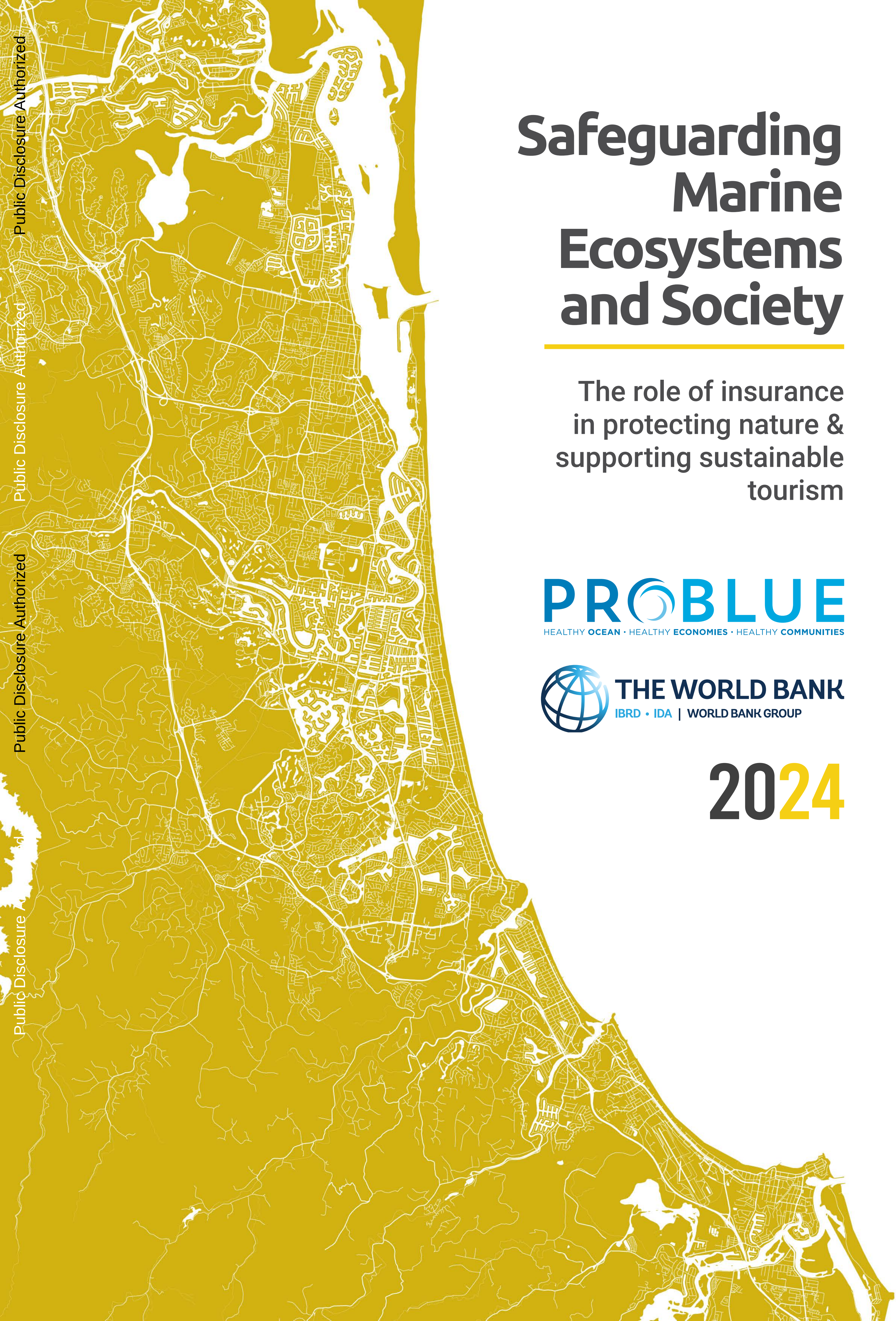

Safeguarding Marine Ecosystems and Society

The role of insurance in protecting nature & supporting sustainable tourism

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Table of Contents

FIGURES 11


STOCK PHOTO

Executive Summary

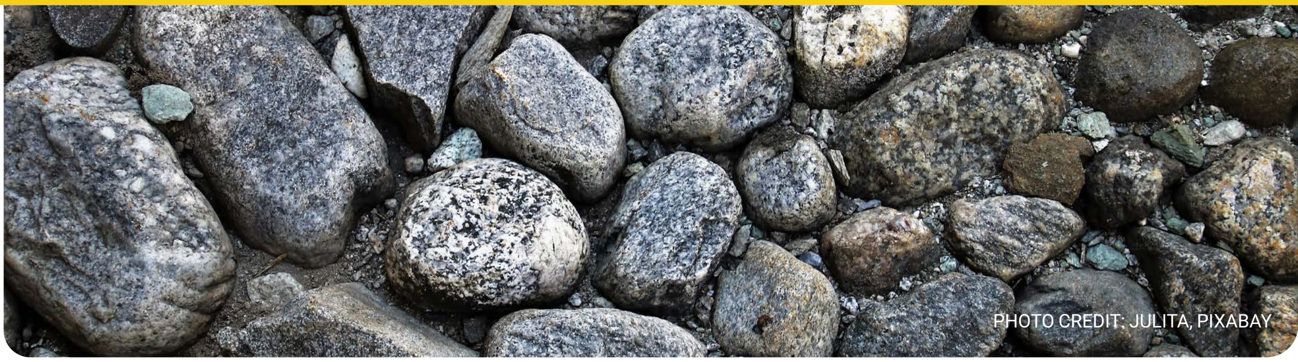


PHOTO CREDIT: JULITA, PIXABAY

Natural disasters and climate change pose serious threats to countries and citizens. In 2020, the World Economic Forum (WEF) Global Risks Report found that "over half the world's total GDP [gross domestic product] is moderately or highly dependent on nature and its services" (WEF 2020), and the 2024 report continues to rank nature-related risks among the most critical challenges faced globally (WEF 2024). According to the WEF perception survey, the top-four global risks for the next 10 years are all related to the environment (WEF 2024). For Small Island Developing States like those in the Caribbean, the risks and impacts are especially acute: hurricanes, cyclones, and other extreme weather events are frequent occurrences that negatively impact the economy, affecting tourism, agriculture, and fisheries in particular (Rozenberg 2021). Going forward, climate change is expected to increase the severity of hurricanes in the Caribbean.

Financial resilience is a critical component of disaster management. It ensures that timely funding is available to cover disaster response and recovery and allows individuals, businesses, and governments to take appropriate action (Swiss Re 2018). The Organisation for Economic Co-operation and Development recommends "effectively managing the impacts of disasters on public finances by evaluating potential financial impacts and developing an approach to ensure adequate funding to respond to financial needs" (OECD 2024).

Well-functioning natural ecosystems can contribute to financial resilience by offering protection from hazards and supporting economies. For example, it is estimated that more than 200 million people benefit from reduced risk of coastal flooding as a result of coral reefs alone (World Bank 2016). Coral reefs are also estimated to produce US$36 billion for the tourism industry (Souter et al. 2020).

But while marine ecosystems protect against hazards, they can also suffer damage in the process. Aside from direct damage during hazard events (e.g., from wind and waves), marine ecosystems also are also affected by climate change and human pressures. Corals have declined globally due to sea-temperature changes and ocean acidification, and the Intergovernmental Panel on Climate Change has found them to be one of the most vulnerable marine ecosystems (Gattuso et al. 2014). Mangroves are affected by sea-level rise and human pressures. Such damage reduces the ability of these ecosystems to provide future protection and other services to society.

It is possible to restore and conserve ecosystems, so they continue to provide vital ecosystem services. Successful restoration activities for marine ecosystems can include introducing marine protected areas (sustainable fishing), replanting mangroves and coral reefs, and reducing waste and pollution (UNEP, n.d).

But these activities—and investment in ecosystems more generally—require finance. One means of accessing financing is insurance, which makes funds available after hazard events occur. Insurance is especially valuable at such times because other urgent financial pressures (e.g., for meeting human needs and restoring infrastructure) could pull funding away from its originally designated purpose of strengthening ecosystems.

This report aims to highlight opportunities for developing ecosystem-linked insurance — that is, insurance that integrates the effect of ecosystems in products covering coastal hazards. These products can provide funds for ecosystem restoration after a disaster occurs.

Research has highlighted the significant challenges in developing ecosystem-linked disaster insurance. A particular challenge is developing the risk models that incorporate ecosystem effects in disaster risk quantification. These risk models are required for modeled-loss insurance and indemnity insurance products, and they also serve to identify locations that could most benefit from insurance for restoring and maintaining ecosystems.

Currently, there is limited knowledge about the relationship between marine ecosystems and climate shocks, and this knowledge gap undermines accurate inclusion of ecosystem effects in risk modeling. The linkages between marine ecosystems, the extent to which these systems ameliorate natural hazard events, and the way that climate change influences both factors are not well understood. More evidence is also needed on the costs and benefits of ecosystem restoration activities; benefits are not limited to damage reduction but include recreation and tourism value, benefits to fishery stocks, are other ecosystem services of relevance.

