Coastal habitats such as salt marshes, mangroves, and coral reefs can serve as a critical first line of defense for storms by reducing surge and breaking waves, thereby reducing flood damages to nearby communities (Sheppard et al. 2005, Ferrario et al. 2014, Quataert et al. 2015, World Bank 2016, Beck et al. 2018, Storlazzi et al. 2021a, Reguero et al. 2021). Recently, researchers from academia, environmental groups, and the risk industry have collaborated to quantify nature's benefits using the risk industry's own tools and models. This is an important step towards building awareness of, and confidence in, nature's benefits within the risk industry. For example, collaborative research conducted with the tropical cyclone and flood models of Moody's RMS indicate salt marshes reduced damages from Hurricane Sandy in 2012 by 15% (Narayan et al. 2017) and mangroves can reduce storm damages by >25% in Florida over a wide range of storm intensities (Narayan et al. 2019). As for fire risks, a recent study by Marsh McLennan and The Nature Conservancy found that natural habitat buffers could have reduced damages from the 2018 Paradise Fire in California by 21% (Chirouze et al. 2021).

Integrating nature into risk science and insurance can support conservation and restoration of habitats. This report shares ways that insurance can 1) de-risk investments in NBS (e.g., with catastrophe wrappers; Evans 2021a), 2) incentivize investment in green infrastructure before a disaster (e.g., by reflecting nature's benefits in insurance premium prices; Reguero et al. 2020, Kousky 2022), and 3) incentivize restoration after a disaster (e.g., with insurances like the Mesoamerican Reef insurance that fund post-disaster repairs; Evans 2021b). Integrating nature better into risk science is critical for informing the design of many of these insurance tools and it can also help unlock greater public funding for NBS, e.g., through Federal Emergency Management Agency (FEMA) funding pathways, which require detailed benefit-cost analyses.

There is growing interest from many sectors – government, insurance, finance, environment – in connecting NBS with risk mitigation efforts and insurance (Kousky and Light 2019, Kelso et al. 2023). A key motivation for the insurance industry is mitigating growing risks and associated costs, which can cause insurance to become too expensive to remain viable in some places. For example, growing wildfire risks in the western U.S. due to climate change was a critical factor in the curtailing of new property and casualty insurance policies in California by State Farm and United Services Automobile Association in mid-2023 (State Farm 2023, Kupfer 2023, Dean 2023a). California insurance regulators worked with the insurance industry on an agreement to end the pause in fall 2023 (Dean 2023b), but the event highlights the need for solutions that can help mitigate risks. Insurance companies may be further motivated to engage with NBS to improve their ESG scores (a metric used by

investors to evaluate a company's environmental, social, and governance policies and impacts) and comply with new frameworks for climate and nature risk reporting, for example those developed by the Task Force on Climate-related Financial Disclosures (TCFD) and the Taskforce on Nature-related Financial Disclosures (TNFD). For their part, risk managers and conservationists are motivated to engage with the private risk industry because these collaborations could help unlock substantial funding for nature-based risk mitigation projects.

Recently, there has been progress in developing innovative, nature-positive insurance products, yet more work is needed to further develop and scale up these solutions. In 2018, The Nature Conservancy and partners created the world's first insurance policy for a natural asset, covering part of the Mesoamerican Reef near Cancun, Mexico (Reguero et al. 2019, Fajardo et al. 2019). This coverage inspired the governments of Guam (Bill No. 372-35), Hawai'i (SCR No. 159), and California (S.B. 30) to explore opportunities to advance similar solutions in their waters. The Cancun coverage was recently expanded to cover four other reefs across Mexico, Belize, Guatemala, and Honduras as part of a partnership between the Mesoamerican Reef Fund and insurance industry partners (Evans 2021b). Innovative projects are being tested in other regions as well. For example, Conservation International is exploring opportunities to insure mangroves in the Philippines and Ecuador (Beck et al. 2019). Recently, Munich Re developed a resilience insurance tool that can reflect the risk reduction benefits from reef habitats in insurance premiums (Reguero et al 2020). Despite these recent successes, integration of nature into risk science and insurance remains nascent (Beck et al. 2019).

This report presents key insights and opportunities to advance solutions at the intersection of insurance, risk mitigation, and conservation. There are 15 recommendations, organized into 4 topic areas: **risk models**, **insurance coverages**, **public-private partnerships**, and **financing opportunities**. It is our hope that these recommendations can help align environmental, risk management, and risk transfer goals, and ultimately lead to more effective protection from coastal hazards and substantial new public and private investments in nature-based solutions. ◆

Risk Models

Background on risk models

Risk models are critical tools that underpin the design of risk mitigation projects, insurance coverages, and other financial products. Risk models quantify the expected damages caused by hazards such as hurricanes, earthquakes, and wildfires. They combine spatially explicit information about the landscape (e.g., topography, bathymetry, land cover, assets, people) with data and simulations of hazards to calculate the probability of different impacts, e.g., to life, property, and interruption of business. Risk models are built and run by scientists and practitioners in many sectors, including academia, government, and private industry.

There is an opportunity to improve risk models by better incorporating the risk reduction benefits from ecosystems (**Figure 1**). Through conversations and collaborations with industry modelers, we have found that it is common for industry flood risk models to poorly represent the risk reduction benefits from nature because many of them 1) insufficiently represent certain habitats within the model, 2) inadequately model wind waves in coastal areas, 3) rarely consider climate change, as the time horizons of interest to their clients are relatively short-term, and 4) do not model fragility of ecosystems. While not universal, these modeling issues are common within the industry.

1. **Representing coastal habitats:** Industry flood risk models represent habitats through topography information and a roughness coefficient. This approach tends to be implemented relatively well for terrestrial and intertidal habitats (including mangroves and salt marshes) and poorly for subtidal habitats such as reefs, which are often not identified as a land cover type or given a roughness coefficient. Due to this, the effects of subtidal habitats are often only partially and indirectly considered. Habitat benefits are seldom quantified by industry modelers because clients rarely request this information, so there is little incentive to do this work.

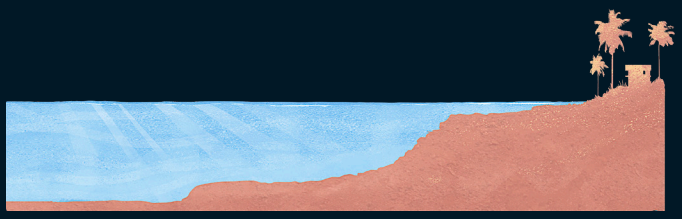
2. **Modeling waves:** Many of the private risk industry's flood modeling efforts are focused on modeling tropical cyclones and associated storm surge and, in many cases, only account for wind waves in a limited manner. Inadequate modeling of wind waves and wave action hinders our understanding of the risk reduction benefits from coastal habitats. This is because, in many places, a substantial portion of the flood risk reduction benefits that coastal habitats provide comes from their ability to attenuate waves. Importantly, waves also impact erosion, which can contribute to coastal risk through the potential loss of land, as well as by feeding back into flood risk (Toimil et al. 2023).

3. **Incorporating climate change:** Industry risk models generally aim to represent current (not future) risks because they are mostly used by clients to inform the design of short-term products, such as insurance coverages (which are most commonly 1-year contracts). Yet, the private risk industry is interested in understanding future risks and could help lead scientific modeling efforts to understand how climate change will impact risks and habitat benefits in the future.

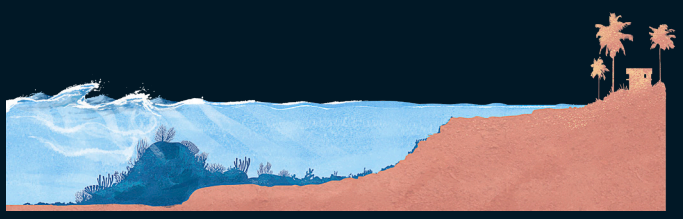
4. **Modeling habitat fragility:** Habitats can be damaged during extreme events, which can change the extent to which they mitigate risks. Many industry risk models do not yet consider habitat fragility, and including this could improve the accuracy of risk estimates.

These same issues are also relevant for many (but not all) government agency risk models, particularly those agency models that cover very large geographies. While there are site-specific, and habitat-specific agency models that handle some of these issues better, in general there is still substantial room for improvement in how both industry and agency models handle habitats, waves, climate change, and habitat fragility. Further, by adding information and considerations about social vulnerability to risk model outputs, there is an opportunity to target more of the benefits from risk reduction projects to vulnerable communities (**Box 1**). Taken together, these

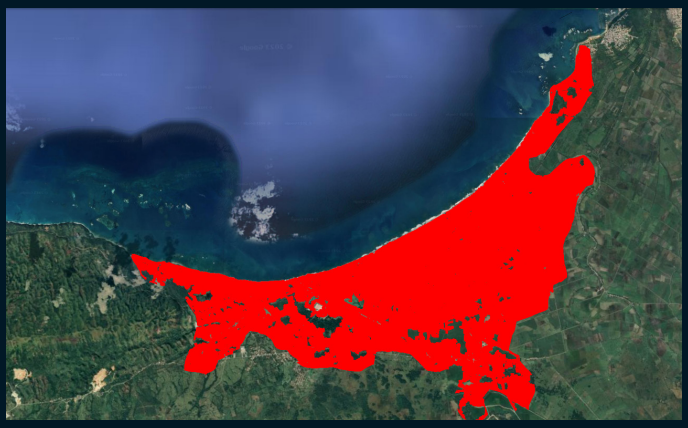
Modeling approach that misses important habitats and waves



Modelling approach that better includes habitats and waves



Inaccurate modeling outputs



More accurate modeling outputs

Lack of nature-positive policies and products

- Only a few instances of insurance covering damage to habitats

Many nature-positive policies and products enabled

- Expanded use of insurance covering damage to habitats
- Insurance coverages that consider habitat benefits in premium pricing
- Benefit-cost analyses for habitats that can be used in funding decisions
- Environmental Impact Bonds that fund NBS

Figure 1. Modeling habitats (e.g., coral reefs) and waves well within risk models is critical for producing accurate risk assessments and quantifying habitat benefits. These improved model outputs can support more effective risk planning and can help enable the development of more nature-positive policies, insurance products, and financial tools.

improvements would support more accurate valuation of the risk reduction benefits of nature and, ultimately, support the use of nature-based solutions to reduce risks, equitably.

Businesses such as insurance and investment companies put an immense amount of trust in industry risk models, so we believe that building industry models that handle habitats well could play an important role in facilitating the inclusion of habitats in products such as insurance coverages and catastrophe bonds. Changing industry risk models will take time, though, because they are intensive to design and run, so they only get updated periodically. Further, industry risk models tend to be a black box because model design is proprietary and has significant value for these companies. Therefore, making these changes will also take trust and collaboration. While challenging, we believe this is a worthwhile effort to undertake. ◆

Box 1. Equity in risk science and risk management

Considering climate justice, equity, and social vulnerability when evaluating risks is critically important, yet this information is often not included in industry and agency risk models. Adding this information to risk model outputs would not require updating the risk model, since vulnerability information can be added after the hazard components (e.g., flood maps) are developed. Adding this information would enable identification of places where high risks coincide with high social vulnerability (e.g., high rates of poverty, high proportion of elderly people, etc.). These may be among the highest priority places to direct resources for adaptation and to encourage uptake of insurance to help close the protection gap.

To motivate risk modelers to include social vulnerability information in their model outputs, there needs to be demand for this information among their users. For agency modelers in the U.S., there is definite demand, spurred in part by the recent Justice40 Initiative, which directed that 40% of all benefits from covered federal programs flow to disadvantaged communities (EO 14008, 2021). For example, social vulnerability is a high priority for the Federal Emergency Management Agency (FEMA), as evidenced by their 2021 Notice of Funding Opportunity for the Building Resilient Infrastructure and Communities (BRIC) program, which emphasized the need to help disadvantaged groups adapt to climate change (FEMA 2021a).

So far, there is less demand for social vulnerability information among the clients of private industry risk modelers. Yet there is some burgeoning interest, and potential to grow this demand. For example, the InsuResilience Global Partnership has the mission to reduce the vulnerability of 400 million vulnerable people through innovative, pro-social insurance mechanisms, thereby strengthening their resilience and protecting their lives and livelihoods (https://www.insuresilience.org/about-us/). In interviews, colleagues at WTW shared that they have found social vulnerability information can be critical in understanding and working to close the protection gap. There could be an opportunity for insurers and other potential clients of industry risk modelers to grow work streams in vulnerable communities in ways that both support these communities (e.g., by helping to close the insurance coverage gap) and benefit companies in the risk industry (e.g., by improving their corporate images, raising environmental, social, and governance (ESG) scores, or laying the foundation for future business in new markets).

1 Recommendation 1: Improve how habitats are included in risk models

Context

For many industry risk models, habitats are currently included in a relatively minimal way with substantial room for improvement. Some details about how habitats are assessed in proprietary models are not known, but the general approach is understood. Coastal flood risk models typically include terrestrial and intertidal habitats (e.g., mangroves and salt marshes) using two pieces of information: elevation data and roughness (e.g., Manning coefficients), which impacts how much the ecosystems dissipate the energy of flood waters in the model. These hydraulic roughness coefficients are meant to reflect how the physical complexity of a habitat, such as the density of stems, leaves, and branches, affects the flow of water.

Subtidal habitats, such as reefs (coral, oyster, worm, and rocky), are not usually incorporated directly into industry flood risk models. These habitats may be indirectly included if they are represented in bathymetric datasets, although typical bathymetric resolutions are not sufficient to represent these habitats accurately and can miss structural features relevant to modeling coastal dynamics. These datasets contain information on elevation, but often not habitat type, which means that industry flood models likely underpredict the risk reduction benefits from habitats such as reefs because they fail to represent the full benefits of these natural, low-crested submerged breakwaters, which impact surge and wave energy dissipation (Harris et al. 2018, Reguero et al. 2019, Reguero et al. 2021).

Another limitation is that industry risk modelers often do not *quantify* the risk reduction benefits from habitats. This can be done by running the model with and without habitats to isolate their impacts (e.g., Narayan et al. 2017). However, these additional model runs are time-consuming and expensive, and therefore rarely done. For industry risk modelers to invest the time and resources to do this, they would need to see interest from clients in this type of information about habitats.

Beyond including habitats in risk models, it is also important for them to be included in the tools that insurance underwriters use to design and price policies, such as rating models (**Box 2**).

Recommended actions for improving habitat modeling

Two important changes that would improve how habitats are included in industry risk models are to represent habitats better in the models, and to assess the benefits of habitats. Additionally, there is also a need to build demand for these changes among the clients of risk industry modelers to motivate modelers to make these changes. These three points are discussed in more detail below.

Represent habitats better in risk models

A key step to incorporating habitats better in risk models is to start including often-neglected habitats, such as reefs. To accomplish this in the U.S., modelers could use available federal land use land cover datasets (many from the U.S. Fish and Wildlife Service) that include data on subtidal reefs that could be pulled into risk models to better represent these habitats. Many industry risk models already use these federal datasets for terrestrial and intertidal habitat types, so it could be relatively straightforward to pull in the data for subtidal reefs.


Matt Curnock / Ocean Image Bank

Improving the hydraulic roughness coefficients used to express the effect of habitats on flow is another way to help represent habitats better in risk models. For example, hydraulic roughness coefficients could be modified to reflect differences in species composition (e.g., different species of mangroves), habitat zones (e.g., high versus low marsh), habitat condition (e.g., high versus low coral cover, as in Storlazzi et al. 2019, Reguero et al. 2021), and water depths (e.g., due to different storm surge heights or sea level rise scenarios, as in Dasgupta et al. 2019). Some of these roughness coefficients have been determined, but there is still more basic science that needs to be done before the private risk industry can incorporate this information into their risk models. The U.S. Army Corps of Engineers (USACE) has research facilities that specialize in determining hydraulic roughness coefficients for habitats under different conditions, and they could play a key role industry fill this need (Bryant et al. 2022). It may not be necessary to increase the specificity of roughness coefficients everywhere because these changes may have a large impact in some places and not in others. Therefore, a sensitivity analysis could be conducted to identify locations and conditions where it matters most to improve roughness coefficients.

Another way to advance how habitats are represented in risk models is to better account for habitat fragility. Habitat fragility models estimate the degree of habitat damage that is likely for different intensities of a hazard. Incorporating probabilistic models of habitat fragility into risk models is important for accurately assessing risk for nearby communities that can lose some of their nature-based protections if habitats are damaged during a disaster. Incorporating habitat fragility could also allow risk models to better

represent changes in protective benefits from habitats after disasters. For example, if mangroves or reefs are lost during one disaster, they may provide less protection to nearby communities during subsequent disasters. Habitats, unlike hard infrastructure, can regrow after damaging events, so they are innately more resilient than hard infrastructure, and some NBS are also highly resistant to damages (Castagno et al. 2021).

Some habitat fragility curves already exist (e.g., for mangroves, see Menéndez et al. 2022) and others could be developed. The U.S. Army Corps of Engineers could partner with risk modelers to produce fragility curves (**Recommendation 4**).

Use models to quantify habitat benefits

Equally important to representing habitats well in models is quantifying habitat benefits. This could be achieved in a couple of different ways, such as 1) running the model more times, with and without habitats, to isolate their effects and 2) conducting post-facto adjustments to model outputs to estimate habitat impacts.

The first option entails running the model with and without habitats to isolate and quantify habitat benefits, e.g., Narayan et al. 2017 (**Figure 2**). Models could also be run with current and future habitat scenarios (e.g., restored or degraded) to quantify restoration benefits or increases in future risk from habitat loss. This method of quantifying habitat benefits can be expensive and time consuming. Therefore, it may only be feasible to take this approach for a subset of locations or disaster scenarios, which could be strategically selected to quantify the impact of habitats on risk under a range of conditions. Alternatively, it is possible to advance public and private models that allow users more accessibility to implement scenarios for assessing habitat benefits and the effects of habitat restoration and loss.

The second option is to adjust model outputs post-facto, for example, by using habitat risk reduction ratios, which represent the percentage reduction in risk provided by a unit of area of a habitat. These could be applied to model outputs to estimate the impact of current or alternate habitat scenarios on risk (as was done in Reguero et al. 2018).

The U.S. Army Corps of Engineers could collaborate with industry risk modelers to help develop regional habitat risk reduction ratios for this purpose.

Quantifying habitat benefits is critical for securing funds for NBS projects. Some potential funding pathways rely on model outputs from agency risk models, while others rely on those from private industry risk models. For example, quantifying benefits from potential habitat restoration projects in agency risk models would directly inform benefit-cost analyses, which are necessary to obtain FEMA funding, among other funding opportunities (Beck et al. 2022). In terms of private industry risk models, estimates of NBS risk reduction benefits could inform the design of novel "resilience insurance" property insurance coverages that reflect nature's benefits in premium rates (**Recommendation 6**).

Build demand for information on habitat risk reduction benefits

Industry risk modelers are very responsive to the needs and requests of their clients, but we consistently heard that there is not currently much demand from clients for information on habitats. This is likely due to a lack of awareness among users of risk data about the substantial risk reduction benefits that habitats can provide and a lack of clarity on how to use information on habitat benefits to create products and business opportunities.

The Engineering With Nature (EWN) program at the U.S. Army Corps of Engineers and some other agencies already work to build awareness about the risk reduction capacity of nature. These awareness-building efforts could be expanded to include typical users of industry risk model outputs, such as insurance companies and financial institutions. Specific actions to build this awareness could include convening interdisciplinary workshops and supporting the creation of professional development curricula on the benefits of NBS for users and creators of risk model outputs (**Recommendation 10** and **Recommendation 11**).

To address the second point about the need for a business case, it would be useful to outline ways that habitat benefit information could be used to develop and market new products within the risk industry. For example, quantified habitat benefit information could inform the design of resilience insurance coverages, which require such information to set insurance premiums (**Recommendation 6**). Information on habitat risk reduction benefits could also be used to market nature-related insurance coverages, such as insurance policies that cover damages to ecosystems (**Recommendation 5**) and insurance policy enhancements that provide additional funding to re-build green after a disaster (**Recommendation 7**). If clients realize the risk reduction benefits from protective habitats, they might be more likely to purchase insurance coverages or enhancements to protect them. Quantified information on habitat benefits could also play a valuable role in spurring the creation and sale of bonds to fund NBS projects, whether they be Environmental Impact Bonds (**Recommendation 13**), blue bonds, green bonds, or sustainability bonds. Finally, quantified habitat benefit information could also be an element of burgeoning risk consulting services offered by insurers and financial institutions. Further collaborative efforts among risk industry professionals, financial experts, academics, and risk managers could help flesh out these ideas and advance the ones with business potential. ◆

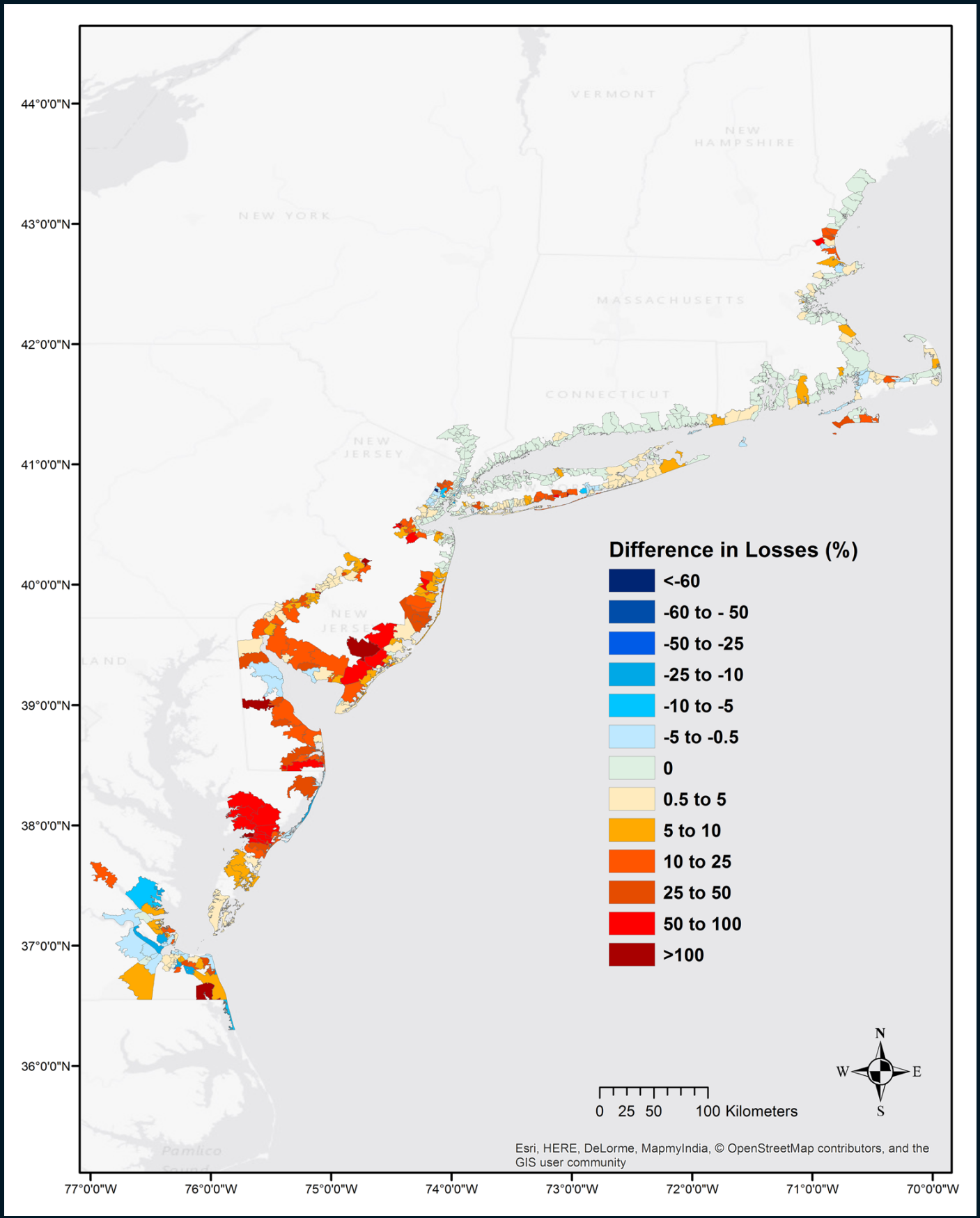


Figure 2. Risk reduction benefits of salt marshes during Hurricane Sandy. Moody's RMS, The Nature Conservancy, Guy Carpenter, the Wildlife Conservation Society, and University of California Santa Cruz collaborated to determine that salt marshes provided roughly $625 million in benefits along the East Coast of the U.S. during Hurricane Sandy alone, and reduce Average Annual Losses (AAL) by 15% (Narayan et al. 2017).

Box 2. The role of rating models

What are rating models?

Rating models are the tools used by underwriters when designing insurance policies and determining coverage and premiums. They allow the underwriter to develop a policy tailored to the specific context and needs of the client.

Do rating models consider habitat benefits?

Many rating models are connected to catastrophe models that may (or may not) capture habitat risk reduction benefits. In these cases, the rating model may passively reflect habitat benefits. It would be valuable to move towards a more explicit accounting of habitats in the tools that underwriters have at their disposal. A first step is to clarify whether ecosystems are already being included in particular rating models, and in cases where they are not, add a way for the underwriter to manually account for them.

Additionally, it is possible for habitats to be included in the design of insurance coverages through one-off efforts that may not rely on rating models.

How could the inclusion of habitats improve rating models?

If habitats were included in rating models, then underwriters could more easily design insurance policies that reflect habitat risk-reduction benefits in their premium prices. Many of the innovative insurance mechanisms discussed in this report would require boutique development of insurance products or policies, at least at first, so would not necessarily rely on existing rating models. However, standardizing the inclusion of habitats in rating models for something like property insurance could help scale up the consideration of habitat benefits in insurance. Ideally, underwriters would have the ability to toggle between different habitat scenarios in their rating models to quantify potential premium reductions as a result of a property owner carrying out an NBS project for risk reduction.

Matt Curnock / Ocean Image Bank

2 Recommendation 2: Improve how waves are included in risk models

Context

Coastal flooding is driven by storm surge and waves. Storm surge is the dominant driver on coastlines with continental shelves, such as the U.S. East and Gulf Coasts, where wind pushes and 'piles' water onto broad shallow shelves and can create extreme flooding as this surge comes ashore. Conversely, waves are the dominant driver of flooding and erosion on shores with small or nonexistent shelves, such as most island nations and the western coasts of the U.S., Canada, Central and South America, Europe, and the U.K.

Most of the private risk industry's coastal storm risk models were developed to assess flooding in high risk and high value markets, particularly the U.S. East and Gulf Coasts, and thus they prioritize modeling storm surge and focus less on modeling waves. As a result, most of these models do not characterize flood risk well in places where waves are an important driver of flooding, nor in places that are principally protected from flooding by reefs (particularly coral reefs), which provide much of their flood protection benefits through wave attenuation. Industry models also largely underestimate or ignore the impact of wave-driven erosive processes on coastal risk (e.g., Toimil et al. 2023). As a result of this lack of focus on modeling waves, industry flood risk models can perform poorly in Small Island Developing States and along the western coasts of the Americas and Europe, among other places.

While some industry risk models do assess waves, it is usually in a limited manner that could be improved. For example, some models use spatially variable multiplication coefficients to adjsut risk estimates in particular areas where wave energy is expected to be greatest, e.g., in FEMA V-Zones (i.e., places FEMA designates as having additional flood hazard due to waves). To account for the impact of high-energy wave action on structures, some risk models also use wave-specific vulnerability functions to calculate property damage in locations with high wave energy. These approaches are reasonable in places where waves are not a major driver of flooding, but they are unsuitable in places where waves are a dominant driver of flooding.

This insufficient consideration of waves can limit insurance product development. We have found through direct experience in the Caribbean that some habitat insurance options could not be priced because industry risk models did not consider waves or reefs and undervalued actual risks and reef benefits.

Including waves in an industry risk model is not a simple task. The full inclusion of waves would require significant new models and equations and additional costs. Therefore, the creation of models that comprehensively include waves will require both time and demand from clients in these (mostly) developing markets.

Despite these challenges, there are compelling reasons for the private risk industry to put energy and resources into improving risk assessments in these developing markets. The industry will be hard-pressed to develop their business in these markets if they knowingly omit a primary driver of flood risk and consideration of solutions that can reduce it.

Inadequate modeling of waves is also an issue in some (but not all) government agency flood and erosion risk models. Agency risk models are a large and diverse set of tools, each with their own strengths and weaknesses. Some agency models handle waves well, but others do not. Therefore, improved wave modeling is also an important need for many agency flood and erosion models, especially those that are used to model large areas.

Recommended actions for improving wave modeling

For many industry flood risk models, the accuracy of outputs could be greatly increased through better modeling of waves, especially in places where waves are the dominant driver of flood risk. This is a difficult problem to address, and a few potential approaches are presented below.

Developing and running rigorous wave models within risk industry flood models would be a major undertaking that would take years to implement. A near- to mid-term alternative could be conducting a sensitivity analysis to determine which places most need comprehensive wave modeling to yield accurate results. To accomplish this, a subset of locations could be selected where modeling waves is thought to be most critical for generating accurate flood outputs. These selected areas could be modeled with both the current industry approaches and a more comprehensive model that explicitly considers waves. Based on these results, modelers could extrapolate to predict where waves need to be modeled, and where the less-involved approach is sufficient.

It is important to pair better wave modeling with better evaluation of the wave-reducing benefits from green and gray infrastructure (**Recommendation 1**). For example, the wave-reducing benefits of coral reefs could be assessed by applying existing risk reduction ratios for coral reefs or using models such as BeWare (Pearson et al. 2017), which describe how flood height changes on shores with fringing reefs, as operationalized by the U.S. Geological Survey for storm emergency response in the U.S. Pacific.

To motivate and facilitate these changes in how waves are modeled, it is important that the risk industry acknowledge the current significant limitations of their models in regions with wave-driven flood risk and seek partnerships to address them. Few industry professionals beyond the core modeling teams recognize that waves can drive flood risk and that industry models do not adequately assess waves.

USACE, and the EWN program in particular, could play an important role assisting the private risk industry as they tackle this challenge of improving how waves and wave-reducing NBS are included in industry models. USACE has worked hard to incorporate waves into their coastal models and EWN is playing a leadership role in assessing the flood-reduction benefits of coral reefs for protecting military installations as part of the U.S. Defense Advanced Research Projects Agency (DARPA) Reefense project. ◆

3 Recommendation 3: Model risks under climate change scenarios

Context

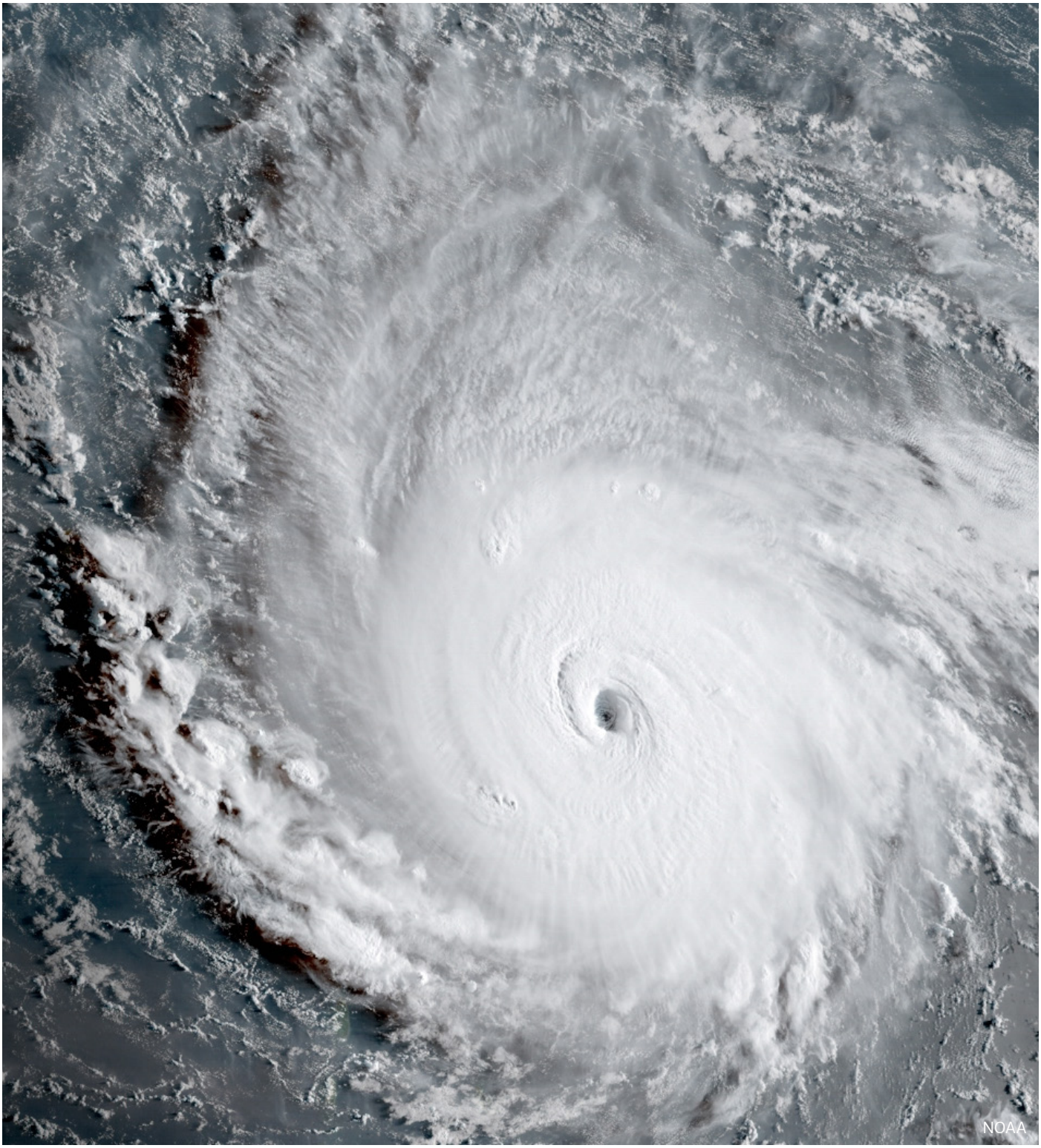
Public risk managers and the private risk industry have a shared interest in understanding how climate change will impact future risks, so there is an opportunity for them to collaborate to advance the inclusion of climate change into risk modeling. Public risk managers, including USACE, play a critical role in designing and implementing adaptation solutions to protect communities, civilian property, military installations, and other resources. Their infrastructure projects are intended to provide protection for decades to come, and therefore should be designed with climate change in mind. Insurers, on the other hand, rarely consider climate change when pricing insurance policies because most policies only cover one year (and up to 3 years in rare cases). Catastrophe bonds are insurance-linked securities that are among the longest-duration products, typically covering 3 years and exceptionally up to 5 years. Accordingly, climate change and seasonal-to-decadal predictions are generally not included in industry risk models. Yet, the private risk industry is still very interested in understanding climate change because it could impact future growth and viability of the insurance industry. While insurers are generally not willing to cover the full costs of mitigation and adaptation efforts that would be required to keep insurance affordable, they are, in our experience, motivated to collaborate on these efforts, e.g., by modeling future risks and identifying and partially supporting effective adaptation opportunities, including NBS projects. Therefore, public risk managers and the private risk industry have a shared interest in advancing the science of modeling climate change risks and developing adaptation solutions.

The science on future physical and climatic conditions is fairly advanced, but this information has not been adequately integrated into risk models and risk assessments. Scientists have developed clear projections for how waves and sea level will change. As global temperatures rise, global wave power will increase as a result of increasing wind energy, which gets transferred to surface ocean waters (Reguero et al. 2019). Global sea level rise is projected to increase 0.15-0.43 m by 2050 relative to a baseline of 2000 (Sweet et al. 2022). Additionally, major tropical cyclones (Categories 4-5) are projected to become more common (IPCC 2021, IPCC 2023). The importance of integrating this climate information into risk models is demonstrated by the recent collaboration between the National Oceanic and Atmospheric Administration and the National Science Foundation to create an Industry-University Cooperative Research Center on this precise topic (NOAA 2023). Including climate change in risk assessments can dramatically change estimates of the benefits from adaptation projects. For example, modeled flood risk reduction benefits provided by salt marsh restoration increase by 10-fold when taking into account sea level rise in some areas of San Francisco Bay in California (Taylor-Burns et al. *in press*).

Collaboration between public risk management agencies and the private risk industry could lead to better, more comprehensive science because they have different areas of interest and expertise. Federal risk managers have a keen interest in understanding the impact of future risks in coastal areas because of their role in long-term protection of communities, property, and other civilian and military assets. Private insurers have important expertise and data for understanding risks associated with business interruption than do public risk managers. Business interruption risks are substantial and growing; in some places, recent business interruption claims have been 139% of claims from direct damages (Allianz 2019). For these reasons and others, collaboration between private risk industry and public risk managers could greatly strengthen efforts to advance risk modeling and risk assessments.

Recommended actions for modeling risks under climate change

To better understand the spatial and temporal impacts of climate change on risk, public risk managers and the private risk industry could collaborate to advance the science of modeling risks under climate change. Targeted adjustments made to waves, sea-level, storm frequency, and precipitation events, as well as consideration of different development and adaptation scenarios, could improve our understanding of the likely impacts of climate change on risk in the not-so-distant future (e.g., < 10 years). These advances will also allow better estimation of the risk reduction benefits from adaptation projects (including NBS) under climate change conditions, thereby facilitating more effective adaptation planning. ◆



4 Recommendation 4: Develop fragility curves for habitats

Context

Fragility curves are used by risk managers and the risk industry to identify when infrastructure might fail under stress. Generally, fragility curves describe the probability that a structure (e.g., a levee, building, or bridge) will be damaged as a function of the intensity of a hazard, such as wind speed during a hurricane or intensity of an earthquake (Pitilakis et al. 2014, FEMA 2022, Madden et al. 2023). Fragility curves are created using damage data that is collected on the ground or via remote sensing after hazardous events. USACE has played a central role in the development of fragility curves, which are widely used in the U.S. and internationally. In the case of habitats, fragility curves can describe the probability that forces from natural hazards, such as wind or waves, will cause damage to habitats (**Figure 3**).