Issues with scalability pose another challenge to developing ecosystem-linked disaster insurance. Because many localized, situation-specific factors influence both ecosystems and losses from natural hazards, certain insurance products may have a limited potential client base for each risk model they develop. To account for the complexity of ecosystems and interactions with disaster losses, risk models require large volumes of many types of data. This requirement means that models developed for specific areas cannot be extrapolated or generalized for use over large geographical areas. In turn, this limits the return on investment for insurers—that is, the costs of modeling local risk are high, while the potential market that products can serve is small.

This report points to several opportunities and ways forward for developing ecosystem insurance. Despite the challenges facing efforts to develop such insurance, advances are possible and could benefit both the insurance sector and Caribbean tourism industry.

1. Use new technology.

New technologies could help overcome the challenges of modeling an ecosystem's interaction with natural hazards. This interaction is highly site-specific, and thus increases the model's data requirements and limits its use over larger geographical areas.

But satellite-imagery, mobile data, and machine learning offer powerful tools that could address this problem. They could fill gaps in knowledge — not only about how events affect human-made assets, but also about how events affect ecosystems and the extent of their ability to protect against hazards and offer other services to society.

Governments and relevant institutions could take specific actions to promote and facilitate improved data collection within their localities and could also share the data so they can be fully harnessed. The insurance and technology sectors could collaborate to improve data collection, dissemination, and use by highlighting existing data gaps and technology solutions that should be prioritized. Several data gaps are identified in this report: the extent to which ecosystems reduce impacts of natural hazards; the amount of damage to ecosystems caused by natural hazards and the time it takes them to recover; granular data on local infrastructure characteristics and its capacity to withstand natural hazards, with and without marine ecosystems; and the extent to which local livelihoods and businesses suffer financial losses after events.

2. Explore possibilities for insurance design.

Appropriate insurance design offers another way to overcome modeling complexities. While both modeled-loss insurance[1] and indemnity insurance require a robust quantification of likely losses and risk reduction to ensure that they are efficiently and fairly priced, parametric insurance does not. Pricing of parametric products is based solely on the expected occurrence of a pre-agreed event and a pre-agreed payout if the event occurs. Consequently, parametric insurance can be an option even in situations where neither the physical effects of the marine ecosystems nor the impact of natural hazards on them can be robustly modeled. At the same time, it is still necessary to communicate the value of disaster insurance to buyers. Risk modeling and forecasting of expected losses can provide motivation to buyers, as well as highlight to the insurance industry which areas could benefit most from insurance offerings.

Parametric and modeled-loss products may be suitable when the timeliness of post-disaster restoration is critical as is the case for some ecosystems. More broadly, the more quickly an ecosystem can be restored after an event, the sooner it can return to providing the full range of ecosystem services to society—including protection from hazards, food provision, and areas for tourism and recreation.

To account for the disaster risk mitigation benefits of ecosystems in the design of insurance and premiums, existing insurance product design offers relevant approaches. Accounting for risk mitigation is a common and successful practice in primary insurance policies throughout developed insurance markets and allow insurers to offer premium reductions for risk mitigation and incentives for protecting property and businesses. The practical issues raised in this report—about maintenancerequire setting up insurance contracts and agreeing on the insured entities and the entities responsible for ecosystem maintenance—require attention in this context.

Governments can also take action to explore new insurance designs. Governments can conduct initial assessments to identify regions or localities that depend heavily on ecosystems (such as areas with high revenues from coastal and eco-tourism, areas with important agriculture or fisheries economies), so that these could be targeted for financial protection against natural disasters.

1- Modelled-loss insurance bases pay-outs on expected loss, which are estimated via risk models.

Areas identified as both highly important for the economy and highly dependent on ecosystems would be most likely to benefit from financial protection against disasters.

3. Promote collaboration between the insurance industry and environmental stakeholders.

The insurance industry could act as a catalyst for ecosystem insurance products by collaborating with environmental stakeholders, including development institutions. Such collaboration could promote investment in ecosystem resilience activities as part of programs focused on ensuring livelihoods, economic development, and sustainable tourism. For example, Munich Re and The Nature Conservancy recently designed a method to combine community-based insurance along the Mississippi River with ecosystem maintenance activities that improve flood prevention (Munich Re and The Nature Conservancy 2021). Initiatives like this one, or like the Quintana Roo Reef Insurance, could be explored for the Caribbean and could leverage regional entities such as CCRIF SPC and the Caribbean Biodiversity Fund.

Going forward, the insurance industry could promote ecosystem insurance products by drawing on its experience in developing products for other purposes. Although modeling the disaster risk reduction benefits of marine ecosystems is still a novel area, there has been more experience of modeling and financing wider disaster risk reduction investments and incorporating them into insurance product pricing. Lessons might be learned from the insurance, risk modeling, and engineering worlds to help guide this agenda. Other experts (e.g., in technology or data science) could offer complementary solutions to aid in advancing risk modeling. Once improved risk models are developed, other key players (governments, businesses) could be vital partners in product development. These collaborative efforts should learn from relevant existing insurance products, and in particular be guided by how successfully they were implemented. Governments and interested organizations could assess financial insurance products in use in their localities to understand what elements worked well, what elements worked less well, and how this knowledge could be applied to new products.

This report looks at efforts to develop disaster insurance that incorporates marine ecosystems as a nature-based solution. The report focuses on damage from waves (often associated with hurricanes and storm surges) and the role marine ecosystems play in ameliorating losses, with a particular focus on the relevance to the Caribbean tourism sector—selected in light of its importance to the region and its vulnerability to natural and climate hazards. The content of the report could be applied more widely, however—that is, to other economic sectors and regions that suffer similar threats. Ideally this broader applicability will increase the value of the report, which could serve as a foundation for further advances in this area.

The report aims to highlight opportunities for developing ecosystem-linked insurance that is, insurance that integrates the effect of ecosystems in products covering coastal hazards. This discussion in the report is informed a risk modeling feasibility study conducted by HR Wallingford (2024a, 2024b, 2024c) commissioned specifically for this paper to illustrate how the necessary risk modeling could be developed. The report also aims to evaluate the challenges in developing ecosystem-linked insurance, in particular challenges related to risk modeling. It concludes with a set of recommendations for overcoming barriers to development of ecosystem-linked products.

Introduction

The tourism industry is a vital part of economies in the Caribbean. The total contribution of the travel and tourism industry to gross domestic product (GDP) in the Caribbean was estimated to be over 10 percent in 2023 - increasing over the previous year (WTTC 2023). Travel and tourism is estimated to account for around 5 percent of direct employment in the region, and wider links from the industry across the economy are estimated to contribute another 10 percent to employment (WTTC 2023). Both employment and GDP from the industry are expected to continue rising over the coming decade.

At the same time, the Caribbean is highly vulnerable to natural disasters such as hurricanes, floods, and severe weather. Since 2017, it has experienced four Category 5 hurricanes: Irma and Maria in 2017, Dorian in 2019, and Beryl in 2024. Hurricane Dorian was the strongest Atlantic hurricane ever recorded to make landfall, with winds reaching 300 kph. Hurricane Beryl affected countries across the Caribbean and damaged 95 percent of houses on the islands of Carriacou and Petite Martinique in Grenada (ReliefWeb 2024).

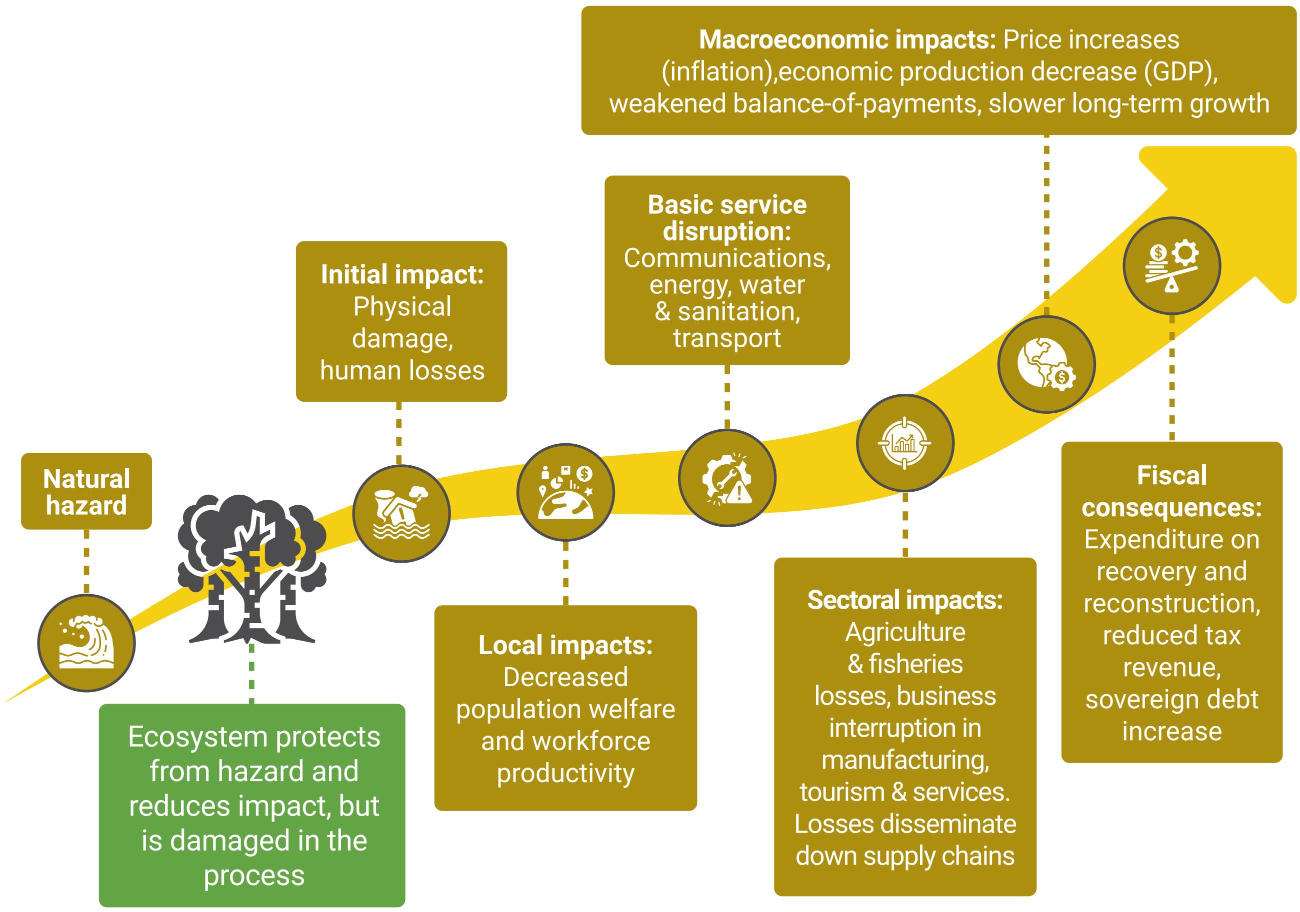
Hurricanes and other hazard events can have devasting impacts on Small Island Developing States, a category that includes many Caribbean nations. Disaster losses in these states are seven times larger as a share of GDP than disaster losses in other countries (UNDRR 2024). In addition, rebuilding and recovery costs after disaster events can be disproportionately high for Caribbean countries and other small states due to their relatively small market sizes and geographic isolation.

Ecosystems provide essential services to society, the economy, and the financial sector. These services include the provision of food, water, clean air, and areas for recreation, all of which have clear links to the ability of the economy (including tourism sectors) to function. One especially vital ecosystem service is coastal protection from hazards such as storm surge waves, which can be provided by coral reefs and mangroves.

Ecosystems also provide protection against the risks posed to the economy (including the tourism sector) by natural hazards and climate change. In effect, ecosystems provide nature-based solutions to the challenges of protecting against hazards. As defined by the World Bank (2022), nature-based solutions are "actions to protect, sustainably manage, or restore natural ecosystems, that address societal challenges . . . effectively and adaptively, simultaneously providing human well-being and biodiversity benefits." These societal challenges include maintaining food and water security and human health, addressing climate change, and reducing disaster risk. For example, in the Caribbean, coral reefs can act as a nature-based solution against beach degradation (by protecting against wave damage and providing sand grains for replenishing), while simultaneously enhancing biodiversity by offering areas for fish stock reproduction and tourist recreation.

Climate and natural hazard events can have severe and cascading impacts on communities, local economies, employment, and in severe cases macroeconomic sectors such as finance, insurance, and the wider economy (Figure 1). GDP and economic growth can suffer in the long term as a result of such events. Though marine ecosystems can provide protection against natural and climate hazards, they can themselves suffer damage in the process. When ecosystems are damaged or degraded, they lose their ability to provide future protection and other ecosystem services to society.

Figure 1. The economic impact of natural disasters on ecosystems and economies



Source: World Bank.

Threats to ecosystems and the services they provide can stem from human pressures (e.g., increases in the conversion of natural areas to farmland or urban areas) as well as pressures from climate change and natural hazards, but in either case restoring and conserving ecosystems is possible. Marine ecosystems can be restored in various ways, such as by introducing marine protected areas (sustainable fishing), replanting mangroves and coral reefs, and reducing waste and pollution (UNEP, n.d).

However, challenges exist in developing financial solutions to protect ecosystems from natural hazards and climate change. The lack of relevant data and information and the very limited modeling in this area limit the ability of financial markets to assess expected losses from these risks. Interlinkages between natural catastrophe events and climate change also make understanding these risks—and their possible future evolution—more difficult (Financial Stability Board 2024).

At the same time, financial markets have an interest in helping to tackle the challenges posed by climate and natural hazards. For example, reductions in ecosystem services can impact the financial system through credit, market, and underwriting risk (see Financial Stability Board [2024] for an overview). The financial sector is increasingly aware of such risks to their balance sheets and in response has developed organizations such as the Network for Greening the Financial System (NGFS) and the Taskforce on Nature-Related Financial Disclosures (TNFD), which help guide action in this space.[2]

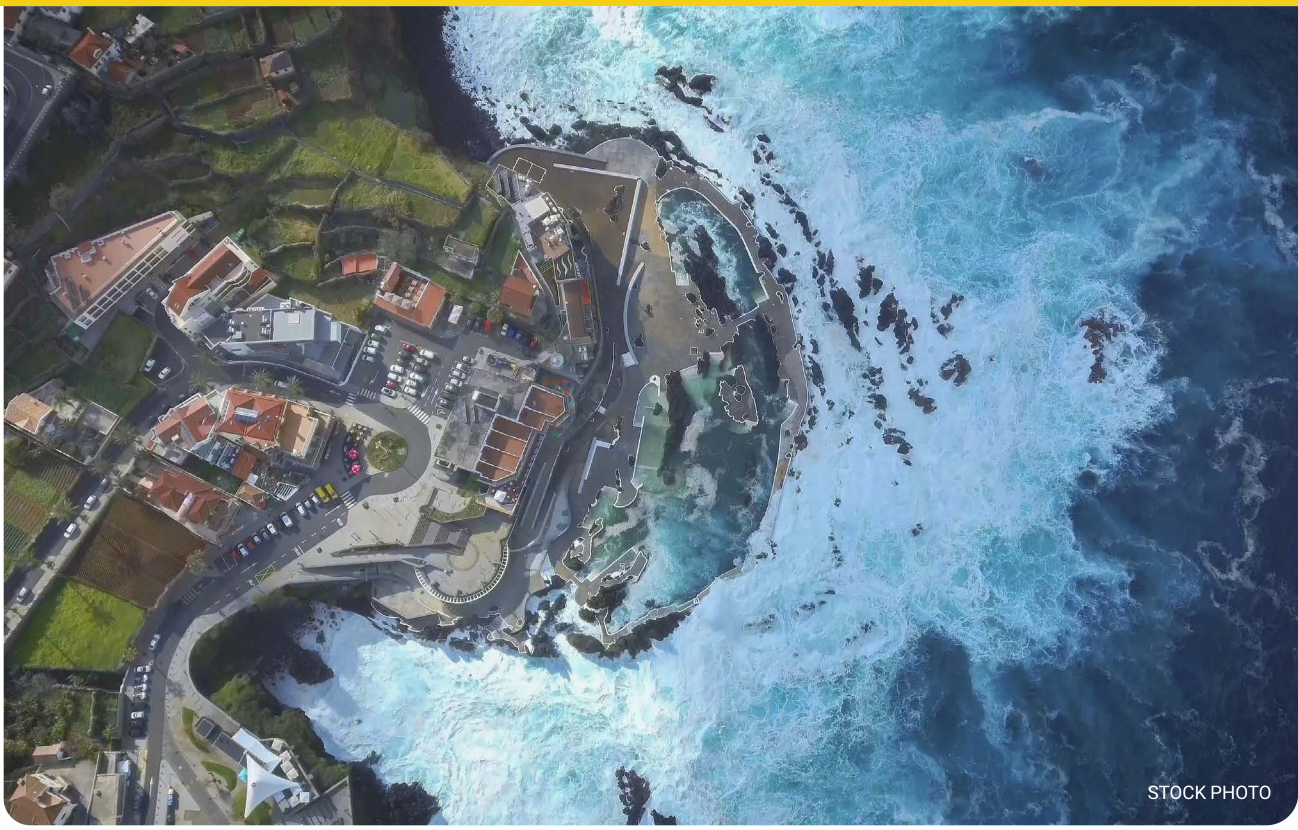
This report explores ways to build and strengthen insurance products that support ecosystems and that incorporate the services they provide (e.g., protection from storm damage), with a focus on the Caribbean. It includes a brief assessment of the impact of natural disasters on Caribbean economies (in particular the tourism industry), synthesizes information on the extent to which marine ecosystems can ameliorate damage caused by the natural hazards, and proposes a theoretical framework for how marine ecosystem effects could be incorporated into risk modeling. The report leverages work produced by HR Wallingford and AON for this report (Aon, 2024; HR Wallingford, 2024a, 2024b, 2024c).

The report finds there are significant challenges yet to be overcome in developing ecosystem insurance products that fully factor in the benefits of marine ecosystems (i.e., the damage reduction for which they are responsible). Nevertheless, opportunities exist to advance work in this area, which could benefit not just the Caribbean tourism sector but the nature conservation community, insurance sector, wider economy and society.