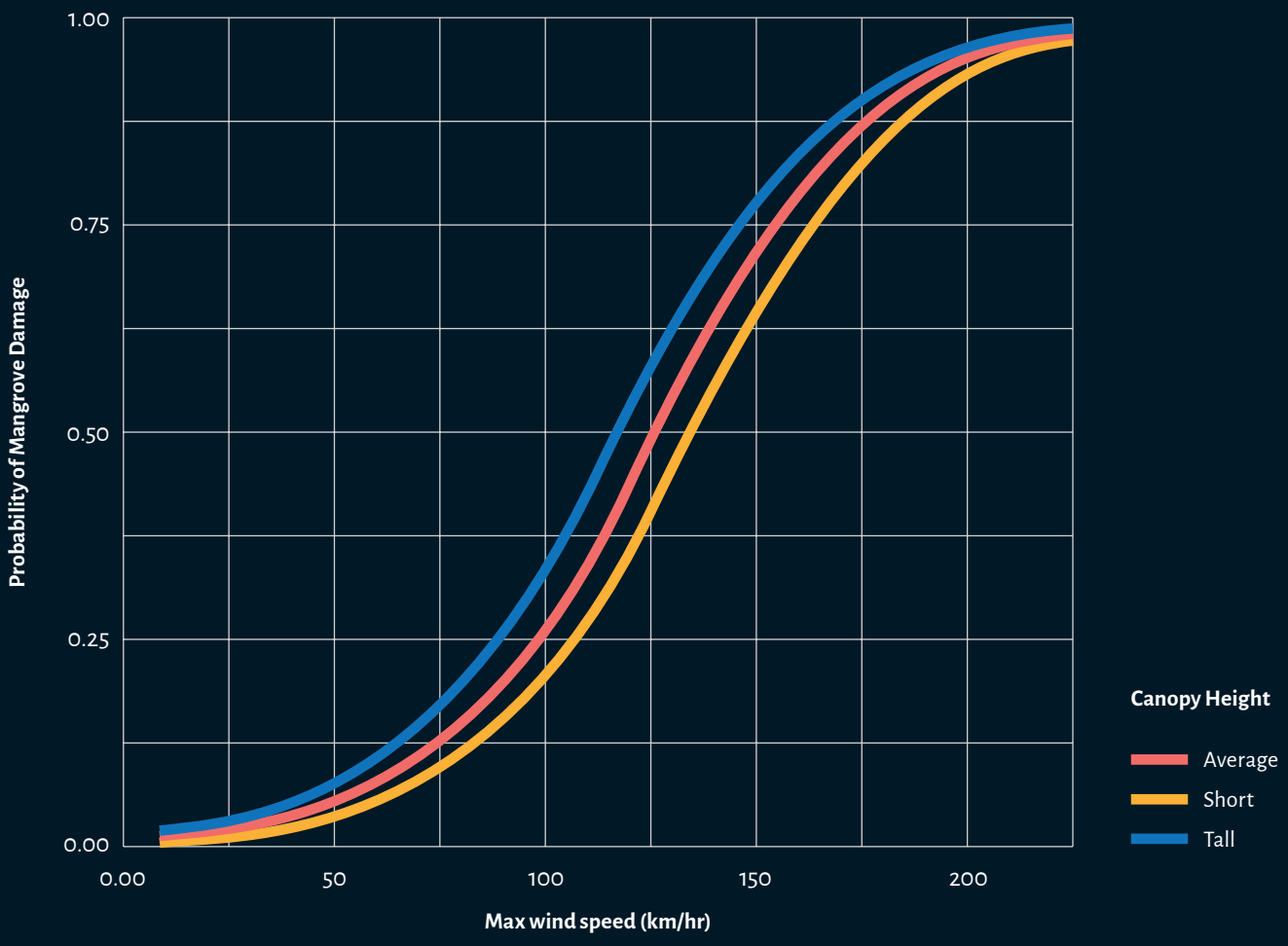


Figure 3. Fragility curves for Caribbean and Mesoamerican mangroves of 3 different canopy heights, showing the probability of damage as a function of maximum wind speed during the 2017 hurricane season (adapted from Taillie et al. 2020).

Shaun Wolfe / Ocean Image Bank

Fragility curves for habitats can enhance risk management in multiple ways. First, including them in risk models is important to accurately assess risks. Currently, habitats are included in risk models in a limited way that does not change if they are damaged (e.g., in a natural disaster). Yet, when habitats are damaged, the protections they offer may decline. Fragility curves can be used to account for damage to protective infrastructure (whether green or gray) in risk models, thereby improving risk estimates. It is common, for instance, to simulate the performance of levees in probabilistic flood models, and the same could be done for habitats that serve as natural infrastructure. Ecosystems can be relatively resistant to many stressors, which is one of the qualities that makes them compelling options for risk mitigation. For example, when Category 5 Hurricane Michael made landfall in Florida in 2018, only 2% of nearby marshes were damaged (Castagno et al. 2021). This resistance to storm damage would be reflected in salt marsh storm fragility curves.

Second, fragility curves can inform the design of insurance policies that cover damages to habitats during natural hazards. There is growing interest in insuring ecosystems as natural assets to provide funding to repair them after triggering hazardous events and ensure that the benefits of natural infrastructure are recovered (Beck et al. 2019; and **Recommendation 5**). When designing insurance policies that cover damages to ecosystems, it is useful to understand the fragility of habitats to different stressors.

Third, developing fragility curves for ecosystems will inform our understanding of the maintenance costs of NBS. The maintenance needs and associated costs of repairing NBS to restore coastal protection benefits

after a disaster are not well known and represent an important knowledge gap to fill. Considering maintenance costs when comparing nature-based and hard infrastructure projects could strengthen the case for selecting NBS because of the inherent resistance to storm damages of habitats like salt marshes, or to a lesser extent, mangroves, provide (Castagno et al. 2021, Xiong et al. 2022).

Despite their importance, very few fragility curves exist for habitats. A substantial body of ecological literature exists on the effects of disturbance on ecosystems, going back to Connell's 1978 Intermediate Disturbance Hypothesis, but this data has not been adequately gathered and developed into fragility curves for many habitats and types of disturbances. For coral reefs, fragility curves already exist that show reef damage for different wind speeds for the Great Barrier Reef (Fabricius et al. 2008) and the Caribbean (Madden et al. 2023). Other studies contain data that could be used to create regionally specific coral reef fragility functions for storms (Puotinen et al. 2016, Puotinen et al. 2020) or prolonged heating events that cause bleaching (Claar et al. 2020). For mangroves, published fragility curves exist for damages due to wind speed in the Caribbean (Han et al. 2018, Menéndez et al. 2022, Tallie et al. 2020, Imbert et al. 2018). These studies and existing datasets can be a useful starting point to develop fragility curves for more regions and habitat types.

Recommended actions for developing habitat fragility curves

To support the consideration of nature in multiple facets of risk science, fragility curves could be developed for more hazards and habitats. A valuable first step would be conducting a comprehensive review of the literature to assess what current and historical habitat damage assessment data exists for different habitats, hazards, and regions. The following studies provide a valuable jumping off point to start such a review: Fabricius et al. (2008), Puotinen et al. (2016), Han et al. (2018), Claar et al. (2020), Krauss and Osland (2020), Puotinen et al. (2020), Taillie et al. (2020), Tomiczek et al. (2020), Castagno et al. (2021), Lagomasino et al. (2021), van Hespen et al. (2021), and Menéndez et al. (2022). The data identified in this review could be gathered into an open access tool that facilitates the creation and sharing of fragility curves.

Initial efforts to develop fragility curves could focus on the impacts of high winds, wave conditions, and storm duration on mangroves, salt marshes, and coral reefs, and then expand to include additional hazards and habitats. Additional coastal hazards to consider include freshwater or saltwater inundation, sedimentation, nutrification, and prolonged heating impacts on habitats. Beyond coasts, other hazards to consider include wildfires, wind blowdowns, and droughts, which threaten a variety of forest ecosystems. Better understanding the damages caused to coastal and inland habitats by a variety of hazards would support the inclusion of NBS in risk models, insurance policies, and benefit-cost analyses. ◆

Insurance Coverages

Background on insurance coverages

Insurance coverages are contracts that allow a buyer to receive financial protection from an insurance company in exchange for paying a fee, i.e., a premium. Insurance transfers some of the financial risk associated with a covered event (e.g., car accident, hurricane, wildfire) from the policyholder to the insurer, for a cost.

Insurance policies are sold by private and public entities. Public insurers include state and federal agencies, such as the Federal Emergency Management Agency (FEMA), which sells insurance through the National Flood Insurance Program (NFIP). Buyers of insurance range from individuals to groups, companies, and governments. **Reinsurance** is the specific case when an insurer buys insurance from another insurer to help spread out the risks they have taken on through their portfolio of underwritten insurance policies. Some companies and many governments "self-insure", meaning they pay for damages in the event of a catastrophe. For governments, this means using public funds that are set aside or raised through legislation. A notable exception to this practice of governments self-insuring is FEMA's recent engagement with private insurance to help transfer some of the risks they take on through the NFIP (Artemis 2016, Evans 2021c, Evans 2022a, Evans 2023), which is an example of reinsurance.

Indemnity and parametric insurance

The most common type of insurance is **indemnity insurance**, in which the damages from a covered event are assessed and then a payout is made once a deductible has been subtracted (i.e., the amount of damages for which the policyholder is responsible before the insurer starts paying) and going up to the coverage limit or total damages, whichever is smaller. A relatively new and burgeoning type of insurance is **parametric insurance**, which does not require damages to be assessed by a loss adjuster. In a parametric insurance policy, a trigger threshold is predetermined for a chosen metric (e.g., wind speed), and if that threshold is met, then the policy pays a predetermined amount of money to the policyholder.

The ability to bypass damage adjustments leads to both the greatest strength and weakness of parametric insurance. Its strength is that it pays out faster than indemnity insurance **(Figure 4)**. Its weakness is a greater 'basis risk', which is the risk that the payout does not match the actual amount of damage because the trigger is an imperfect proxy (Franco 2010). For the insured party, a greater basis risk is undesirable because of the possibility that the insurance may not cover the full cost of damages.

Integrating nature into insurance

Incorporating nature into insurance can help mitigate disaster risks and promote conservation and restoration. The vast majority of insurance coverages do not consider or pertain to nature, but recent innovations, such as those listed below, highlight opportunities to advance this space.

1. **Insurance that covers damages to nature**: Insurance policies can be designed to cover damages to ecosystems during natural disasters. The first ever insurance policy of this kind was created in 2018 to cover hurricane risks to a portion of the Mesoamerican Reef off the coast of Mexico's Yucatan Peninsula near Cancun. This policy was replicated and expanded to cover additional portions of the Mesoamerican Reef off the coasts of Mexico, Belize, Guatemala, and Honduras (**Box 3** for a history of reef insurance). This policy inspired the development of a similar reef insurance in Hawaii, and hopefully will also lead to additional reef insurances in other geographies, as well as coverages for other ecosystems such as mangroves (**Recommendation 5**).

2. **Property insurance that incentivizes nature-based solutions for risk reduction:** There is enormous potential to reduce risks and promote conservation and restoration of ecosystems by integrating nature into the pricing and design of property insurance policies (e.g., policies that cover damages to buildings and

other infrastructure). This approach could be transformative because property insurance policies are ubiquitous and therefore offer an exciting pathway to scale up impact. Nature could be integrated into property insurance in multiple ways, including through resilience insurance, which links reduced risks from nature-based solutions (NBS) with lower premium payments (**Recommendation 6**), and policy enhancements, which can be used to incentivize rebuilding damaged hard infrastructure with NBS (**Recommendation 7**). Both have been vetted scientifically and theoretically, and the next step is piloting them in practice.

3. **Insurance that de-risks investments in nature-based solutions:** Insurance can be used to de-risk investments in NBS, thereby catalyzing increased funding flows for NBS. For example, catastrophe wrapper insurance coverages can be used to de-risk investments in blue and green bonds (**Recommendation 8**) and insurance coverages can be developed to de-risk the purchase of ecosystem-derived carbon credits (**Recommendation 9**). ◆

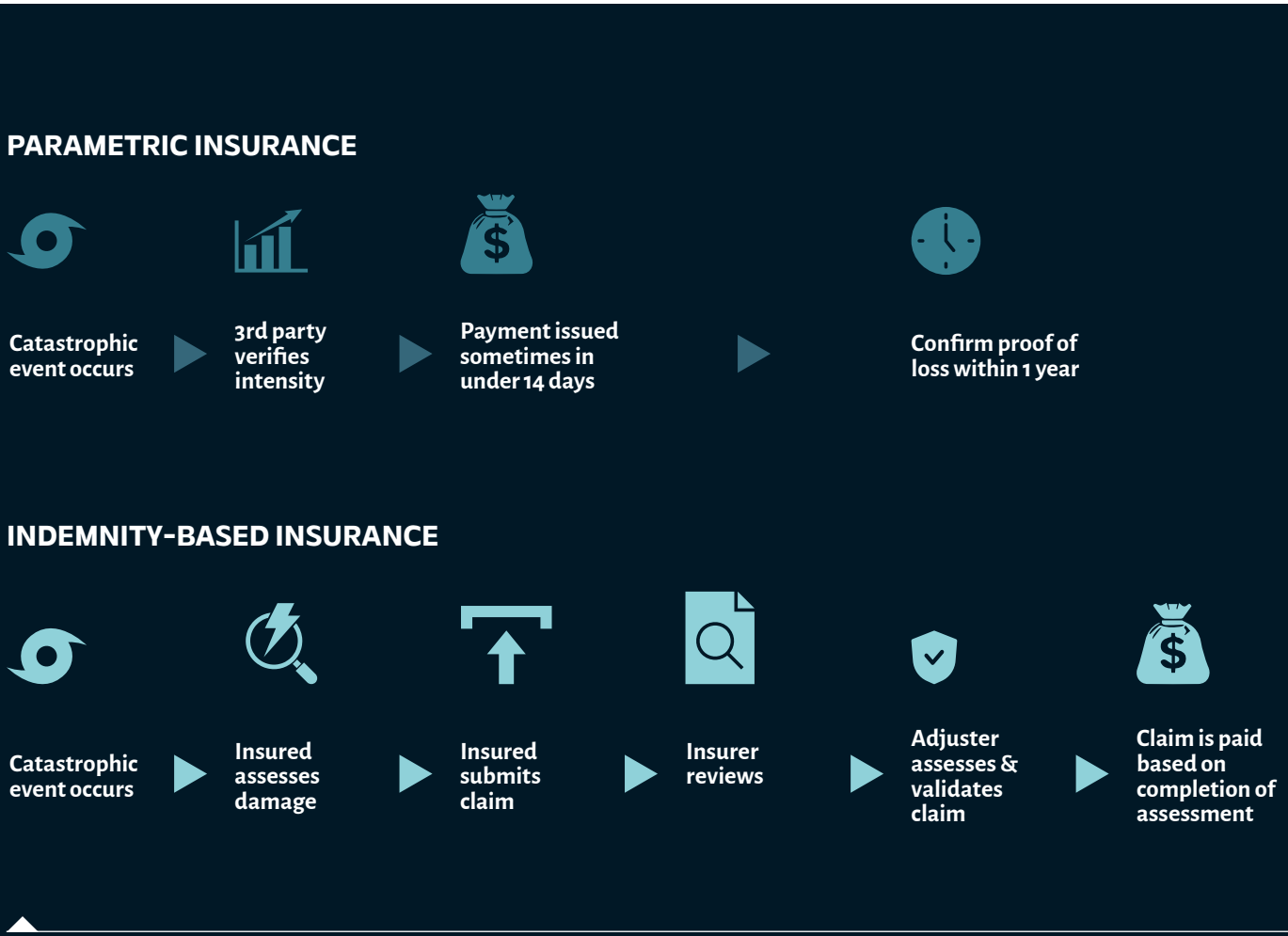


Figure 4. A comparison of parametric insurance and indemnity-based insurance. Source: Modified from AmWINS Alternative Risk Group.

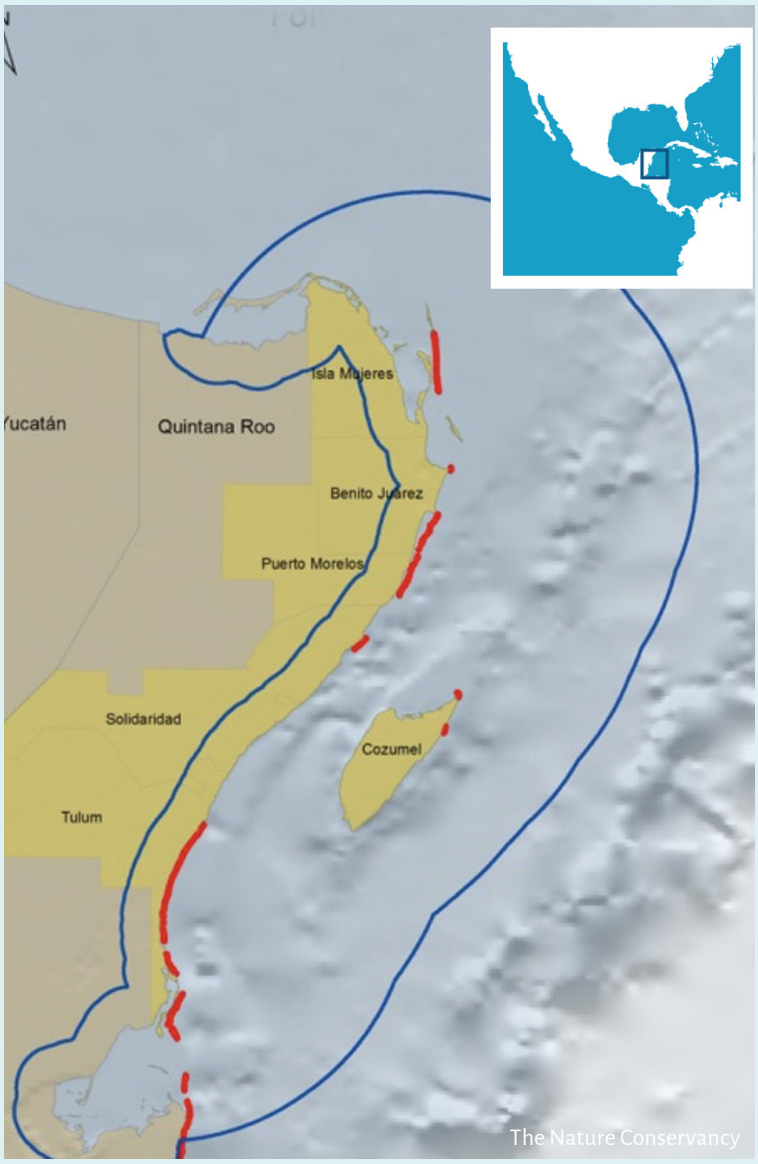
Box 3. A history of parametric reef insurance

2018

The Nature Conservancy (TNC) and SwissRe, with partners, help the government of the state of Quintana Roo, Mexico develop an innovative parametric insurance policy for a 167 km stretch of the Mesoamerican Reef (MAR), including sites in Cancun, Tulum, and Cozumel (Artemis 2018b). Beachfront hotels and businesses contribute money to a fund held by the Coastal Zone Management Trust, which pays the policy premium.

2019

This first-of-its kind policy goes into effect on June 1st, 2019, providing coverage of up to US$3.8 million for rapid triage of reefs following a triggering storm event. The policy is designed so wind speeds greater than 100 knots within the polygon on the map trigger a payout, with greater wind speeds resulting in larger payouts (Beck et al. 2019, TNC 2021a).



2020

Hurricane Delta triggers the Quintana Roo reef insurance policy, resulting in a payout of US$850,000. Within a week, reef brigades survey damage and, over the next 3 months, stabilize 2,152 coral colonies and rescue and outplant over 13,500 coral fragments (TNC 2021a).

The state government of Quintana Roo renews the parametric reef insurance policy with partner Hannover Re.

2021

The Mesoamerican Reef Fund (MAR Fund), together with AXA XL, the InsuResilience Solutions Fund, and WTW, launch a new parametric reef insurance policy with plans to cover portions of the Mesoamerican Reef across Belize, Guatemala, Honduras, and Mexico. This is the largest ecosystem insurance policy of its time with AXA Climate as the primary insurer. The four coral reef areas covered by the first installment of the policy include Banco Chinchorro, Arrecifes de Xcalak, Hol Chan, and Turneffe Atoll, with intentions to expand to other sites in Guatemala and Honduras (MAR Fund 2021). MAR Fund is the policyholder, and is ready to receive a payout and rapidly deploy the money to reef response brigades being trained by the MAR Fund and TNC (ISF 2019).

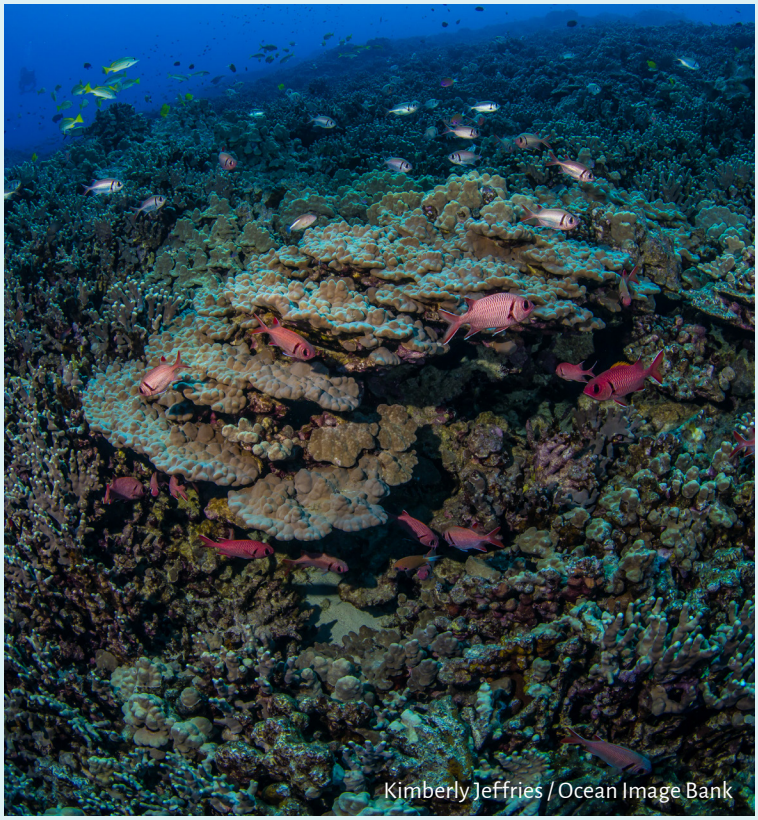

Alex Tyrrell / Ocean Image Bank

2022

The MAR Fund parametric reef insurance is expanded to cover three additional sites, bringing the total area covered to >130,000 acres. The new sites are Motaguilla reef in Guatemala and the Bay Islands Marine National Park and Cayos Cochinos National Marine Park in Honduras (ISF 2019, Evans 2022b).

Hurricane Lisa triggers a $175,000 payout for emergency reef response in Belize (MAR Fund 2022).

In November, TNC announces the first ever insurance policy for coral reefs in the U.S. to protect a large area of reefs in the Hawaiian Islands. WTW helped investigate and design the $2 million parametric insurance policy.


Kimberly Jeffries / Ocean Image Bank

5 Recommendation 5: Expand insurance for ecosystems as natural assets

Context

Insuring ecosystems directly as natural assets guarantees that funds are available to repair them if they are damaged during a disaster. The first ever insurance policy for nature was developed in 2018 by The Nature Conservancy (TNC), in partnership with the reinsurance company Swiss Re, and covered potential storm damages to a portion of the Mesoamerican coral reef in Quintana Roo, Mexico (Artemis 2018b). The policy was parametric and the payout was tied to a predetermined wind speed threshold such that, if triggered, the policy would automatically pay out recovery funds which could be used for time-sensitive reef restoration activities. This policy was triggered by Hurricane Delta in 2020, and reef brigades carried out restoration activities over the next few months (Einhorn and Flavelle 2020, TNC 2021a, **Box 3** for more details). Subsequently, a new, larger reef insurance policy was developed to protect additional sections of the Mesoamerican reef across Mexico, Belize, Guatemala, and Honduras (Evans 2021b, Evans 2022b). This expanded Mesoamerican reef policy was triggered in 2022 by Hurricane Lisa and resulted in a payout (Evans 2022c, and **Box 3** for more details). Building on these examples, in 2022, TNC worked with Munich Re and WTW to purchase a parametric insurance policy for the coral reefs around the islands of Oahu, Molokai, Lanai, Maui, and Hawaii (Evans 2022d, Flavelle and Einhorn 2022, and **Box 3** for more information).

Parametric insurance is streamlined, objective, and predictable, and there is a clear opportunity to replicate this model across habitats, hazards, and geographies. Despite this potential, parametric insurance for ecosystems currently remains limited to tropical storm coverages for coral reef ecosystems. Factors limiting the broader expansion of this tool include the following: 1) a lack of **habitat fragility curves** that describe the relationship between the intensity of a hazard and the corresponding damage to a habitat; 2) a lack of **measurable hazard parameters** (e.g., wind speed) that can be used as triggers for parametric insurance policies; 3) **geographic limitations** on where ecosystem insurance policies would be affordable enough to be viable; 4) a lack of **identified post-hazard recovery actions** that could restore, retain, or enhance an ecosystem after a disaster; 5) the need to **identify appropriate buyers** to hold an ecosystem insurance policy, receive the payout, and handle rapid disbursement; and 6) **governance issues** that can limit uptake and success of ecosystem insurance policies. These limitations and suggested steps to help address them are discussed in more detail in the recommendation below.

Recommended actions for expanding ecosystem insurances

The development of parametric insurance policies that cover damages to ecosystems could be expanded by filling several of the following key scientific, knowledge, and capacity gaps.

1. **Develop habitat fragility curves.** The U.S. Army Corps of Engineers (USACE) and other federal agencies could support this effort by collecting hazard and damage data for a variety of habitats, hazards, and geographies and leading scientific efforts to synthesize this information into fragility curves that could be used in the design of ecosystem insurance policies. **Table 1** identifies priority habitats and hazards. This would be a valuable contribution because the insurance industry does not have the capacity to quantify all the relevant hazards and associated damages to habitats that would be relevant to parametric ecosystem insurances. These fragility curves would also be useful in flood risk assessments because they identify when habitats are likely to fail and no longer offer protection benefits (**Recommendation 4**).

2. **Identify measurable hazard parameters that can be used as triggers in the design of parametric ecosystem insurance policies.** These parameters must be collected and reported by an independent, trusted third party such as the National Weather Service, U.S. Geological Survey (USGS), or USACE, and must be a good indicator of the damage a habitat might sustain during the hazard event. USACE and other federal agencies have expertise in field-based data collection and are well-positioned to gather and report parameter data in habitats ranging from salt marshes to mangroves to sand dunes. Table 1 presents a list of high priority habitats, hazards, and potential parameters to consider measuring. Agencies could also establish methods for reporting these independent parametric data to insurance industry partners so that policies can be reliably and rapidly triggered when a parametric threshold is surpassed.

3. **Identify geographies where risk profiles are compatible with insurance.** The cost of parametric ecosystem insurance policies will vary geographically according to the frequency and intensity of hazardous events. For example, a coral bleaching insurance policy would have a very high associated premium in a place where bleaching events occur frequently, and a lower premium in a place where bleaching events are rare. Accordingly, certain insurance coverages may be too expensive to be viable in particularly high-risk geographies. It is critical to identify geographies where risks are low enough for insurance to be viable and helpful. Further, it is important to do this for a variety of hazards because insurance viability varies by hazard, e.g., a place where coral bleaching insurance is non-viable may still be compatible with hurricane insurance or some other hazard insurance.

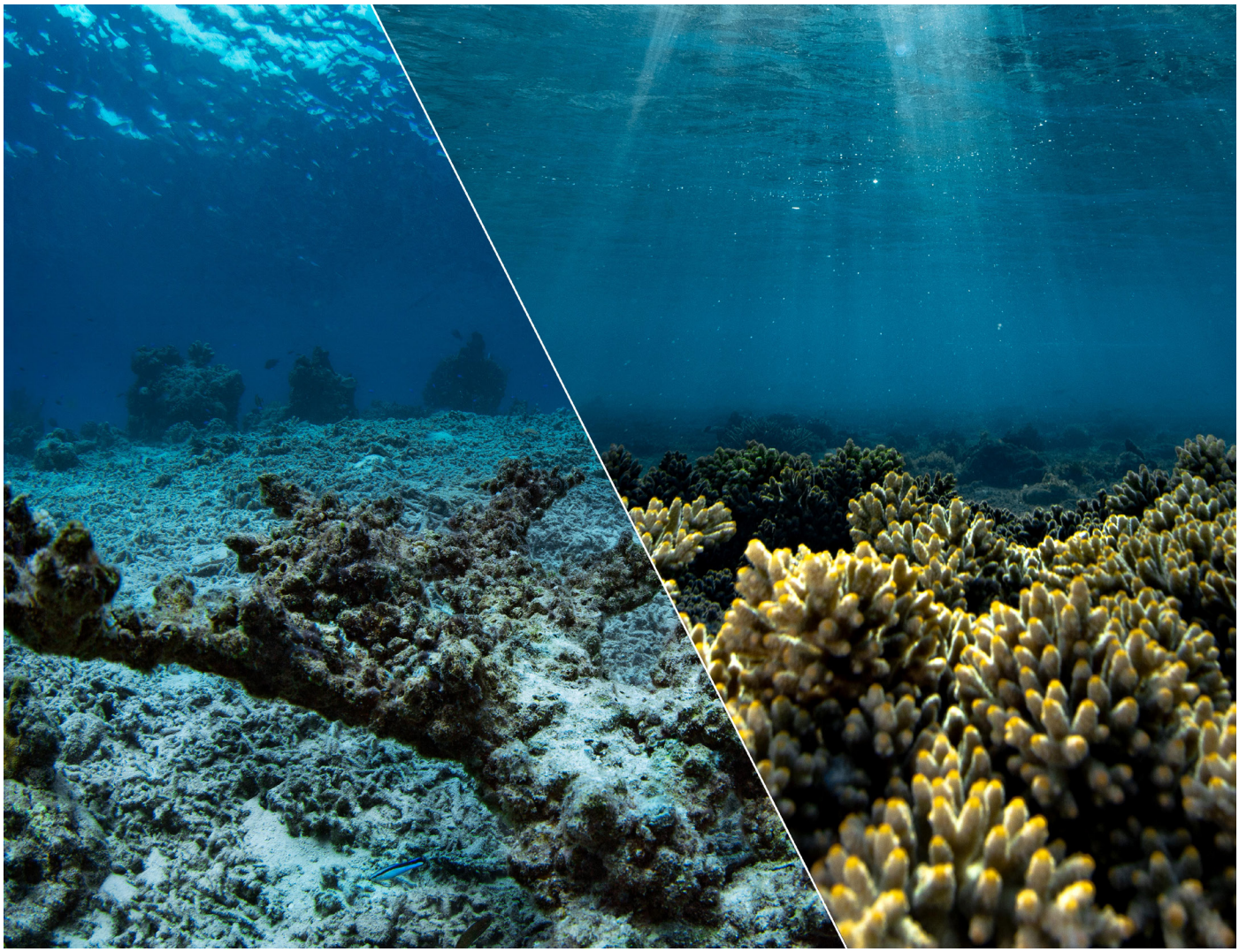
4. **Identify post-hazard recovery actions.** Insuring nature as a natural asset is particularly useful when restoration or intervention activities have the potential to restore, retain, or enhance the habitat after a catastrophic event. The appropriate response actions for different hazards must be considered before developing an insurance policy, yet this type of knowledge is very limited within the private risk industry. USACE and other federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA), Fish and Wildlife Service (FWS), and USGS, could work collaboratively to identify appropriate post-hazard recovery actions for habitats and develop guidelines with methods and metrics for success. These would both guide recovery actions by natural resource managers and inform risk industry efforts to develop ecosystem insurance policies.

5. **Identify appropriate buyers to hold an ecosystem insurance policy, receive the payout, and handle rapid disbursement.** Finding the right buyer for an ecosystem insurance policy is critical. It is important that the buyer be a trusted entity that can efficiently receive and rapidly disburse funds to support ecosystem recovery efforts. Buyers may include government agencies, local businesses, environmental groups, development banks, community groups, or governing bodies established to represent a group of interested parties. In the case of the expanded Mesoamerican reef insurance, the MAR Fund is the policyholder. For the Hawai'i reef insurance, TNC is the policyholder (Flavelle and Einhorn 2022).

6. **Navigate Governance Issues.** Governance and capacity issues can limit acceptance and success of an ecosystem insurance policy. These can include mistrust between buyers, sellers, response teams, and resource managers; the misuse or mismanagement of payout funds; limited workforce capacity to carry out ecological triage activities; and difficulty obtaining permits for post-disaster ecosystem recovery actions; among others. In general, deeper understanding is needed of the governance factors that support the success of ecosystem insurance policies. As more of these projects are implemented, it would be useful to conduct research on these governance challenges and, based on the findings, promote efforts to build the governance capacity needed to support successful ecosystem insurance policies. ◆

Table 1 Habitats, hazards, and potential parameters for developing ecosystem insurance policies.

Habitat	Hazard	Parameter
Coral Reef	Coral bleaching	Degree heating weeks
	Sedimentation	Rainfall amount and/or intensity
	Wave damage	Maximum sustained wind speed
	Post-storm marine debris	Rainfall amount, rainfall intensity, or maximum sustained wind speed
Mangrove Forest	Post-storm marine debris	Rainfall amount, rainfall intensity, or maximum sustained wind speed
	Freshwater inundation	Cumulative rainfall
	Wave damage	Maximum sustained wind speed
Maritime Forest	Saltwater inundation	Maximum storm surge inland reach
Sandy Dune	Dune erosion	Storm surge height



6 Recommendation 6: Develop pilot projects of resilience insurance

Context

Resilience insurance is a novel risk financing tool that can help build resilience by jointly incentivizing risk reduction, risk transfer, and habitat restoration. Essentially, in a resilience insurance coverage, the policyholder invests in nature-based adaptation projects and their insurance premium prices are accordingly reduced to accurately reflect the reductions in risk due to the nature-based solutions (Reguero et al. 2020 and **Figure 5**). This has the potential to drive greater investment in NBS and help narrow the insurance protection gap, thereby reducing risks to people and supporting ecosystem conservation and restoration efforts. Resilience insurance links risk reduction and risk transfer (i.e., insurance), two elements of risk planning that are usually considered separately (and often with tradeoffs), but which provide better risk protection when employed together. The theory for resilience insurance is well-developed (Reguero et al. 2020) and draws on related conceptual advances, such as resilience bonds, which similarly propose a method to link insurance with investment in risk reduction projects to monetize avoided losses (Re.Bound 2015, 2017). The next step in advancing resilience insurance is conducting field-based pilot projects.

The concepts of resilience insurance have been incorporated into a few insurance products, but none yet that include nature. For example, the MyStrongHome program provides residential homeowners in South Carolina, Florida, Alabama, Mississippi, and Louisiana with the opportunity to fortify their roofs and receive significant savings on their insurance premiums, which pay for the roof upgrades over a 7-year period (PRNewswire 2020). A similar framework could be developed to promote upfront investment in NBS with reduced insurance premiums that reflect reductions in risk.

Resilience insurance involving NBS has been developed in concept, with examples of applications that could yield positive returns on investment, but it has not yet been employed in the field. Reguero et al. (2020) assessed the potential return on investment for resilience insurance in the Caribbean using a hypothetical reef restoration example informed by real world parameters for storm risk and restoration costs. Under conservative assumptions, they found that greater than 40% of the upfront reef restoration project costs could be covered by insurance premium reductions over the first 5 years. Over a 25-year period, the risk reduction benefits would exceed 600% of costs. These results were robust across a wide range of assumptions.

While resilience insurance involving investments in NBS has not yet been implemented in the field, FEMA has come close with their Community Rating System (CRS), which is part of the National Flood Insurance Program (NFIP). Through the CRS, communities can earn credits that reduce the cost of their flood insurance premiums by implementing certain flood management activities. Currently, the CRS program does not explicitly offer premium reductions for *habitat restoration*, but it does offer reductions for *open space preservation* (without requirements for restoration or habitat quality). This program could be expanded to explicitly offer premium reductions for NBS projects tailored to reduce coastal risks and enhance habitat. Of existing programs that we are aware of, this is the most promising and practical avenue for investments in nature to reduce insurance premiums.

An important next step in advancing resilience insurance is to support pilot projects to further build the evidence base for this blended finance mechanism. In addition to supporting resilience insurance, these pilots would also build the evidence base for NBS more generally, which is also an important scientific need (**Box 4**).