PHOTO CREDIT: MARIO, PIXABAY

2- See NGFS (2023) and the TNFD website at https://tnfd.global/.els.

Current situation



RISK TO THE TOURIST INDUSTRY DUE TO COASTAL NATURAL HAZARDS

In the Caribbean, climate-related hazards are frequent. In 2014 it was estimated that in any given year, Caribbean countries have a 14 percent probability of being affected by a natural hazard (Laframboise and Acevedo 2014). Storms and flooding are some of the most common natural hazards, but these countries also experience landslides, volcanic eruptions, and drought.[3] Other threats in the region—such as sea-level rise, temperature change, and changes in precipitation—may be exacerbated by climate change.

When such events occur, Caribbean countries are highly vulnerable due to their small populations and the concentration of economic activity in a small number of sectors, specifically agriculture, fisheries, and—the focus here—tourism. Indeed, Small Island Developing States in the Caribbean rank among the world's most tourism-dependent economies as measured by the proportion of GDP generated by tourism (World Bank 2020). The total contribution of the travel and tourism industry to GDP in the Caribbean was estimated at over 10 percent in 2023 and is forecast to continue rising over this decade (WTTC 2023).

This dependence on tourism means that disaster events can have significant economic consequences. Disasters often disrupt the air and sea travel on which the Caribbean tourism sector depends, and also cause damage to hotel and hospitality assets. A recent survey of businesses in the Caribbean found that 98.5 percent of firms depend on air transport for access to clients (Erman et al, 2021).

3- For details see EM-DAT: The Emergency Events Database, Université catholique de Louvain, Belgium, https://www.emdat.be/.

High-damage hurricanes have been estimated to reduce tourist arrivals by 11 percent on average during the 12 months following the event, compared to a year with little or no hurricane damage (Scott et al. 2020).[4]

To understand how disaster affects the Caribbean tourism industry, it is important to understand how types of damage are categorized. Direct damage refers to damage to assets such as tourism accommodation, restaurants, and other related businesses. The insurance sector can cover this type of damage by paying out to cover repair activities as well as temporary rehabilitation. **Business interruption** refers to disrupted operations and loss of income, in addition to wider costs suffered by associated sectors (e.g., transport) and basic services (energy, sanitation). The insurance industry can also cover some of these business interruption costs.

The Caribbean tourism sector experiences both these types of damage when a disaster occurs. Recent research on business interruption covered 11 events (hurricanes, cyclones, and floods) in 11 Caribbean countries between 2016 and 2019 (Erman et al. 2021). On average, 42 percent of businesses were forced to close due to the events. Nearly a third (62 percent) of the businesses reopened within a week, but others had longer closure periods, which brought the average length of closure to 70 days. As might be expected, the study found substantial variation in the impact across events and individual businesses, but could not draw country- or event-specific conclusions with certainty.

Research has also shown that shocks to the Caribbean tourism sector have consequences for the workforce, particularly women. The proportion of the population employed directly or indirectly in the travel and tourism sector is estimated to be around 15 percent (WTTC 2023). Women are more likely than men to work in the tourism and hospitality sector and along with other marginalized groups may have fewer resources to draw upon if they are impacted by tourism downturns after a disaster event (World Bank 2020).

PHOTO CREDIT: PHUONG NGUYEN, PIXABAY

4- The cited study controls for other factors that may impact tourist arrivals (pandemics, economic trends, and characteristics of local institutions).

Figure 2. Current risk in the Caribbean from natural hazards

Source: World Bank.

USE OF INSURANCE AGAINST DISASTERS

In the aftermath of a disaster event, if businesses have not put in place mechanisms to finance losses ex ante, they will be forced to reallocate funds from other planned investment. This can mean putting other development and investment projects on hold and consequently jeopardizing economic growth potential.

Countries can manage disaster risk using a multitude of mechanisms, including interventions that reduce the expected damage (mitigation activities) and financial solutions to fund restoration and recovery. Ex ante financial mechanisms commonly used by governments include insurance, contingent credit lines, catastrophe bonds, drawdown options, and contingent budgets. Insurance is particularly common and can also form the basis for other mechanisms that employ similar structures (e.g., catastrophe bonds, contingent credit). Insurance is not used only by governments but is also available to private individuals, firms, and other organizations.

Insurance products use one of three main methods for calculating a payout. Traditional indemnity insurance calculates payouts on the basis of the actual damage that occurred; parametric insurance provides predefined payouts based on pre-agreed parametric triggers; and modeled-loss insurance bases payouts on modeling of the loss expected for different events. More detail on each type of product is in Table 1.

PHOTO CREDIT: WILLIPIXEL, PIXABAY

Table 1. Insurance solutions

Type of insurance	How it works	Data & information needed	Suitability for flood loss management
Indemnity insurance	Considered the "traditional" type of insurance. Payouts are based on the actual loss and damage that occur.	Data on the number and type of assets in an area, as well as the value or the price of replacing the lost assets. The data are required both before events take place (in order to allow insurers to accurately price products) and after events take place (to assess the actual damage incurred).	Pro: Insurance payouts most closely match the actual losses that occur; thus, they offer a "less risky" form of insurance. Con: It takes time to assess the assets that were damaged and estimate their monetary value, so that many months can elapse before payouts are provided. This delay may be problematic if timely access to funds is required for response and reconstruction. In addition, good data are required before events take place to allow accurate modeling of expected losses and pricing of products.
Parametric insurance	Rather than matching the exact damage incurred, the payout is based on previously agreed and predefined conditions that are expected to produce a certain amount of damage—for example, the windspeed or rainfall in an area reaching a predefined threshold.	Data on the characteristics of the hazard that took place, such as local wind speed.	Pro: The data required (such as weather data) are not extensive and can be obtained quickly and easily; hence payouts are made promptly. Once an event threshold is reached, payouts can occur almost immediately. Con: Insurance payouts may not match the actual losses incurred. When the real event and losses do not closely match what was expected from predefined weather or hazard conditions, the payout may be less (or more) than the value of damage that occurred. In technical terms, the basis risk is higher than for other forms of insurance. Thus, the product could be seen as "more risky."
Modeled-loss insurance (subtype of parametric insurance)	The method of calculating payouts is a combination of or middle ground between indemnity and parametric insurance. The losses expected from events are modeled to produce an estimate of the actual damage incurred.	Data on the approximate number, location, and characteristics of assets as well as their value; data on the weather or geographical conditions expected to influence the impact the event has on the assets. The data are required before events take place (in order to allow insurers to accurately price products).	Pro: Models are developed in advance, often with regional or global data sets. This means that models can be run relatively quickly to produce an estimation of the value of damage in an area and therefore allow timely payouts. Con: The extent to which the estimated value and payout match the value of the actual damage will depend on the precision of the model and data used. In technical terms, improvements in the model and data reduce the basis risk.

Source: World Bank.

To ensure that ecosystems can be restored quickly after being damaged in a hazard event, parametric and modeled-loss insurance could be attractive options. They can disburse funds quickly following an event, thus aiding ecosystems' timely recovery, restoration, and normal functioning and increasing their ability to provide protection from future threats as well as provide other valuable ecosystem services (e.g., coral reefs or beaches for recreation, mangroves for fish-stock reproduction).

Using modeled-loss insurance or indemnity insurance for ecosystems has a key drawback: each type requires a large volume of data—on characteristics of the natural hazards likely to impact an area, the assets in the area likely to be damaged, the extent of expected damaged, and the likely monetary value of the damage. If these products also integrate ecosystem effects, the information requirements are amplified and the modeling becomes more complex.

Parametric insurance offers a way to overcome modeling complexities. It is priced based solely on the expected occurrence of a pre-agreed event and the pre-agreed sum paid out if the event occurs. Consequently, parametric insurance can still be used even in a situation where robust modeling is not possible. In addition to providing funds for ecosystem restoration, parametric insurance can be used to cover direct damage to human assets and business interruption losses. Although risk models are not absolutely required for the insurance industry to offer parametric insurance, purchasers of insurance are likely to require risk models to verify the value of the insurance product.

Parametric insurance is already used by Caribbean countries. Sixteen Caribbean countries hold parametric insurance against disasters through the Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF SPC). CCRIF SPC was the first-ever multicountry risk pool and consists of 19 member countries. Since its inception in 2007, CCRIF SPC has delivered US$268 million in total through over 64 payouts (CCRIF, 2024).

Beyond the sovereign parametric disaster insurance offered by CCRIF, insurance against disasters in the Caribbean is limited at the domestic level. Limited private sector insurance coverage means that governments may need to foot more of the bill for post-disaster recovery. Concerning property insurance, penetration was found to be relatively low, ranging from a maximum of 4.2 percent in Antigua to just over 2 percent in Trinidad and Tobago, according to a review of Axco reports in the region (Cook et al. 2024).

Domestic markets favor traditional indemnity insurance, potentially due to the heterogeneity of personal or commercial assets covered (property, motor, etc.), as well as its familiarity for clients. Of 1,400 Caribbean tourism businesses surveyed between 2016 and 2019, around two-thirds held indemnity insurance, predominantly to cover direct losses caused by disaster events (Erman et al. 2021). Indemnity insurance for business interruption was found to be less common, with many businesses using mitigation activities (running generators, relying on water tanks) to limit disruption. Parametric insurance exists mainly at the regional level through CCRIF.