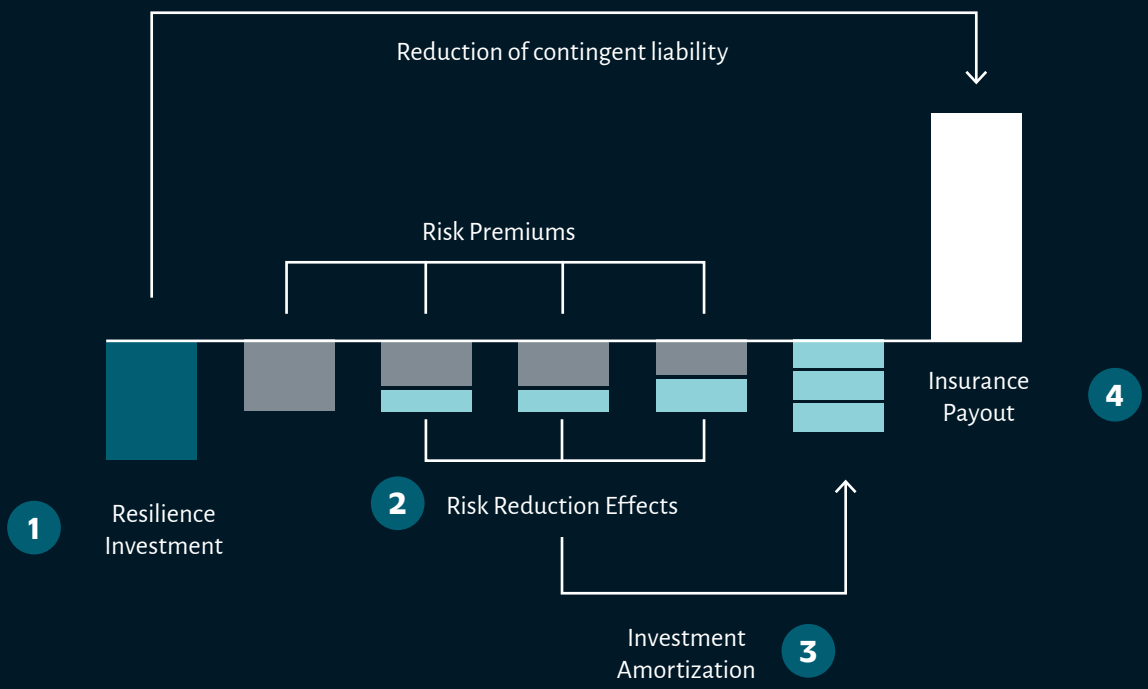


Figure 5. Resilience insurance links risk reduction with risk transfer. It involves an initial investment in NBS (dark teal bar, number 1), which reduces risk. This lower risk translates into reductions in annual premium payments (light teal bars, number 2), that over time amortize the initial investment in NBS (number 3). Some portion of the remaining risk is transferred through the insurance coverage (white bar, number 4), which pays out if a triggering event occurs (adapted from Reguero et al. 2020).

Recommended actions for piloting resilience insurance

Developing pilot projects for NBS resilience insurance would advance this innovative solution that links nature-based risk mitigation with risk transfer. The key steps in designing and implementing a resilience insurance mechanism include identifying a buyer and insurer, assessing the baseline risk at the project site, calculating the risk reduction benefits of the NBS project, estimating NBS project costs, structuring the risk transfer solution, securing funds to pay for the project, and implementing the NBS project (Reguero et al. 2020). USACE, along with other federal agencies and academics, could work collaboratively with industry professionals to carry out these steps.

One of the biggest hurdles that needs to be overcome to enable more resilience insurance pilot projects is the upfront cost of implementing an NBS project. USACE already supports NBS projects and could help identify projects within their funding portfolio that are well suited to also implement resilience insurance. Another opportunity is to identify land managers interested in resilience insurance and support them in pursuing funding, such as through FEMA pre-hazard mitigation funds (**Recommendation 14**), green and blue bonds, and Environmental Impact Bonds (**Recommendation 13**). Additionally, it would be valuable to develop cost estimates for implementing an NBS project, to help managers, environmental groups, and other potential buyers of resilience insurance identify appropriate levels of funding.

There are also important scientific hurdles involved in structuring resilience insurance coverages. For example, local hazard and resource managers may need support assessing baseline risk in areas where there is interest in piloting resilience insurance. Additionally, they may need support designing the NBS project and estimating the expected risk reduction benefits. USACE and other federal agencies, along with academic scientists, could work collaboratively with the private risk industry and local resource managers to help fill these scientific needs and advance the piloting of resilience insurance. ◆

Box 4. Piloting NBS risk reduction projects

There is a need for more NBS pilot projects to further demonstrate the effectiveness of NBS for risk reduction, and to help convince engineers and potential funders with lingering hesitations about the effectiveness of NBS. Myriad types of evidence exist that show the effectiveness of NBS for risk reduction, including observational data on damages during natural disasters with and without intact habitats and robust hydrodynamic modeling outputs. Nevertheless, more field studies on the effectiveness of NBS constructed with the express purpose of mitigating risks would further build the evidence base. There are likely abundant opportunities to partner with scientific or academic organizations to evolve pilot NBS risk reduction projects into larger research projects that can provide rigorous assessment of NBS benefits.

7 Recommendation 7: Include nature-based solutions in green building coverage enhancements

Context

Green building insurance policy enhancements (also called endorsements) could be used to incentivize property owners to rebuild damaged hard infrastructure with nature-based solutions (NBS) after a disaster. Policy enhancements are optional coverages that modify existing insurance policies. In the case of green building enhancements, they provide policyholders with additional funds if they rebuild more sustainably after a disaster, e.g., using sustainable practices and materials. Functionally, this encourages customers to upgrade their property at the time of loss. A similar insurance tool, called a supplemental coverage, can be used to achieve the same goal using a slightly different mechanism that layers on a separate supplemental coverage rather than modifying the terms of an existing policy.

Green building policy enhancements already exist to cover damage to buildings, and a similar type of coverage could be developed for nature-based solutions. In 2008, AXA XL released a green building enhancement in the U.K. called the Sustainable Property Endorsement (Insurance Times 2008). This enhancement applies to buildings and allows customers to collect an amount that exceeds the value of the damaged property provided they rebuild in accordance with the recommendations of the highly respected U.K. Building Research Establishment's Environmental Assessment Method (BREEAM). A similar type of enhancement could be developed that incentivizes construction of nature-based solutions during rebuilding. This type of enhancement would allow a policyholder to collect a greater payout if they rebuild damaged hard infrastructure with NBS. Even small to moderate incentives could effectively encourage landowners to develop NBS. In coastal Alabama, landowners indicated a willingness to restore salt marsh habitats instead of replacing damaged bulkheads with only small to moderate incentives (Scyphers et al. 2020).

Another challenge to overcome is that, even when green building policy enhancements are available, they are not always used. The underlying reasons for this are unknown, but may include insurers not advertising enhancements widely, buyers not finding them compelling enough to purchase, or buyers not rebuilding with sustainable infrastructure even if they did purchase the enhancement. Because they are seldom purchased, green building enhancements may be unfamiliar to claims workers, which could contribute to underuse. Further, insurance companies generally aim to settle claims as quickly as possible, and green building enhancements may cause a payout to take more time. The incentive structures in an insurance company may therefore inadvertently disincentivize the use of green building enhancements. It would be helpful to better identify the factors limiting the use of green policy enhancements so they can be addressed in order to encourage better rebuilding practices post-disaster.

Recommended actions for including NBS insurance enhancements

Developing green building insurance coverage enhancements (or supplemental coverages) that include incentives for NBS could help advance the uptake of NBS for risk reduction. These could be called Coastal Restoration Enhancements or Green Infrastructure Enhancements. These enhancements could incentivize a variety of NBS projects, from

living shorelines that reduce wave energy to green landscaping that effectively diverts and holds flood waters.

A key product need that would facilitate the development of this type of policy enhancement is guidance for the design and construction of NBS for risk reduction, similar to the BREEAM guidance that is referenced in AXA XL's Sustainable Property Endorsement. USACE is well suited to lead this effort, due to their scientific and engineering expertise.

To promote the use of green enhancements, insurance companies could alter internal company incentive structures to reward workers for using and documenting use of green policy enhancements. Insurance companies might be more motivated to set up these internal structures if this information was reportable in their environmental, social, and governance (ESG) and climate risk reports (**Box 9**).

Further, insurance regulators such as the California Department of Insurance, among others, could establish incentives to help drive the development, uptake, and use of green building enhancements, especially ones that include NBS for risk reduction. ◆

8 Recommendation 8: Support the development of catastrophe wrappers for debt instruments that fund nature-based solutions

Context

Catastrophe wrappers are an insurance tool that could help overcome one of the greatest barriers to the development and implementation of more nature-based solutions (NBS) projects: lack of funding. One of the ways that governments raise money for environmental projects, including NBS, is selling debt instruments, such as green and blue bonds (**Box 5**). However, governments can struggle to raise funds through this pathway if they have significant risks from natural disasters that increase their chances of defaulting on interest or principal payments to investors. This can be a barrier to raising funds for NBS projects as well as for other purposes.

An insurance tool that can help solve this problem is a catastrophe wrapper (also called a 'cat wrapper'), which provides an insurance payout (often through a parametric mechanism) that can be used to cover bond payments in the event of a covered catastrophe. A government with a catastrophe wrapper can better follow through on debt payments to investors, including those from green and blue bonds. They are therefore likely to receive a higher credit rating, which can help them raise more funds with better interest rates for projects, including NBS. This approach was pioneered by WTW and Munich Re when they designed the "Blue Bond Catastrophe Wrapper" for Belize (Evans 2021a). Belize had an existing blue bond organized by The Nature Conservancy's NatureVest program and Credit Suisse, and they faced some risk that they would not be able to pay back the funds in the event of a severe hurricane (TNC 2022). WTW created a separate cat wrapper coverage that would pay out in the event of a triggering hurricane, thereby making it more likely Belize would be able to continue making payments on their blue bond and other debt instruments. Triggers for the catastrophe wrapper were aligned with the severity of historical hurricanes that had impacted Belize's ability to make payments on its debt. This cat wrapper led to a 3-level jump in S&P's sovereign credit rating for Belize. In this example, Belize's blue bond does not have an NBS element to it, but a similar cat wrapper could be designed for a bond that funds NBS projects.

Recommended actions for developing cat wrappers to de-risk bonds that fund NBS

Insurance brokers, (re)insurance companies, development organizations, risk managers, conservation organizations, and governments could work together to identify places where catastrophe wrappers could be used to increase governments' capacity to raise funds for NBS through green and blue bonds and other debt instruments. It would be valuable to bring these actors together to explore opportunities to advance NBS with catastrophe wrappers.

The following steps could help promote catastrophe wrappers for NBS:

1. **Cultivate relationships between actors involved in designing NBS, blue and green bonds, and catastrophe wrappers.**

2. **Identify candidate places to implement cat wrappers for bonds that fund NBS.** Ideal places would have governments with credit ratings constrained by exposure to natural disasters, who are interested in raising money for NBS through debt instruments such as green and blue bonds.

3. **Identify potential NBS projects that would provide substantial disaster risk reduction benefits** for these governments, and then design green and blue bonds that could fund the construction of these NBS.

4. **Design catastrophe wrappers** that could help increase the credit ratings of governments issuing green and blue bonds**.** Match the trigger for each catastrophe wrapper with the severity of catastrophe likely to cause the government to default on repayments of debt instruments, thereby lowering the chances that default occurs. ◆

Box 5. Green and blue bonds

Green and blue bonds are fixed-income debt instruments that can be issued by an entity, such as a government, to raise funds for projects with positive environmental impacts. The bond issuer receives money from investors who buy the bond, and then pays interest at regular intervals to the investors, and finally pays back the principal when the bond has matured. Green bonds cover a variety of projects related to climate or the environment, while blue bonds are more specifically focused on raising funds for marine or ocean-based projects that benefit the environment or climate (World Bank 2018).

To qualify as a green or blue bond, a bond is usually verified by a third party, such as the Climate Bond Standard Board, that certifies the bond will fund projects with environmental benefits. The first bond labeled as a "green bond" was sold by the World Bank in 2008. Since then, interest in green bonds has grown dramatically, with nearly $270 billion in green bonds issued in 2020 (Climate Bonds Initiative 2021). Blue bonds are newer, with the Republic of Seychelles launching the first sovereign blue bond in 2018 (World Bank 2018).

Martin Colognoli / Ocean Image Bank

9 Recommendation 9: Develop insurance coverages for carbon credits

Context

Insurance could help raise money for nature-based solutions by de-risking investments in nature-derived carbon credits. Carbon credits are a tool for raising funds for carbon mitigation projects. Essentially, a project that mitigates carbon can be verified and then listed on a carbon marketplace, and carbon credits from that project can be sold to buyers who want to help mitigate climate change. A subset of carbon credits are created through nature-based projects such as tree planting, active forest management for carbon storage, and protection or restoration of coastal wetlands (Griscom et al. 2017). Nature-based solutions (NBS) are among the lowest-cost and most ready-to-implement carbon mitigation strategies available, and they have the potential to provide one third of the total carbon mitigation required to keep global warming under 2 °C by 2030 (Griscom et al. 2017). Carbon credits can provide valuable revenue for NBS projects for many years. For example, a forest restoration project can yield carbon credits for more than 20 years (Matzek et al. 2014). Many NBS carbon projects also provide valuable hazard mitigation benefits. For example, mangrove restoration projects can both sequester carbon and provide flood protection benefits to nearby communities (Zeng et al. 2021). Therefore, developing insurance to de-risk investments in nature-derived carbon credits could help support the development and implementation of more NBS projects, both for carbon storage and risk reduction.

Carbon credits from NBS projects that provide both carbon storage and hazard adaptation benefits are called "dual-benefit" carbon credits, and can be sold for a higher price, thereby incentivizing projects that serve both functions. The Climate Community and Biodiversity (CCB) carbon credits that were developed in 2014 by the Climate Community and Biodiversity Alliance, in collaboration with other partners, are an example of "dual-benefit" credits (VERRA 2017). Demand is growing for these kinds of carbon mitigation projects that also produce community co-benefits. For example, the use of the verification standard for CCB credits increased by 277% from 2020 to 2021 (from 17.4 MtCO2e to 65.9 MtCO2e) and credits from projects with verified co-benefits beyond carbon mitigation sold for three times higher prices (FTEM 2022). Overall, the potential for carbon credits to support nature is rapidly growing. Growth trends of the voluntary carbon market indicate that the carbon credit industry could be worth $50 billion per year by 2030, a 15-fold increase from 2020 (TSVCM 2021).

However, nature-based carbon storage projects face risks of carbon storage reversal due to fires, deforestation, and erosion. As investments in nature-based carbon credits rise, addressing these risks will become increasingly important to investors. Insurance is not currently being used, but is actively being considered, to cover the risk of carbon storage reversal. This would help de-risk investments in nature-based carbon credits, scale up the voluntary carbon market, and promote NBS as a preeminent source of reliable carbon credits. This insurance could be purchased either by buyers or sellers of carbon credits, and the insurance payouts could be used to restore lost credits (e.g., replant trees, monitor mangrove damage).

To date, the only insurance product that exists for carbon credits involves protecting buyers of fraudulent or "bad" carbon credits. Developed in 2016 by U.K. reinsurance broker Howden, the product covers a portfolio of verified carbon credits. In the event that some of those credits are fraudulent, the verifier (Respira) can make a claim and compensate the buyers of those "bad"



credits (Jessop et al. 2022). This product arose due to the high risk and uncertainty associated with the voluntary carbon market in the early 2000s when certification standards for carbon offset projects were essentially nonexistent. Since then, voluntary and non-voluntary carbon markets have become much more established and companies like Verra provide global standards for certifying carbon offset projects, thereby reducing the risk of low-quality carbon credits. These developments, as well as blockchain registries have helped to improve transparency and build trust in the industry. While there is a decreasing need for insurance for fraudulent or "bad" carbon credits, there is still a real need for insurance to cover the risk of carbon reversal in nature-derived carbon credits.

Recommended actions for developing insurance for carbon credits

Developing insurance products to cover the risk of carbon storage reversal could help de-risk the purchase of nature-derived carbon credits, which could build investor confidence and ultimately help carbon markets be a stronger source of funding for NBS. Through "dual-benefit" carbon credits, which come from projects that provide both carbon storage and risk reduction benefits, carbon markets can support not only NBS carbon projects, but also NBS risk reduction projects.

Federal and state risk managers, including USACE, could support the development of more "dual-benefit" carbon credits by helping to identify NBS projects that provide both carbon storage and hazard adaptation benefits, and then collaborating with carbon verifying organizations to develop the carbon credits for those projects. These "dual-benefit" carbon credits could be labeled or certified as such and sold to investors for a higher premium, hopefully boosting interest in developing NBS projects that meet both carbon sequestration and hazard mitigation objectives.

Another critical need that scientists at USACE and other agencies could help support is quantifying the risk of carbon storage reversal for nature-based carbon credits. Better quantification of these risks would inform the design of insurance coverages for carbon credits. For example, better estimations of the risk of carbon loss due to wildfire could greatly inform our understanding of the risks associated with carbon credits from reforestation projects. Similarly, erosion modeling could inform our understanding of the risks associated with blue carbon credits, such as those from mangroves and

salt marshes. Further, in some regions of the world, corruption or weak enforcement of environmental protections mean that carbon may be lost due to illegal deforestation or ecosystem mismanagement, and quantification of these risks would also be very valuable. These risk estimates would vary by region, ecosystem, and threat.

Beyond these scientific contributions, there is a need for knowledge-sharing and relationship-building among risk management agencies (such as USACE, the FEMA, etc.), insurers, and carbon credit certifiers to support the development of insurance products that could de-risk NBS carbon credits. ◆

Public-Private Partnerships

Background on public-private partnerships

Successfully integrating insurance and nature-based solutions (NBS) will require participation by many different groups, from local communities to public risk management agencies, insurers, risk modelers, and academics. Each of these actors has an important role to play in incentivizing, designing, implementing, and maintaining solutions that link NBS and insurance. Local communities have knowledge about hazards and social context, and they provide much of the labor for NBS projects. Public risk management agencies, such as the U.S. Army Corps of Engineers (USACE) and the Federal Emergency Management Agency (FEMA), provide funding and technical expertise for NBS. Risk modelers and insurers can create products that incentivize construction and maintenance of NBS. Academics can provide technical and educational support and bridge gaps between other actors.

Public-private partnerships can advance the integration of nature into insurance by filling knowledge gaps and building much-needed capacity around NBS and insurance. While NBS risk reduction projects make sense scientifically and economically, they have been underutilized due to a lack of knowledge and capacity. For example, most local communities lack sufficient capacity to design, build, maintain, monitor, and insure NBS risk reduction projects. This is especially true for more vulnerable communities, which tend to have the lowest capacity, which in turn limits their ability to take steps to mitigate their risks, thereby perpetuating their vulnerability. These community capacity needs could be improved through partnerships with public risk management agencies, the private risk industry, and academia. On the other hand, public risk management agencies could benefit from collaborations with the private risk industry to jointly advance the science and practice of risk modeling and financial strategies to advance NBS for risk reduction. As for the private risk industry, they could benefit from a deeper scientific and engineering understanding of NBS, which academic institutions and public risk managers such as USACE could help provide. Public-private partnerships can help break down traditional silos and build the skills and knowledge necessary to advance the inclusion of nature into insurance and, ultimately, increase implementation of NBS for risk reduction.

This report identifies three specific ways that public-private partnerships can jointly advance NBS and insurance. First, public-private partnerships between local communities, public risk managers, the private risk industry, and academics could help build community capacity around NBS and insurance (**Recommendation 10**). Second, creation of professional development courses on NBS for public risk managers and private risk industry professionals could help increase integration of nature within risk industry tools and help overcome barriers to implementation of NBS for risk reduction (**Recommendation 11**). Finally, stronger working relationships between public risk managers, such as USACE, and the private risk industry could advance the science of risk modeling and spark innovations that link risk reduction to risk transfer in ways that increase resilience and support NBS (**Recommendation 12**). FEMA's engagement with the private risk industry in the last decade demonstrates the potential of this kind of public-private partnership. FEMA has been a leader among public risk management agencies in engaging with the private risk industry and has improved the financial viability of the National Flood Insurance Program (NFIP) through these partnerships (**Figure 6**). ◆

10 Recommendation 10: Develop community capacity to plan, implement, maintain, and insure nature-based solutions

Context

There is growing interest from communities in using nature-based solutions (NBS) as a tool for climate adaptation, yet community capacity for designing, implementing, and maintaining NBS is low nearly everywhere (FEMA 2021b). Communities are often drawn to NBS for their more natural landscapes, the benefits they can provide to local economies, and the increasing number of public funding opportunities for NBS, e.g., FEMA Building Resilient Infrastructure and Communities (BRIC) funding (Nesshöver et al. 2017). While there is a diversity of guidance for how to carry out NBS projects (FEMA 2021b, World Bank 2017, TNC 2021b, Pathak et al. 2022, FEMA 2020a), there is still a significant need to build the necessary skills within communities to make use of this guidance. Key skills include stakeholder engagement, modeling, grant-writing, engineering, and project management, among others.

Building community capacity around risk mitigation and NBS is critical to ensure that communities can fully and competently engage in the design and management of their risk reduction strategies, and that NBS are available as tools in their toolbelt (Munich Re and TNC 2021b). Community involvement in risk planning may also increase long-term success of risk mitigation efforts because communities understand the context and vulnerabilities specific to their community (e.g., mobility of residents, informal social safety nets, patterns of movement and resource use, etc.), and are in close proximity to the project, allowing easier access for monitoring and maintenance (Giordano et al. 2020, Bernhardt et al. 2021).

Importantly, building community capacity is a way to advance equity in hazard mitigation because capacity gaps tend to be most severe in disadvantaged communities, which can prevent them from securing funding for hazard mitigation and post-disaster recovery, which can in turn perpetuate a cycle that reinforces inequalities. Advancing equity is a top priority for federal agencies in the U.S., especially since the announcement of the Justice40 Initiative, which calls for 40% of all benefits from covered federal programs to flow to disadvantaged communities (Executive Order 14008 2021). Building local capacity is a critical component of fulfilling this mandate.

When developing community capacity, it could be useful to engage with existing governance structures such as city, county, or state governments; Geologic Hazard Abatement Districts; FireWise Communities; soil and water conservation districts; or levee districts. The appropriate group will depend on the type of disaster risk being considered, the character of the landscape, and the strength of existing governance structures. For some situations, a new administrative unit may be needed.

Public risk managers and the private risk industry both have strong reasons to invest time and resources in building community capacity around NBS. For risk managers, building community capacity helps support the success of risk mitigation projects. For the private risk industry, the benefits are twofold. First, enhancing the success of mitigation projects reduces risks, potentially helping to keep insurance viable in a context of rising global risks. Second,

building a community's capacity around NBS also lays the foundation for the community to become a competent, informed potential buyer of community insurance policies in the future. There is broad interest within the private risk industry in developing and expanding community-based catastrophe insurance products, which could cover damages to NBS infrastructure, residences, businesses, or other public infrastructure. The potential benefits from community-based catastrophe insurance include enhanced community financial resilience, increased coverage affordability, and increased incentive to implement community-scale mitigation projects (Bernhardt et al. 2021).

Recommended actions for developing community capacity

Public risk managers, including USACE and FEMA, could collaborate with academics and risk industry professionals to help communities build skills and knowledge relevant to NBS and insurance. We suggest a few potential pathways to achieve this aim.

- **Technical Assistance Teams:** Risk management agencies, such as USACE and FEMA, could send teams to help underserved communities learn about and build skills for undertaking an NBS project. These teams could function in a manner similar to FEMA's BRIC Technical Assistance Program (FEMA 2021c). Teams could organize and lead workshops to guide communities through the NBS planning process, build skills in project design and scientific monitoring, and connect communities to NBS project partners.

- **Hazard planning support:** Federal risk managers could also assist communities and states to incorporate NBS into planning documents like climate action plans (CAPs), hazard mitigation plans (HMPs), and disaster recovery plans (DRPs) during periodic updates to these documents. Including NBS in these

documents can help increase the chances of receiving federal funding for NBS projects (**Recommendation 14**).

- **Adaptation extension specialists:** Academic institutions, in collaboration with federal risk management agencies and insurers, could create adaptation extension specialist positions as a resource for municipalities interested in pursuing NBS adaptation projects and insurance coverages. Communities could reach out to these specialists, who could provide information and connect them to additional resources and partners.

- **Seed grant funding:** Federal agencies, such as USACE or FEMA, could consider distributing seed grants to communities to fund NBS pilot projects. This would help build community capacity for NBS and create a pipeline of much-needed NBS demonstration projects (**Box 4**). A seed grant program could be modeled off of the National Science Foundation's Stage 2 Civic Innovations Grant, which, in 2021, provided almost $1 million in seed funding to develop a pilot for parametric community-based flood insurance in New York City, where flood insurance uptake among low- and middle-income households is disproportionately low, but flood impacts are high (Kousky and Wiley 2021). Following this model, seed funding and technical assistance could be provided to communities at high risk from natural disasters around the country. Once pilots are established and flourishing, the responsibility for paying the premium could shift from the agency providing the seed funding (e.g. USACE, FEMA, or another potential funder) to the community, state, or other federal mitigation assistance programs. Seed funding for these pilots could be targeted particularly at disadvantaged communities, promoting resilience in these communities and aligning with the Justice40 Initiative. ◆

11 Recommendation 11: Support training and professional development on nature-based solutions

Context

Creating a professional development course on nature-based risk reduction projects could help build much-needed capacity among risk professionals in public agencies and private industry. Many risk modelers believe the risk reduction benefits from habitats are very small and not worth assessing. This is far from the truth, since habitats such as salt marshes and mangroves can reduce damages from natural disasters by 15%-25% (**Figure 2**, Narayan et al. 2017, Narayan et al. 2019). Further, many engineers have more experience with, and therefore more confidence in, hard infrastructure than nature-based solutions (NBS), which can reinforce selection of hard infrastructure projects over NBS. These knowledge gaps limit the use of NBS for risk reduction, which means substantial nature-based mitigation opportunities are being missed.

Some educational resources on NBS already exist (or are in development) that could be utilized in the creation of a professional development course on NBS adaptation projects. The U.S. Army Corps of Engineers (USACE) has partnered with the University of Georgia to develop resources on NBS for engineers. The Federal Emergency Management Agency (FEMA) has also created relevant education materials (e.g., FEMA 2021b).

We have observed keen interest in this topic from diverse organizations spanning academia, risk science, insurance, engineering, and conservation, particularly as there is increasing pressure on agencies and companies to mitigate risks associated with climate change and nature loss (e.g., from the White House, Securities and Exchange Commission, Task Force on Climate-related Financial Disclosures, Taskforce on Nature-related Financial Disclosures). We have heard from multiple groups interested in collaborating on such a professional development course, including Guy Carpenter (a reinsurance broker), AXA XL (an insurance/reinsurance company), and AECOM (an engineering company), to name a few. This curriculum could be offered as part of continuing education credits for licensing organizations or lead to an NBS certification.

Recommended actions for advancing professional development around NBS

We recommend the creation of professional development courses on NBS, specifically for risk managers and risk industry professionals. Building capacity among these groups would enable more widespread implementation of nature-based risk reduction projects and foster the creation of more nature-positive insurance products. To ensure the relevance and uptake of such courses, we recommend they be created collaboratively with input from private industry modelers, public and private (re)insurers, public risk management agencies (such as USACE and FEMA), municipal leaders, and academics. USACE is already engaged in capacity-building efforts for risk managers related to NBS and could play a valuable role supporting expanded capacity-building efforts.

Some of the topics that could be covered include:

- **Science on the effectiveness of NBS for risk reduction**, including diverse evidence from sources such as engineered NBS projects (e.g., Depietri and McPhearson 2017), observational studies of natural ecosystems (e.g., Chausson et al. 2020), and mesocosm experiments (e.g., Bai et al. 2022)

- **Current climate change projections**, including changes in temperatures, sea levels, ocean


Beth Watson / Ocean Image Bank

acidification, waves, and storms and associated information on the expected performance of NBS under future climate scenarios

- **Effects of climate change on NBS**, including, for example, how projects such as reef restoration will fare with climate change, what future maintenance costs might be, and how these compare to those for gray infrastructure
- **Guidance on designing NBS to future climate conditions** and how to document those decisions and communicate expectations, uncertainties, and risks effectively to clients
- **Resistance and resilience of NBS to hazards** and implications for ongoing maintenance costs
- **Guidance on modeling the risk reduction benefits of NBS** and key applications
- **Benefit-cost analyses for NBS**
- **Policy landscape relevant to NBS**, including environmental, social, and governance (ESG) reporting, Task Force on Climate-related Financial Disclosures (TCFD) and Taskforce on Nature-related Financial Disclosures (TNFD) recommendations, and Securities and Exchange Comission (SEC) requirements
- **Funding pathways for NBS**, from FEMA BRIC to corporate investments, to the possibility of adaptation credits and an adaptation marketplace
- **Insurance coverages that support NBS**, e.g., by covering potential damages to habitats from hazards, by de-risking NBS investments, or by incentivizing investments in NBS for risk reduction
- **Professional liability insurance for NBS projects**
- **Equity and engagement best practices** for designing and implementing risk mitigation projects

To boost interest from industry professionals, these courses could be offered as part of an NBS certificate program endorsed by USACE or could count towards continuing education credits through professional organizations such as the American Institute of Architects (AIA), the American Council of Engineering Companies (ACEC), and the California Department of Insurance's licensing program. ◆

12 Recommendation 12: Develop working relationships between public risk managers and the private risk industry

Context

Closer working relationships between public risk management agencies, such as the U.S. Army Corps of Engineers (USACE), and the private risk industry could lead to joint learning and powerful opportunities to advance nature-based solutions (NBS). USACE is a seasoned leader in the design and implementation of risk reduction infrastructure and NBS, while the private risk industry has deep expertise in pricing risks and financial planning, and both entities have their respective strengths in risk modeling.

Through collaboration with the risk industry, USACE could learn different ways to model risks and make financial plans for their infrastructure projects. Integrating these skills with their own expertise on NBS could lead to improved analyses that show the strengths of NBS (e.g., natural regenerative potential, strong protection for high-frequency/low intensity flood events that are currently often overlooked, undervalued wave-breaking benefits) and potentially lead to more frequent selection of NBS projects over hard infrastructure alternatives. Better risk modeling and financial planning can also help avoid unexpected budget shortfalls and moral hazards that can arise if risks associated with self-insured projects are inadequately measured and communicated to taxpayers (**Box 6**).

By working more closely with USACE, insurance companies can deepen their knowledge about NBS in ways that strengthen their top line and advance NBS. For example, many insurance companies are developing risk consulting services as an additional revenue stream, as well as offering these services pro bono in some cases to support good causes and enhance their reputations. NBS for risk reduction could be incorporated into these risk consulting services, which would be a value-add for clients, and could bolster an environmentally friendly

Box 6. Moral hazards

A moral hazard is a situation where one party's behavior influences risk borne by another (Baker 1996). This can lead to a lack of incentive for someone (a person, a community, an agency, etc.) to guard against risk because they are protected from its consequences, e.g., because someone else will pay for them or they are 'too big to fail' (Cunningham 2006). Similarly, the term moral hazard can also be used to describe a situation where someone enters into a contract in bad faith.

In the case of self-insured federal government infrastructure projects, a moral hazard can arise if the risks for a project have not been appropriately assessed and communicated to the ultimate payer who will cover costs if a disaster occurs – in this case, federal taxpayers. This is a moral hazard because taxpayers are on the hook for damages without having had the appropriate risk information in advance.

image for insurance companies. An example of the transformative potential of industry risk consulting services can be seen in The Insurance Development Forum, a public-private partnership led by insurance companies with the mission of using insurance and related risk management skills to build resilience in communities that are vulnerable to disasters (https://www.insdevforum.org/).

Beyond strengthening existing programs within each organization, collaboration between USACE and the private risk industry could lead to novel opportunities to link risk reduction with risk transfer – both critical elements of comprehensive risk planning, but which are rarely planned for and carried out together.

Recommended actions for fostering collaboration across the public and private risk sectors

Insurers and public risk managers, such as USACE, could pursue working relationships to jointly advance nature-based solutions and link risk reduction with risk transfer in novel ways. These working relationships could be cultivated through joint workshops and cooperative agreements. Close collaboration would support many of the recommendations presented in this report. Specific topic areas with significant potential for USACE and the private risk industry to learn together and collaborate include the following:

1. **Improving how habitats are included in risk models and risk assessments**. There is substantial room for improvement in how habitats are included in risk models and risk assessments by both the private risk industry and public risk managers (**Recommendation 1**). In addition, there is an opportunity for the private risk industry to incorporate NBS into their risk consulting services, thereby educating clients about the risk reduction benefits provided by nature and supporting expanded implementation of NBS.

2. **Incorporating climate change scenarios into risk analyses**. Climate change is expected to increase the frequency and intensity of natural disasters and it is important to include these projected changes into risk analyses and mitigation plans (**Recommendation 3**). USACE could incorporate this information into analyses of the expected benefits from infrastructure projects, which are intended to provide protection for decades to come. In addition, extreme climate events can damage infrastructure, so it is important to consider how climate change might impact infrastructure maintenance costs. In light of this, the resistant and resilient qualities of NBS may become even more important with climate change. To understand the complete picture of maintenance costs, there are several science gaps that need to be filled, such as fragility curves for habitats (**Recommendation 4**) and data on decommissioning costs. The private risk industry could be a valuable collaborator in exploring how to best incorporate climate change into risk models and strategizing how to marshal the efforts and resources to mitigate these growing risks.

3. **Advancing how waves and erosion are modeled** (**Recommendation 2**). USACE and private risk industry both have projects and opportunities that would greatly benefit from improved modeling of waves and erosion. For USACE, this work could promote national security and increase coastal resilience. For the private risk industry, it could open new markets for insurance, reduce uncertainty in risk assessments for vast regions, and improve the accuracy of risk results for places where waves are a major driver of risk.

4. **Exploring potential opportunities down the road where it could be beneficial for USACE to transfer risks** associated with their risk mitigation work, as FEMA did (**Figure 6**). ◆

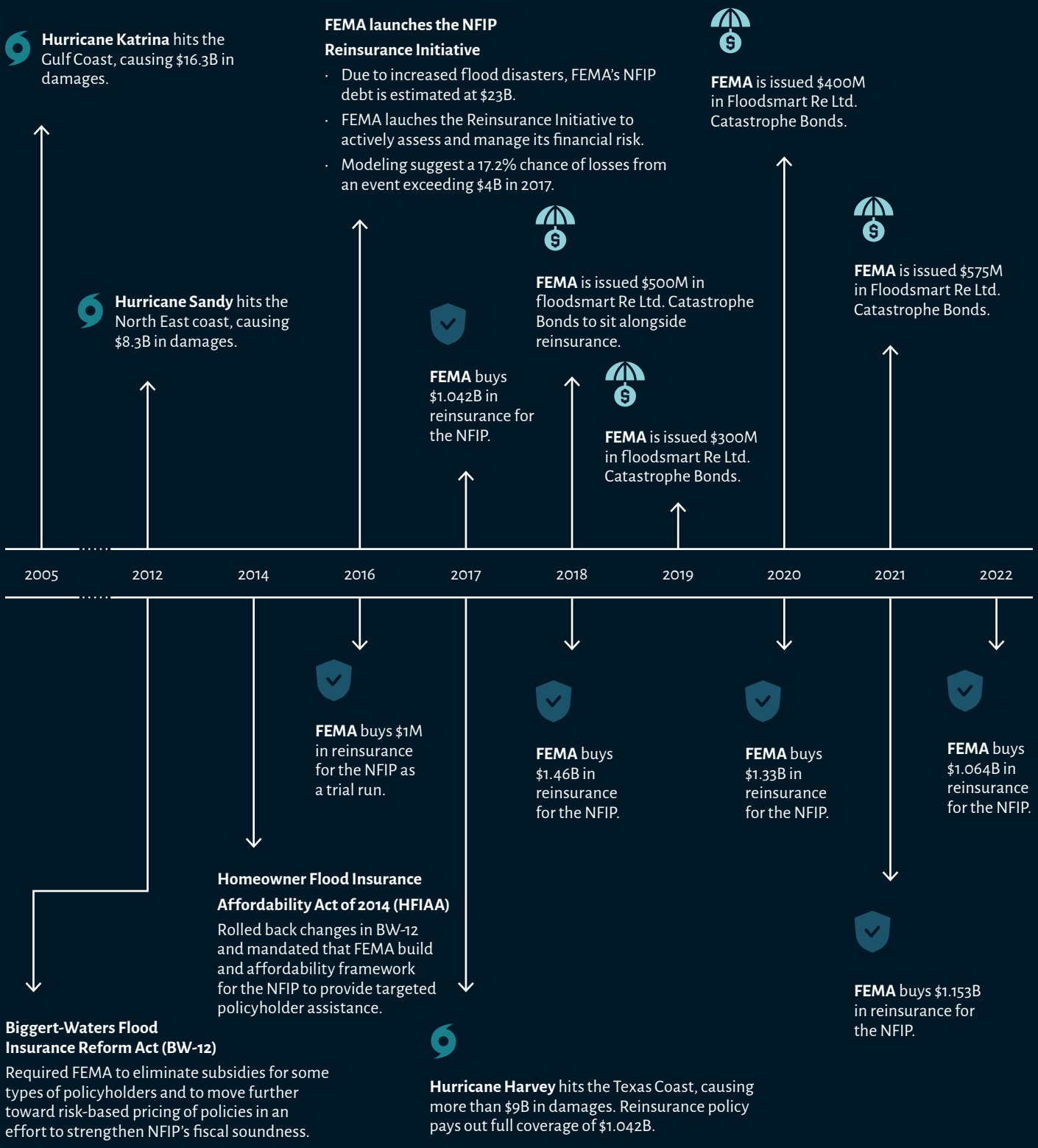


Figure 6. Timeline for FEMA's engagement with reinsurance to transfer risk from the NFIP. More frequent and intense flooding disasters, particularly Hurricanes Katrina (2005) and Sandy (2012), paved the way for interest in reinsurance. In 2012 and 2014, congress passed two federal policies to support FEMA's entrance into the public and private risk financing markets. FEMA purchased a trial run $1 million indemnity reinsurance policy in 2016 (Artemis 2016), and purchased a $1.042 billion expanded policy in 2017 (Artemis 2017), which paid out the full coverage in 2018 due to Hurricane Harvey in Texas (Artemis 2018a). Since then, FEMA has continued to purchase flood reinsurance on an annual basis (Artemis 2019, Evans 2021c, Evans 2022a, Evans 2023). In addition, FEMA secured additional reinsurance for the NFIP through insurance linked securities (ILS), in the form of catastrophe bonds ('CAT' bonds) (Evans 2019), which are a tool used by insurers to transfer part of their risk to private capital markets.