Local insurance providers exist, but the number is relatively limited. State insurance companies are also absent in most countries; an exception is the State Insurance Company of Antigua (SIC) (Cook, et al. 2024).

A couple of explanations are possible for the limited insurance market development in the Caribbean:

- **The cost of premiums is high, and the range of products is relatively limited, combining to make products less attractive.**
- **There is a heavy reliance on international reinsurance to manage risk.** Risk retained locally in the Caribbean property insurance markets is less than 10 percent in Barbados, Jamaica, and Belize, though in The Bahamas it is a more reasonable 23 percent (Cook, et al. 2024). Reliance on international reinsurance can increase the price of insurance and limit domestic market development.

The limited current development of domestic insurance markets means that there is opportunity for new market growth, product development, and domestic economic benefits. The section below focuses on parametric disaster insurance as a potential instrument for both managing financial risk from disasters and maintaining marine ecosystems and the benefits they provide to society.

EXISTING PRODUCTS IN THIS SPACE

Insurance products are already benefiting Caribbean countries, offering a mechanism for financial management of natural disasters.

Parametric insurance for natural disasters delivers payouts after disasters if the event magnitude meets predefined parameters (such as wind speed). These payments can cover physical damage as well as lost business revenue. As mentioned above, countries in the region have access to parametric insurance through CCRIF. The insurance covers tropical cyclones, earthquakes, and excess rainfall. CCRIF also offers a subproduct for the fisheries sector, COAST (Caribbean Ocean and Aquaculture Sustainability Facility). This pilot project is being carried out in St. Lucia and Grenada and covers two types of events: adverse weather (business interruption losses due to rough seas and heavy rainfall) and tropical cyclone (damage to fishing assets caused by high winds and storm surge) (World Bank 2019a). Another new product developed by CCRIF extends insurance to the private sector, specifically electric utility companies (CCRIF 2020). Both COAST and the electric utilities product offer lessons about how parametric insurance for natural disasters can be delivered to businesses and private individuals.

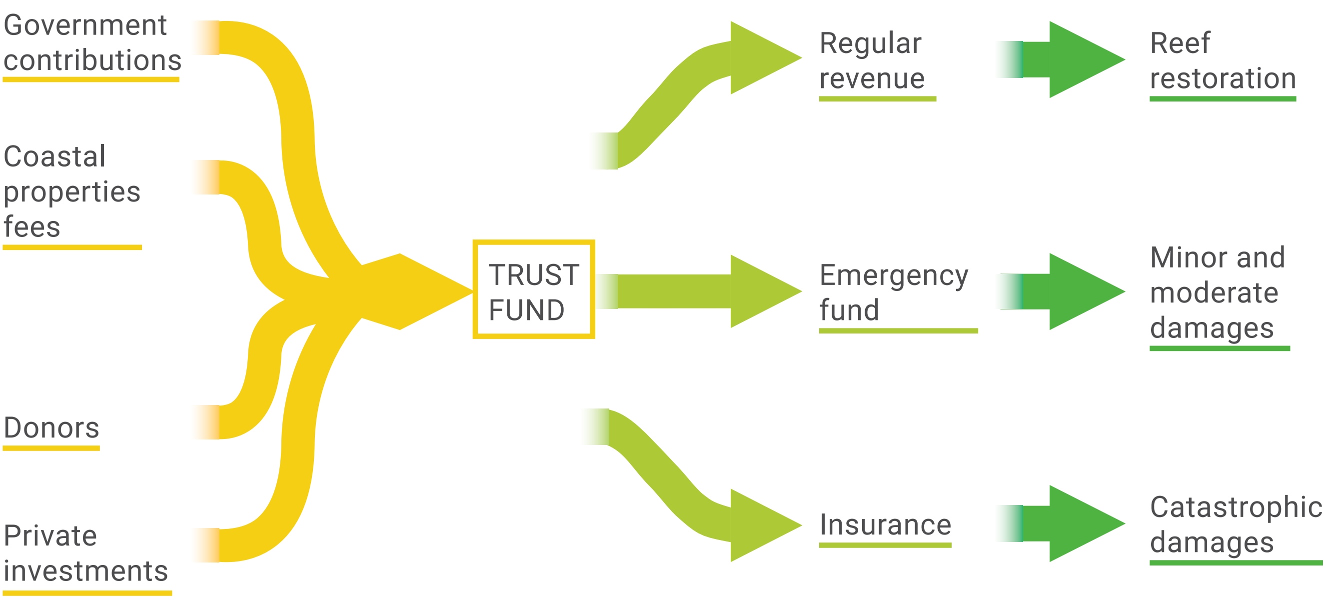
Some insurance in the region is specifically designed for ecosystem restoration and maintenance; these products pay out after disaster events to channel funding to ecosystem restoration activities. Some examples are discussed below.

Quintana Roo Reef Protection (Mexico)

Launched in 2018, this was the first insurance product designed for ecosystem recovery purposes (rather than for the traditional purpose of covering human-made assets and losses, like buildings). It functions as parametric insurance, and payouts are triggered by hurricane winds (100 knots) along 160 km of coastline in Quintana Roo, Mexico. When a trigger event occurs, funds are quickly disbursed for coral restoration activities (see Deutz et al. [2018]; Visser et al. [2023]). The product was developed by The Nature Conservancy in partnership with government and tourism stakeholders; it combines an index-based insurance policy and a trust fund—the Trust for Coastal Zone Management, Social Development, and Security, which was established in 2018 to manage beaches and coral reefs and purchase hurricane insurance.

The parametric policy allows for rapid payouts and quick commencement of repair activities following storm impacts, which prevent further damage and enhance recovery. The first payout—of US$850,000—was triggered in 2020 by Hurricane Delta (JNCC, 2023). Response activities undertaken include a first responder team which immediately cleans and repairs the coral, and produces further restoration plan, activities to increase the success of future coral reproduction, rescuing and replant damaged corals, and implementing no-fishing areas to allow population recovery (The Nature Conservancy, 2018). Figure 3 provides an overview of how the product channels funding to reef maintenance. The Mesoamerican Reef Fund has extended coverage provided by Quintana Roo Reef Protection to other areas of the reef by working with AXA Climate, InsuResilience Fund, and Willis Towers Watson. The Asian Development Bank is exploring the feasibility of similar programs offering coral reef coverage in Fiji, Indonesia, and the Solomon Islands (Asian Development Bank 2023).

Figure 3. Structure of trust fund managing reef insurance in Quintana Roo, Mexico



Source: Adapted from Rogers et al. 2023.