Hannes Klostermann / Ocean Image Bank

Financing Opportunities

Background on financing opportunities

Lack of funding is one of the key factors limiting the proliferation of nature-based adaptation projects, and there is an opportunity to unlock significant new funding for these projects through engagement with the private risk industry. The underfunded state of nature-based adaptation projects is exemplified by the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program (HMGP), which is one of the most important funding sources for post-disaster recovery and adaptation in the U.S., but which largely does not fund nature-based solutions (NBS) projects. In fact, the first ever instance of an HMGP-funded NBS happened recently, in June 2023, when FEMA allocated $3 million for the first phase of a coral reef restoration project in Puerto Rico (Blakemore 2023). Hopefully this precedent will pave the way for more HMGP-funded NBS. Another example of the underfunded state of NBS adaptation projects is how little climate funding they receive. Climate funding, which comprises hundreds of billions of dollars annually from both public and private sources, funds very few adaptation projects relative to carbon mitigation projects (**Box 7**); and even fewer *nature-based* adaptation projects. Climate change impacts are here now, and there is a pressing need to adapt, and an opportunity for NBS to be a large part of that effort. The U.S. Army Corps of Engineers (USACE) is one of the organizations leading in this space, having funded and implemented numerous NBS adaptation projects, many of which are described in the Engineering With Nature Atlases (Bridges et al. 2018, 2021). Despite this bright spot of USACE support, lack of funding remains one of the greatest barriers to NBS adaptation projects, and one of the most important to overcome.

Insurance can help generate funding for NBS adaptation projects through multiple pathways, including 1) tools that de-risk investments in NBS, 2) post-disaster recovery payouts for insured habitats, and 3) direct investments in NBS from insurance companies as part of corporate sustainability goals.

1. De-risking NBS investments: Insurance tools that de-risk NBS investments include catastrophe wrappers (**Recommendation 8**), which can de-risk investments in, for example, green and blue bonds; insurance coverages for carbon credits (**Recommendation 9**), which can de-risk investments in nature-derived carbon credits; and Environmental Impact Bonds (**Recommendation 13**), which are low-risk debt instruments that can help raise capital for NBS projects. Catastrophe wrappers and insurance for carbon credits are covered in the Insurance Coverages section of this report, while Environmental Impact Bonds are covered in this section.

2. **Post-disaster payouts for habitat restoration**: Another way insurance can help fund NBS is by providing post-disaster payouts to fund habitat restoration. An example of this type of coverage is the Mesoamerican Reef insurance policy (**Box 3** and **Recommendation 5**). There is an opportunity to expand the use of these types of coverages by including them in disaster plans at the national, state, and local levels (**Recommendation 14**).

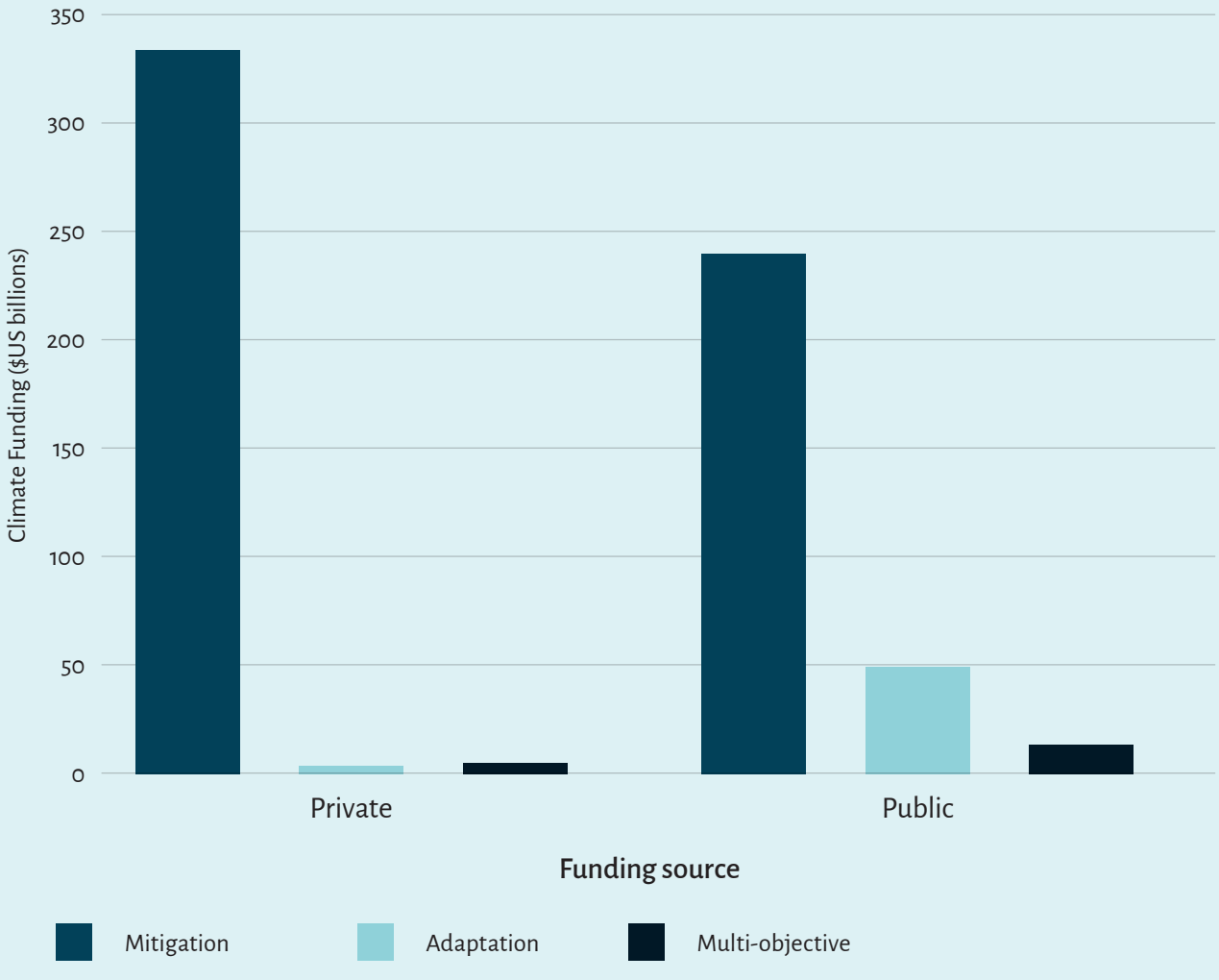
3. **Direct investments in NBS from insurance companies**: Many companies, including those in the risk industry, are increasingly motivated to invest in sustainability by environmental, social, and governance (ESG) scores and risk reporting. There is an opportunity for NBS adaptation projects to be part of these corporate sustainability efforts. Developing guidance on how to evaluate the adaptation benefits of NBS projects (**Recommendation 15**) would help corporations include NBS in their corporate sustainability strategies. For companies in the risk industry, NBS adaptation projects could be particularly compelling because they not only support a sustainable corporate image, but they also support the future viability of the insurance industry by reducing near-term risks, thus helping to keep insurance more affordable and viable

into the future. While the risk reduction benefits from adaptation projects are often not enough on their own to motivate (re)insurance companies to single-handedly fund adaptation projects, they might be enough to spur investment when combined with momentum around ESG and risk reporting.

These recommendations can help expand funding for NBS adaptation projects, which is a critical step to scaling them up for widespread impact. ◆

Box 7. Climate funding under-supports adaptation

Impacts of climate change are here now, yet adaptation projects receive very little climate funding relative to carbon mitigation projects. While mitigating carbon is critically important for minimizing future risks, it is not enough – we must also adapt to the risks that are already here. Despite this, only ~10% of current climate funding goes to adaptation projects, and most of that comes from public sources, with less than 1% of private climate funding going to adaptation (Climate Policy Initiative 2021). There is a pressing need to increase funding for adaptation projects, and a specific opportunity to increase funding from private sources.



13 Recommendation 13: Consider Environmental Impact Bonds as low-risk funding for nature-based solutions

Context

Environmental Impact Bonds (EIBs) could help municipalities raise low-risk funds for nature-based solutions (NBS). An EIB functions similarly to other bonds, except it must be used to fund an environmental project and it is often designed so the amount investors are repaid is dependent on the success of the project (Brand et al. 2021, Chen and Bartle 2022, Tiikkainen et al. 2022). This transfers some of the risk of the project to investors, thereby de-risking the project for the municipality or other issuer of the EIB, which could help encourage more municipalities to try nature-based solutions.

How Environmental Impact Bonds work

A municipality seeking funding for an environmental project, such as an NBS project, can design an EIB to sell to investors to raise money for the project. The seller of the EIB commits to measuring and reporting project impacts. If the project is successful, the municipality pays back the principal plus additional returns to investors. However, if the project is not successful, then the municipality may not need to pay back investors the full amount of the principal plus interest, with repayment details dependent on how the bond is structured. EIBs can be structured in different ways to meet the needs of the seller. Therefore, an EIB is essentially a form of risk transfer, where some or all of the project risk is transferred from the seller of the EIB to the investors.

Environmental Impact Bonds for NBS

Environmental Impact Bonds have already been used by some municipalities to fund certain kinds of NBS, such as stormwater management, but their use could be expanded to other types of NBS projects (Chen and Bartle 2002, Tiikkainen et al. 2022). In 2016, DC Water issued the first ever EIB to fund stormwater solutions such as permeable pavement and rain gardens (DC Water is Life 2021). While it has not been done yet, EIBs could be developed to fund coastal NBS flood risk reduction projects, such as coral reef, mangrove, or salt marsh restoration. In fact, Louisiana is currently considering creating EIBs for wetland restoration, using the area of wetland restored as the metric of success for the EIB, rather than a direct measurement of risk reduction benefits from wetlands (Herrera et al. 2019). Further, EIBs could be used by municipalities to raise their matching funds for NBS projects carried out in collaboration with the U.S. Army Corps of Engineers (USACE) or other partners.

Recommended actions for developing EIBs

Communities could consider developing EIBs to raise capital for NBS adaptation projects. Risk management agencies, such as USACE and FEMA, could support these efforts by providing communities with guidance and resources to help them develop EIBs. For example, USACE could offer this support to communities collaborating with USACE to build an NBS project, in order to help communities raise their portion of project funds. This support could include sharing information with communities about EIBs, connecting them with relevant financial experts, or helping communities build their capacity to monitor and report on project success, which is a requirement for EIBs. This recommendation to build community capacity for EIBs dovetails with our broader recommendation to build community capacity relevant to NBS (**Recommendation 10**).

To successfully develop and follow through on an EIB, it is necessary to monitor project success. Depending

on how the EIB is structured, this could be measured in terms of acres of habitat created or restored, in terms of the amount of risk averted (e.g., based on modeled risk reduction estimates), or on other metrics for desired outcomes. Selecting useful, measurable metrics is an important part of developing quality projects, and federal agencies, such as USACE, could play a key role in supplying relevant guidance. Similar work is outlined in our recommendation on creating guidelines for measuring benefits from NBS (**Recommendation 15**). ◆

Ian Markham

14 Recommendation 14: Include nature in national, state, and community disaster mitigation and recovery plans

Context

Including nature-based solutions (NBS) in disaster plans can reduce risks for people and property, support conservation and restoration of habitats, and make disaster response more financially efficient. Approaches to disaster planning vary by country, but often include plans for 1) risk mitigation before disaster strikes, 2) immediate response actions after a disaster, and 3) longer-term recovery. Currently, nature is under-represented or completely absent from most disaster plans. It would be particularly valuable to incorporate nature into pre-disaster risk mitigation plans (#1 above) and post-disaster longer-term recovery plans (#3 above), while immediate post-disaster response plans (#2 above) are appropriately focused on life-saving actions for people, and do not typically need to address nature. The World Bank recognizes the importance of disaster plans that include risks to habitats and works with countries to help create them. For example, we learned through our conversations with the World Bank that they are currently working with the Mexican federal government to update FONDEN, Mexico's Natural Disaster Fund, to include habitats. However, this is still a rarity and most national adaptation and disaster plans do not cover nature.

Disaster plans are more useful if they consider how to fund their mitigation, response, and recovery actions, yet this financial piece is not always present. Especially after a disaster, resources (e.g., time, person power, and money) are often stretched thin and a pre-existing financial plan can help facilitate the rapid and equitable deployment of resources (Donahue and Joyce 2001).

In the U.S., The Federal Emergency Management Agency (FEMA) is the federal agency responsible for disaster response and recovery. They provide extensive guidance to help local regions develop pre-disaster hazard mitigation and post-disaster response and recovery plans. There are important opportunities to incorporate ecosystems into hazard mitigation plans (#1 above) and recovery plans (#3 above).

Hazard mitigation plans

Hazard mitigation plans (HMPs) are written by localities and include detailed risk assessments that inform mitigation, response, and recovery planning. Nature is generally missing from these risk assessments and its inclusion would increase awareness of nature's risk reduction benefits and strengthen arguments for investing in nature for risk reduction. Additionally, HMPs include lists of shovel-ready projects that would increase resilience of a region. To be eligible for FEMA Hazard Mitigation Assistance (HMA) funding, a project or action must be listed in a jurisdiction's HMP. These plans are mandated to be updated every 5 years, so there is an opportunity for regions that do not currently include NBS to add them in future updates.

Recovery plans

Localities write regional recovery plans that outline critical actions and direct the flow of resources (e.g., people, money, and supplies) for the weeks, months, and years after a disaster. Nature is not well represented in most regional recovery plans, which means that resources are less likely to flow to nature after a disaster. Further, most regions fail to set aside or secure timely funding for habitat recovery actions. Much of FEMA's post-disaster funding to states and regions is provided in the form of reimbursements, which means that states and territories need to have the necessary resources on hand to pay for time-sensitive post-disaster response and recovery actions, and then submit those expenses

for reimbursement later. If states or regions have not done adequate financial planning, they can be financially limited in their ability to act swiftly in the aftermath of a disaster. This is where insurance could play a key role, providing rapid cash after a disaster occurs. Further, if the insurance policy were parametric, the payout could be used not just to rebuild what existed before, but to rebuild differently, and better (Franco 2020).

Beyond regional disaster recovery plans, federal recovery plans in the U.S. also fail to adequately include habitats. The guiding federal disaster recovery planning document in the U.S. is the Disaster Recovery Framework (FEMA 2011), which only includes nature in a very broad way (within the Natural and Cultural Resources Recovery Support Function) and has no specific references to habitats, NBS, or the values they provide to people. Many localities structure their recovery plans using this federal framework as a guide, so updating the federal Disaster Recovery Framework to better include habitats is also important.

Improving local and regional disaster plans is an equity issue because it can impact the flow of federal disaster funds. In many countries, recovery and adaptation funds disproportionately go to less vulnerable states and municipalities, which have greater capacity to apply for funds. This means more vulnerable places are not receiving equitable disaster support, which can perpetuate their vulnerability by amplifying damages and hampering recovery when disasters occur.

Recommended actions for including nature in disaster plans

Federal agencies, including USACE and FEMA, could work with government agencies at all levels (community, state, national) to support the development of disaster plans that include habitats, both in the U.S. and abroad. Incorporating nature into disaster plans requires gathering information about where habitats exist, understanding their fragility to different types and intensities of hazards, designing effective recovery actions, identifying actors to lead these actions, and creating diverse financial mechanisms to support them. Some specific actions that could advance inclusion of habitats into disaster plans in the U.S. and beyond are provided below.

The following actions would help advance the science that underlies including habitats in both hazard mitigation plans (HMPs) and recovery plans:

1. **Conduct a study across the U.S. to evaluate the quality of state and regional disaster plans** (HMPs and recovery plans) and the extent to which they include habitats. This study would reveal the current state of disaster planning related to

habitats and could inform strategic choices about the best ways to make improvements.

2. **Compile data on the spatial extents of habitats that provide hazard adaptation benefits** in the U.S. and abroad. This information would support improvements to both HMPs and recovery plans. For HMPs, it would allow for high-quality risk assessments to be conducted that include habitats. For recovery plans, it would inform the design of regional habitat recovery actions after a disaster. Further, this information would be highly relevant to the new National Nature Assessment that is currently being designed to, for the first time in history, assess natural resources across the U.S. (EO 14072 2022).

3. **Develop fragility curves for a variety of hazards** (**Recommendation 4**). This would inform risk assessments in HMPs, as well as habitat damage estimates and appropriate habitat recovery actions in recovery plans.

Additional actions that would further advance inclusion of habitats into hazard mitigation plans in the U.S. include the following:

4. **Assist states and regions in conducting high-quality regional risk assessments that quantify the risk reduction benefits from habitats**. This could be achieved in a variety of ways, such as creating guidance for states and regions on how to conduct risk assessments that quantify habitat benefits (**Recommendation 15**), running workshops for states and regions to build capacity for conducting risk assessments, and sending technical support teams to consult communities as they update their HMPs (**Recommendation 10**).

5. **Support states and regions in developing lists of shovel-ready NBS adaptation projects** for inclusion in their HMPs. Guidance, workshops, and technical support teams could be useful mechanisms to offer this support.

Actions that would further promote inclusion of habitats in disaster recovery plans include the following:

6. Gather information on appropriate habitat recovery actions and their costs for various types and degrees of hazards (**Recommendation 5**).

7. **Support the creation of FEMA Mission Assignments for rapid assessment and triage of habitat damage after a disaster** (**Box 8**). Mission Assignments are formal agreements between FEMA and another government agency to accomplish specific tasks related to disaster response and recovery. These assignments should be well-established before a disaster occurs to ensure that agencies have time to plan their response and build the necessary capacity. Mission Assignments are an opportunity to address capacity and resource

limitations within one agency by drawing on capacity in other agencies to complete short-term habitat recovery actions after a disaster (**Box 8** and **Figure 7**).

8. **Support states and regions in considering parametric insurance as a short-term funding option for habitat recovery actions** (**Recommendation 5**). There is currently a lack of funding sources for short-term habitat recovery actions, leaving regions to either pay out of pocket or wait (sometimes long durations) for FEMA disaster recovery funds, potentially missing relevant ecological recovery windows. Parametric insurance is a promising option for filling this funding gap (Franco 2020 and **Figure 7**). Parametric insurance could be particularly useful in vulnerable places (which are likely to be very limited in their ability to pay out of pocket for recovery actions immediately after a disaster) as long as there is an entity with the ability to pay the necessary insurance premium.

Finally, we have a couple of overarching recommendations to consider throughout these efforts of incorporating habitats into disaster plans:

9. **Promote habitats being identified as natural infrastructure in regional and federal disaster planning documents, policies, and laws**. Shifting mindsets towards considering habitats (e.g., coral reefs, mangroves, wetlands, and oyster reefs) as natural infrastructure that protects people and property would streamline the use of FEMA and other hazard mitigation and recovery funds for preserving, repairing, and restoring habitats. Specific actions to advance this mindset shift could include working with states and regions and federal agencies to identify habitats as natural infrastructure in disaster planning documents, supporting other policy amendments that explicitly identify NBS as natural infrastructure, and leading education and capacity building efforts within federal agencies to ensure reviewers of funding applications understand the value of NBS for hazard mitigation.

10. **Work to promote equity in disaster mitigation, response, and recovery**. Throughout all these efforts to improve disaster planning, it is important to consider equity and strategize ways to foster equity along axes of wealth, gender, race, health, and other axes relevant to vulnerability. It could be useful to research cases where disaster mitigation, response, and recovery have been equitable and cases where they have not, and use that information to guide actions. ◆

Box 8. A note on FEMA Mission Assignments

Mission Assignments can support the integration of NBS into the disaster recovery process by helping to identify capacity to, e.g., survey NBS condition after a disaster, perform immediate debris removal and triage, and prioritize habitat recovery needs at a site-level, among other actions.

An example of a Mission Assignment is the National Oceanic and Atmospheric Administration (NOAA) partnering with FEMA to conduct post-hurricane rapid habitat surveys and triage. In Puerto Rico, after Hurricane Irma in 2017, the NOAA Restoration Center conducted extensive in-water surveys of the coral reef resources and stabilized toppled coral colonies. Because this work was performed by a federal agency, the costs were reimbursable by FEMA through their Mission Assignment policy.

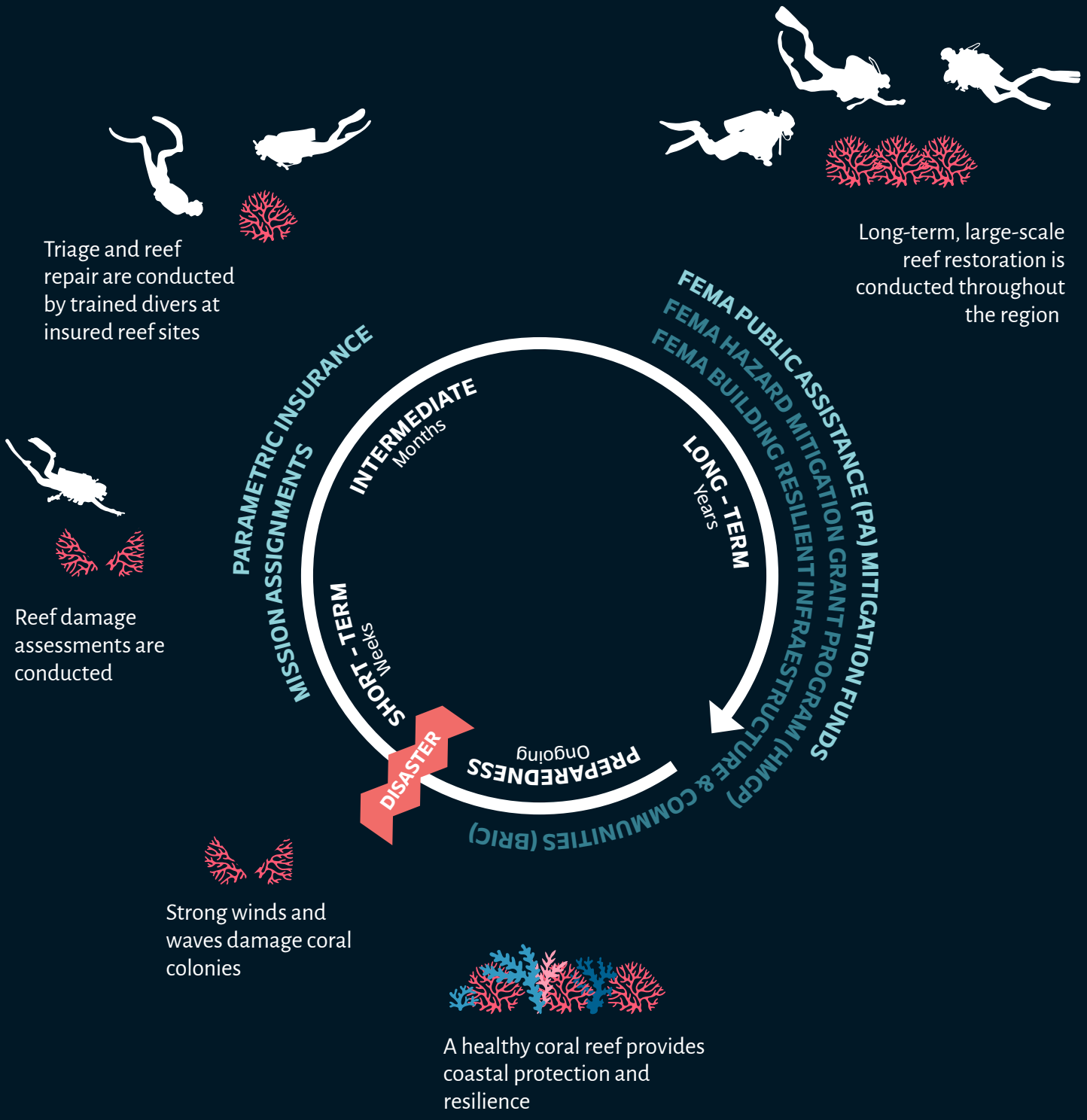


Figure 7. The disaster response and recovery continuum, showing existing (dark teal text) and potential future (light teal text) funding sources for habitat recovery actions. Existing funding sources do not pay out rapidly after a disaster, and they mostly fund hard infrastructure, although FEMA is working to fund more NBS projects under these programs. There is a lack of funding sources for short-term and intermediate- term habitat recovery actions, which Mission Assignments and parametric insurance could help address. Funding for habitat recovery could be further enhanced by making FEMA Public Assistance (PA) mitigation funds available for habitats. Around the outside of the cycle is a hypothetical coral reef restoration example, demonstrating how these funding sources could support actions for habitat response and recovery after a disaster.

15 Recommendation 15: Develop guidance for evaluating the adaptation benefits of nature-based solutions

Context

Substantial new funding for nature-based adaptation projects could be catalyzed by developing better guidance for evaluating the adaptation benefits of nature-based solutions (NBS). There are many potential pathways to raise public and private capital for NBS adaptation projects—e.g., FEMA HMA funding, Green Climate Fund grants, disaster recovery funds, and investments from private companies to bolster their environmental, social, and governance (ESG) scores and risk reports, among others. However, these pathways are not currently realizing their full potential of generating funds for NBS. Creating standardized, trusted methods for evaluating NBS adaptation benefits would allow NBS to be better considered in the decision processes for many of these funding pathways and could lead to many more NBS adaptation projects getting built.

The science for quantitatively evaluating the risk reduction benefits of NBS already exists, but it still needs to be packaged into clear step-by-step guidance to facilitate use by practitioners across the fields of engineering, conservation, corporate sustainability, insurance, and finance. For example, the basic scientific approaches that are used to model wave breaking in wetlands (Mendez and Losada 2004) and friction factors for coral reefs (Sheppard et al. 2005) have existed for decades. More recently, methods have been developed for including the risk reduction benefits from NBS in standard averted damages approaches (World Bank 2016, Bridges et al. 2021, Bridges et al. 2022). These approaches have been applied in risk industry models (Narayan et al. 2017, 2019), national wealth accounts (World Bank 2021), regional and global academic models for coral reefs and wetlands (Menéndez et al. 2020, Beck et al. 2018, Reguero et al. 2021), and estimates of the benefits from and damages to natural infrastructure (Storlazzi et al. 2021 a, b). While these approaches have been applied widely (i.e., across many sectors), they are still only used rarely, which is why guidance is critically needed to facilitate uptake.

Some efforts are already underway to create better guidance for evaluating the benefits of NBS. For example, there are coastal resilience accounting standards in development that provide a clear step by step approach for the assessment of flood risk reduction benefits of mangroves (Beck et al. 2021). However, similar "standards" or step by step methods are needed for other habitats (e.g., salt marshes and coral reefs) and hazards, and that can be included in sector-specific models. The methods are simplest for wetlands and dunes and only a little more difficult for reefs.

Unlocking corporate investments

Developing guidance to quantify the adaptation benefits from NBS could help unlock substantial new corporate investments in NBS. Corporate environmental commitments have been steadily growing, as reflected in the increasing number of corporations who have signed onto the Principles for Responsible Investment (**Figure 8**). This growing corporate awareness and commitment to sustainability is largely motivated by ESG scores and voluntary and required risk reporting. Current environmental reporting frameworks and regulations include corporate ESG frameworks, recommendations from the Task Force on Climate-Related Financial Disclosures (TCFD), regulations from the U.S. Securities and Exchange Commission (SEC), and the recently released recommendations from the Taskforce on Nature-related Financial Disclosures (TNFD) (see **Box 9**). These frameworks provide high-level direction, but many companies need additional, more specific guidance on how to report and mitigate their risks (SEC 2022). NBS adaptation projects could become a core part of corporate

risk mitigation strategies, but there would need to be better guidance that connects NBS to the specific prompts and questions in each framework. This could rapidly spur investment in NBS for risk reduction and climate adaptation, in a way that parallels already-growing industry investments in carbon mitigation projects.

Recommended actions for developing guidance to evaluate NBS benefits

Developing step-by-step guidance for evaluating and reporting the risk reduction benefits of nature-based solutions (NBS) could help unlock substantial new public and private funding for NBS adaptation projects. The U.S. Army Corps of Engineers (USACE) is well-positioned to play a key role in the development of such guidance.

The following considerations could help ensure the guidance is useful for target audiences:

- **Align the guidance with the language and metrics of important regulations and frameworks**, such as FEMA benefit-cost analyses (BCAs), popular ESG frameworks, the Task Force on Climate-related Financial Disclosures (TCFD), the Taskforce on Nature-related Financial Disclosures (TNFD), and regulations from the U.S. Securities and Exchange Commission (SEC).

- **Collaborate with public and private sector experts**, e.g., from USACE, FEMA, and the private risk industry, to create the guidance and help ensure its usefulness and uptake.

- **Improve definitions of NBS** to distinguish between the climate mitigation benefits (i.e., carbon storage) and hazard adaptation benefits (e.g., flood risk reduction) that can come from NBS.

- **Suggest standard metrics for NBS benefits**. The adoption of standard metrics would facilitate comparisons across NBS projects in different geographies and using different approaches. This would both promote transparency and advance the science of NBS by creating comparable data that could be used in analyses.

- **Include guidance on how to set meaningful organizational goals** related to NBS and how to track progress towards those goals.

After the guidance is created, the following outreach and collaborative research efforts could help promote its use:

1. **Create BCAs for NBS projects in collaboration with agency scientists** utilizing benefit information generated with the guidance. These BCAs could help NBS projects be considered more often in funding processes for FEMA and other federal agencies, among other uses.

2. **Conduct outreach to governments and development organizations to promote NBS risk reduction projects** based on the quantified NBS benefit information generated with the guidance.

3. **Support communities in using the guidance** to generate NBS benefits information that can be included in proposals to fund NBS risk reduction projects, e.g., through FEMA.

4. **Support companies in using the guidance to develop and report on their corporate sustainability plans** and to conduct TNFD, TCFD, ESG, and SEC reporting.

5. **Support the creation of an adaptation marketplace**, where companies, individuals, and other entities can find and fund adaptation projects. The guidance could be used to evaluate the adaptation benefits of NBS projects listed in the marketplace. ◆

Box 9. Environmental risk reporting

As climate change impacts continue to grow, consumers and investors are calling for companies to become more sustainable and communicate transparently about the climate-related risks they face. This has resulted in the development of a variety of frameworks for corporate sustainability and risk reporting, most notably environmental, social, and governance (ESG), Task Force on Climate-related Financial Disclosures (TCFD), Taskforce on Nature-related Financial Disclosures (TNFD), and the Securities and Exchange Commission (SEC). Growing momentum behind this kind of environmental risk reporting has caused corporations to become more interested in managing and reducing their long-term environmental risks and mitigating their negative environmental impacts There is an opportunity for nature-based adaption projects to play a larger role in these efforts.

Environmental, social, and governance

ESG is the most widely known framework for corporate sustainability reporting. ESG has limitations as a metric for environmental impacts because it is covering three different things in one score. For example, a company making great S and G decisions could be performing poorly in their E practices (or vice versa) and still receive a relatively strong ESG rating. Further, ESG scores from different rating agencies vary substantially, highlighting the challenge of producing consistent and comparable ESG scores (Berg et al. 2022). Some investment leaders are calling for more transparent and comparable alternatives for corporate environmental reporting.

Task Force on Climate-Related Financial Disclosures

In 2015, at the request of the G20 Finance Ministers and Central Bank Governors, the Financial Stability Board established the TCFD to provide recommendations for voluntary corporate disclosures on climate-related risks to their assets, operations, and profitability, as well as their mitigation efforts for these risks. In 2017, the TCFD recommendations were released (TCFD 2017) and, as of October 2022, more than 3,900 organizations had signed their support (TCFD 2022). Many signatory companies need help following through on TCFD reporting. In particular, additional guidance is needed to help companies develop and report on nature-positive risk mitigation strategies, which could include NBS adaptation projects.

Securities and Exchange Commision

The SEC regulates all required U.S. climate risk reporting. Currently, these regulations are based on the SEC's 2010 Release 33-9106, which provides principles and examples to guide corporate climate risk disclosures (SEC 2010). In spring 2022, the SEC proposed new, more specific, and rigorous climate risk reporting rules in Release 33-11042, which it will consider finalizing in spring 2024 (Ho 2023, SEC 2022). If approved, this new proposal would make corporate climate risk reporting requirements in the U.S. more comprehensive and consistent, and accordingly would greatly increase the burden of climate risk reporting. In its current form, the proposal contains many new requirements based on TCFD recommendations, including such disclosures as how a company's management and board oversees climate-related risks, how climate risks have or are likely to impact business, how they might impact business strategy, the impact of climate risks on line items of financial statements, direct and indirect greenhouse gas emissions (Scopes 1-3), and a company's climate-related targets or goals, among others.

Taskforce on Nature-Related Financial Disclosures

Building on the TCFD, in 2022, TNFD was created to provide recommendations for corporate reporting on risks related to nature loss and degradation (https://tnfd.global/). TNFD recommendations were released in September 2023 (TNFD 2023). They follow the same general structure as the TCFD recommendations and cover important environmental risks from stressors other than climate change, such as those from poor air quality and habitat loss, among others.

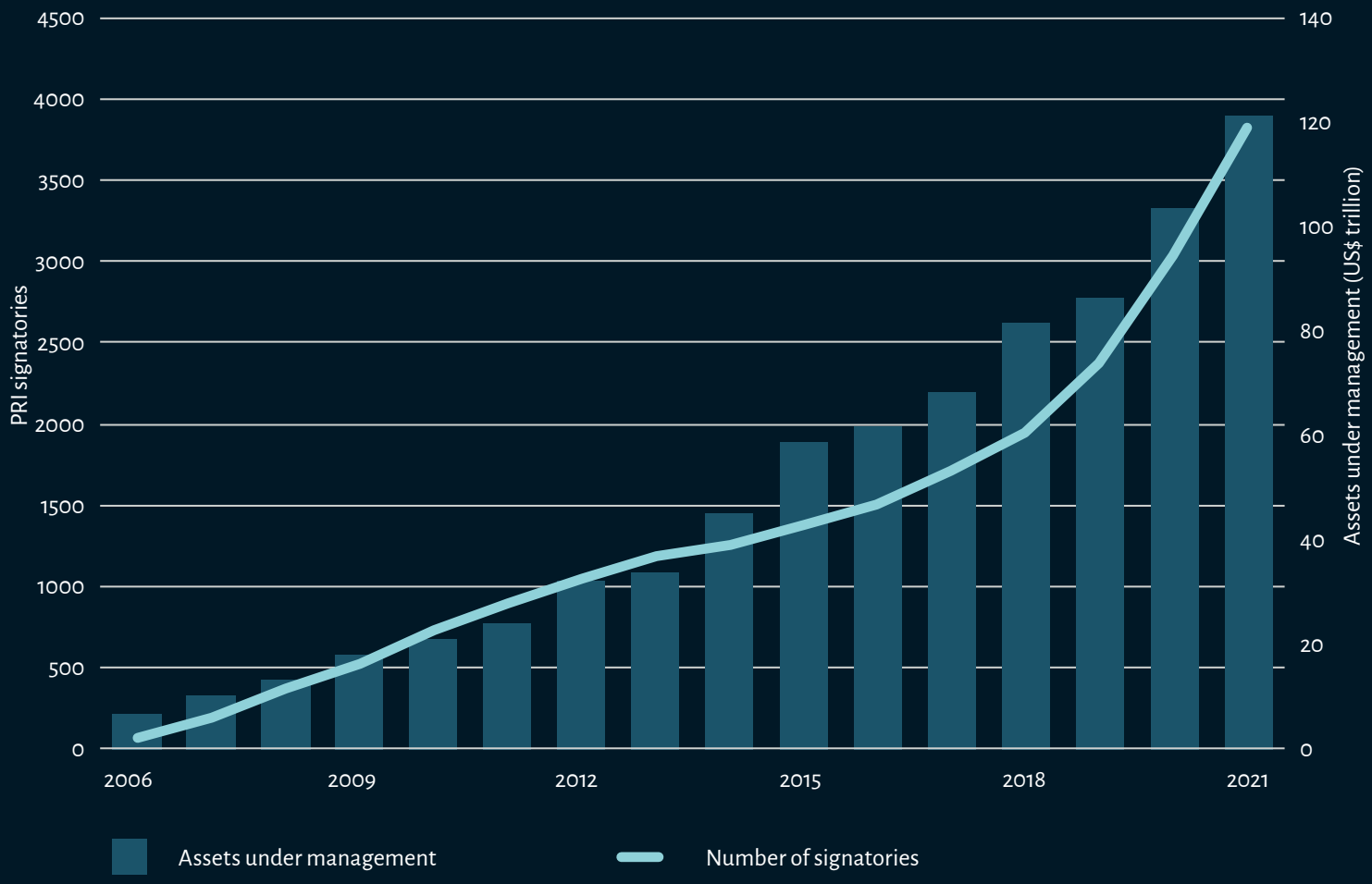


Figure 8. The number of companies that have signed onto the Principles for Responsible Investment (PRI) (light teal line) and the total value of assets under management of signatory companies (dark teal bars) have grown rapidly in recent years, signaling a strong appetite in the private sector to improve corporate sustainability by improving environmental, social, and governance impacts. Data source: Principles for Responsible Investment (2021).

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