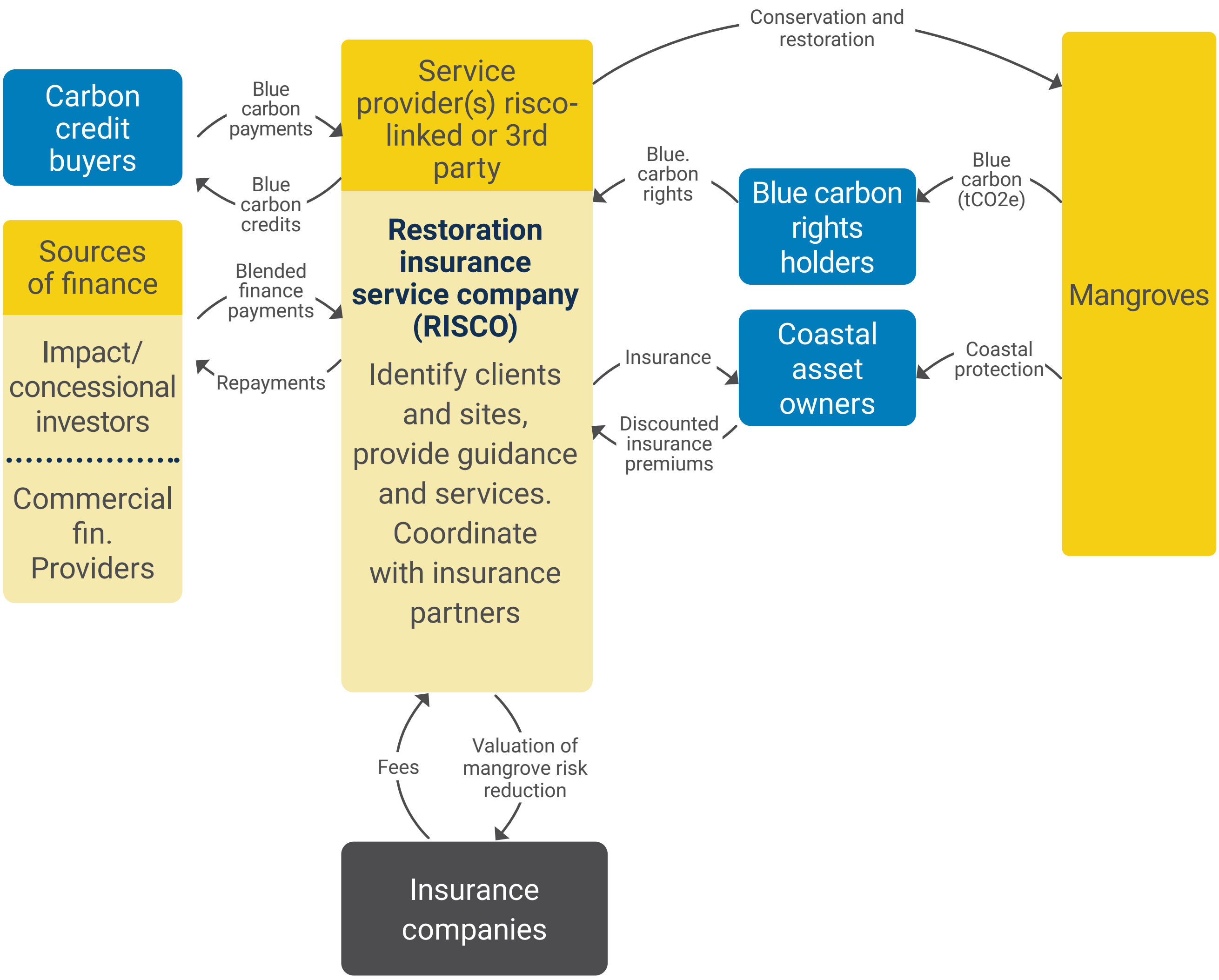
Hawaiian Islands reef insurance

After successful piloting in Honolulu, the 2024 reef insurance policy extends coverage to all the main Hawaiian Islands. Payouts are triggered when tropical storm winds reach 50 knots or more within the geographical area covered. Each year the maximum payout across all the islands is capped at US$2 million; the maximum per storm payout is US$1 million. The minimum payout has increased to US$200,000 (The Nature Conservancy, 2024). Setting a minimum as well as maximum payout can be useful for reducing liabilities to the insurance sector and for lowering administrative costs, but it also means that smaller events need to be covered by the policyholders.

Restoration Insurance Service Company (RISCO)

RISCO is a social enterprise that seeks to develop new sources of revenue for mangrove restoration and conservation by collaborating with the insurance sector. The insurance sector plans to pay RISCO for the mangrove maintenance activities, and in return receives the expected flood loss reduction benefits provided by the mangroves (Climate Policy Initiative, 2019). Following a similar principle, RISCO may extend to selling blue carbon credits to interested parties. The carbon credit pilot program is being trialed along the Caribbean coast of Cispatá Bay in Colombia (Climate Finance Lab 2019). RISCO's structure is shown in Figure 4.

Figure 4. Design of the RISCO product



Source: Adapted from Climate Policy Initiative 2019.

Blue bond parametric insurance extension

A more indirect type of insurance for marine conservation is offered by the Belize Blue Bond initiative and its recent extension to parametric cover. Belize has contracted insurance that will aid marine conservation in the face of disasters. In 2021, the Government of Belize converted US$364 million of its debt (equivalent to 12 percent of GDP) in a commitment to protect of 30 percent of the ocean in Belize. In effect, the country raised capital to reduce its debt and fund marine conservation activities (The Nature Conservancy 2022). Through this initiative Belize has also secured a parametric insurance policy against catastrophes, which covers "Blue Loan" debt repayments in the event of a hurricane. By insuring these debt repayments against the risk of economic losses caused by disasters, the parametric insurance provides resilience for the Blue Bond initiative and improves the government's ability to continue marine conservation activities, rather than reallocating previously planned conservation funds for other purposes.

The December 2021 transaction, a parametric insurance policy combined with a sovereign debt transaction (a "blue bond") was placed on the market for US$364 million (Owen, 2022). The blue bond was arranged by Credit Suisse, and the so-called catastrophe wrapper was created by Willis Towers Watson (with risk capacity provided by Munich Re) as insurance protection for Belize's loan repayments after hurricane events. With such a safeguard as part of the country's 20-year sovereign debt structure, the parametric transfer of risk will strengthen Belize's resilience to climate shocks, in turn helping to prevent credit rating downgrades and reduce the time it takes for the economy to recover following a shock.

The transaction with the Government of Belize facilitated the reduction of the country's debt burden while generating funds for marine conservation. The proceeds of this transaction are being used to meet Belize's commitment to protect 30 percent of its ocean, and to establish a regulatory framework for coastal blue carbon projects. This transaction demonstrates how parametric insurance can be used to support biodiversity goals while protecting loan repayments to help promote economic stability.

Further information and evaluation of the case studies can be found in the literature. Beck et al. (2019) highlight lessons learned and requirements for developing future projects. These include the importance of identifying a buyer from an early stage and the collaboration of the insurance industry throughout. Consideration of financial requirements is critical, highlighting the need to communicate to buyers the expected benefits of ecosystem protection - for example via risk modelling. Consideration of practical issues to overcome (such as institutional arrangements) can also smooth implementation. The TNC have developed a guide to developing future ecosystem insurance products, based on learning from Quintana Roo (Secaria et al, 2019). This highlights the need for assessment of the ecosystem's role in protection from natural hazards, the extent to which it is damaged by hazards and methods of cost-effective restoration. Other pointers include the need to estimate the funds needed after a storm for ecosystem restoration, and estimates of the value this would provide to insurance buyers. The challenge of overcoming basis risk in parametric insurance is also mentioned in the literature (The Green Finance Institute 2024). This risk can be tackled through improved risk modelling which enables better forecast of expected payout needs, depending on the magnitude of events. Many of these topics are expanded upon in the section of this report focusing on the challenges in developing insurance (section 3).

Linking insurance to regional vehicles for ecosystem enhancement

Following a logic similar to that used by the Belize Blue Bond parametric insurance extension, insurance could be offered to protect funds dedicated to nature conservation and enhancement, such as the Caribbean Biodiversity Fund. The fund acts as a regional umbrella, consolidating finance for projects that are then implemented in 14 Caribbean countries. Its core aim is to ensure that projects focused on protecting nature have access to long-term, reliable finance, rather than depending on annual funding from government or other entities that could cease in the event of unforeseen budget shocks. Insurance covering damage to ecosystems from natural hazard events could ensure that projects protecting nature can access cash for restoration activities. Without this extra finance for the additional restoration work required after disaster events, projects might not achieve the results planned for at project inception.

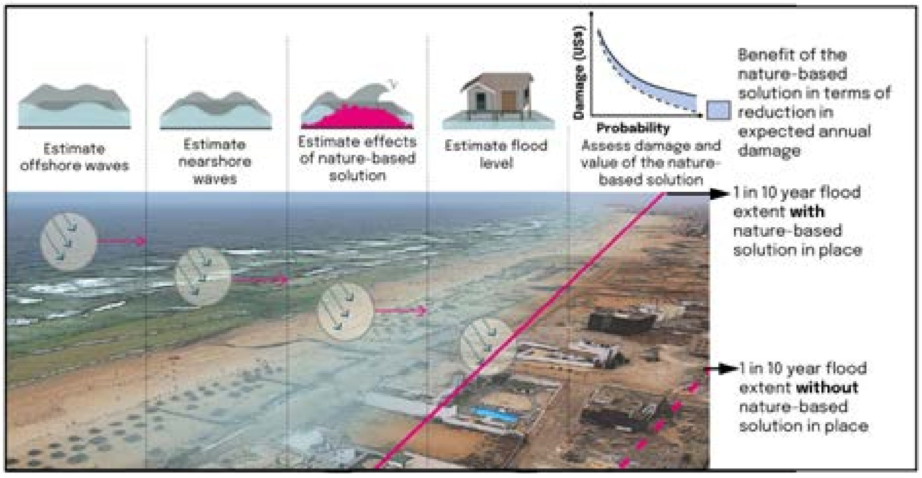
The next section explores how existing insurance mechanisms could be built upon to develop products that couple disaster insurance with insurance for ecosystem maintenance, and that also factor in the effect of ecosystems in reducing expected disaster losses. By protecting ecosystems that protect against natural hazards, the insurance industry indirectly reduces expected future losses to its books. Consequently, in the longer term, risk to human-made assets would be reduced and allow for insurance premium reductions. Box 1 depicts what a new ecosystem-linked disaster insurance could look like.

What might ecosystem-linked disaster insurance look like?

A disaster insurance product that considers the benefits of marine ecosystems would need to be developed in two stages.

First, modeling would be carried out to estimate the benefits provided by a marine ecosystem (such as a coral reef or mangrove forest) in alleviating the effects of a natural hazards (such as coastal waves, storm surge). See Figure 5 for an example of how this estimation might be conducted.

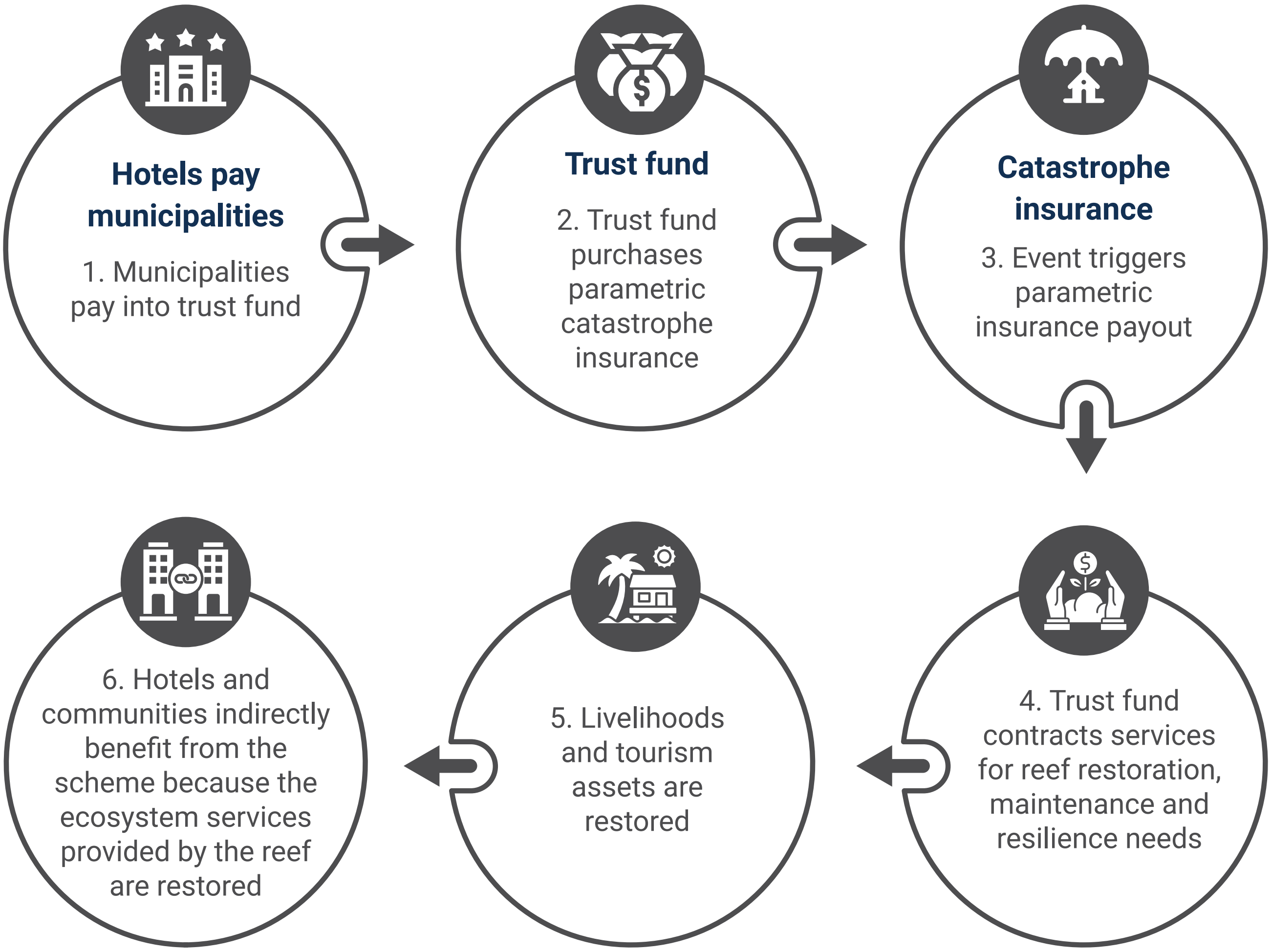
Figure 5. Example of the steps in estimating the benefit provided by a marine ecosystem (coral reef) against natural hazards (wave surges)



Source: HR Wallingford, forthcoming; adapted from Beck et al. 2018.

Second, financial instruments would be designed to (i) smooth financial losses caused by natural disaster events, and (ii) incentivize marine ecosystem restoration and maintenance. For example, an insurance product could reduce its premiums in exchange for restoration activities being undertaken. The expectation is that insurers would be willing to reduce premiums in exchange for marine conservation activities that by protecting coastal assets and ecosystems would reduce their expected financial losses. The Quintana Roo Reef Protection scheme, which offers coastal protection to Quintana Roo marine communities in Mexico, is an example of such a product. See Figure 6.

Figure 6. How the Quintana Roo Reef parametric insurance scheme works



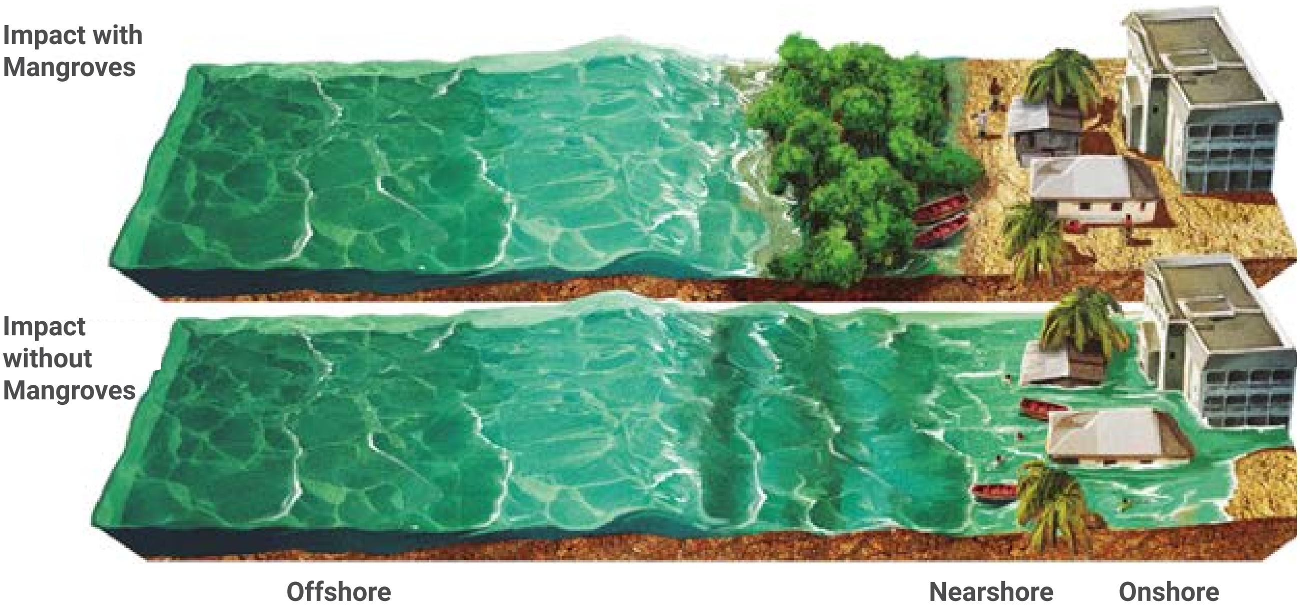
Source: Adapted from HR Wallingford, forthcoming; adapted from the Green Finance Initiative 2024.

Opportunities for developing insurance for marine ecosystems

PROTECTION PROVIDED BY COASTAL NATURE-BASED SOLUTIONS

Marine ecosystems offer protection against natural hazards, such as hurricanes, waves, and storm surges. The effect of coral reefs and mangroves in reducing damage from waves and flooding has been estimated. A relatively extensive body of literature suggests that mangroves can ameliorate wave height and energy (as illustrated in Figure 7). A recent literature review concludes that for water traveling through mangroves, reductions in wave height vary from 15 percent to 85 percent for each 100 m that the water travels, although where trees are very young their effect can be smaller (HR Wallingford, 2024a). There is not consistent evidence on whether mangroves ameliorate the effects of other natural hazards.

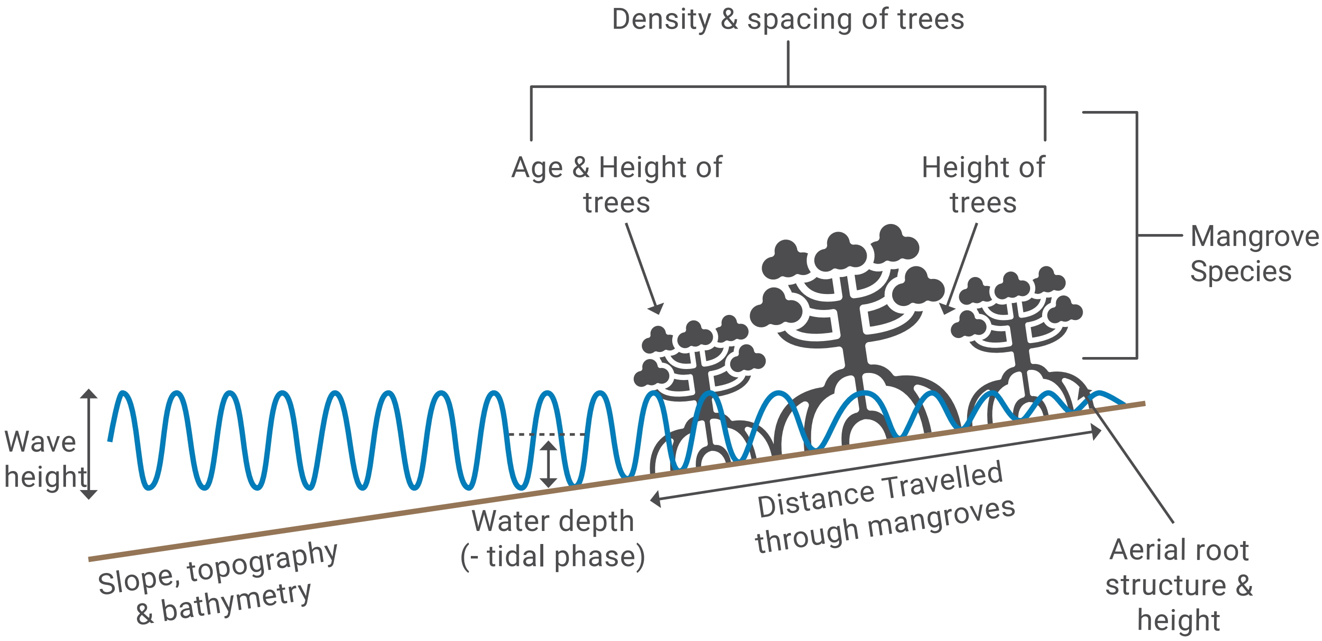
Figure 7. Impact of wave hazards, with and without mangroves



Source: World Bank 2019b.

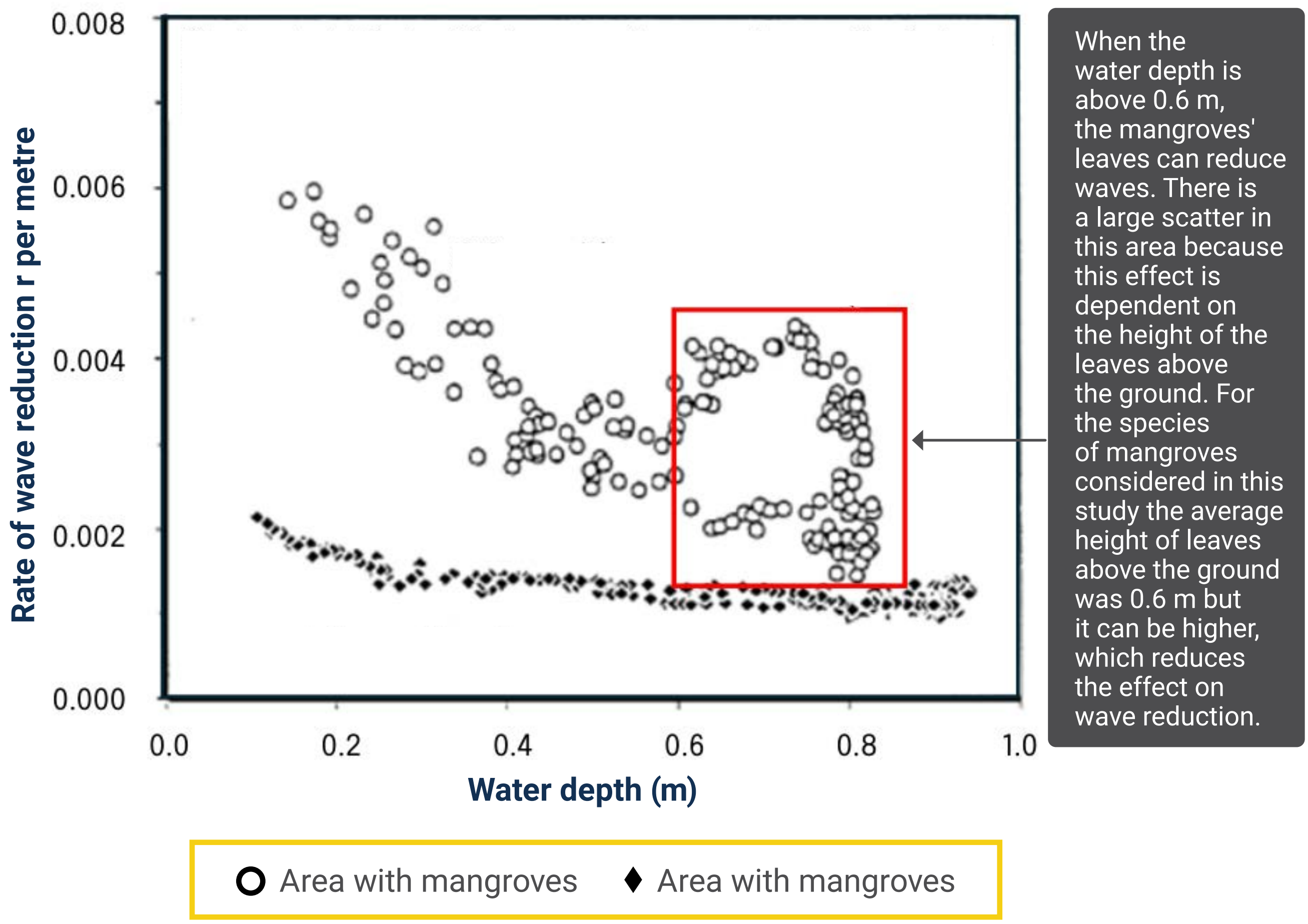
The extent to which mangroves offer protection from natural hazards depends on a wide variety of factors. In general, the key characteristics of mangroves that contribute to reducing waves include the width of mangroves, the density of the tree spacing, the maturity and height of trees and leaves, and the structure of the roots (Figure 8). These factors depend in turn on the health of the mangroves, as well as their species (Baldock et al. 2014). Another factor influencing the impact of mangroves on waves is the depth of water; in low water depths, more of each tree extends above the water surface, allowing more roots and leaves to dissipate the wave. In higher water depths, where each tree is more covered, the effectiveness is reduced. Mangroves seem to have a diminishing ability to reduce wave height as the water depth increases, but at the highest water depths there is large variation in findings. It is hypothesized that this could be due to variation in the leaf height above the wave (Mazda et al., 2006).

Figure 8. Factors affecting wave attenuation in mangroves



Source: Adapted from HR Wallingford, 2024a; adapted from the Green Finance Initiative 2024.

Figure 9. Relationship between rate of wave reduction and water depth for areas with and without mangroves

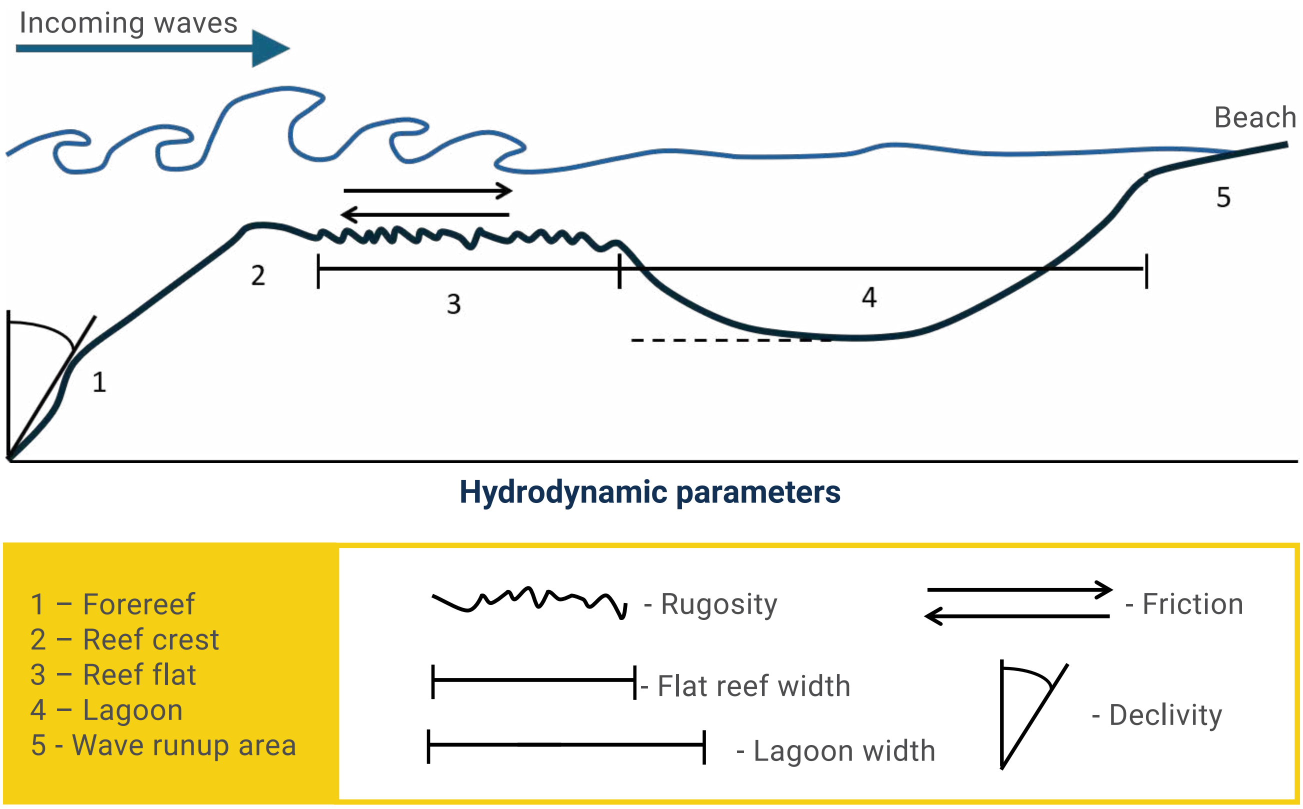


Source: Adapted from HR Wallingford, 2024a; adapted from the Green Finance Initiative 2024.

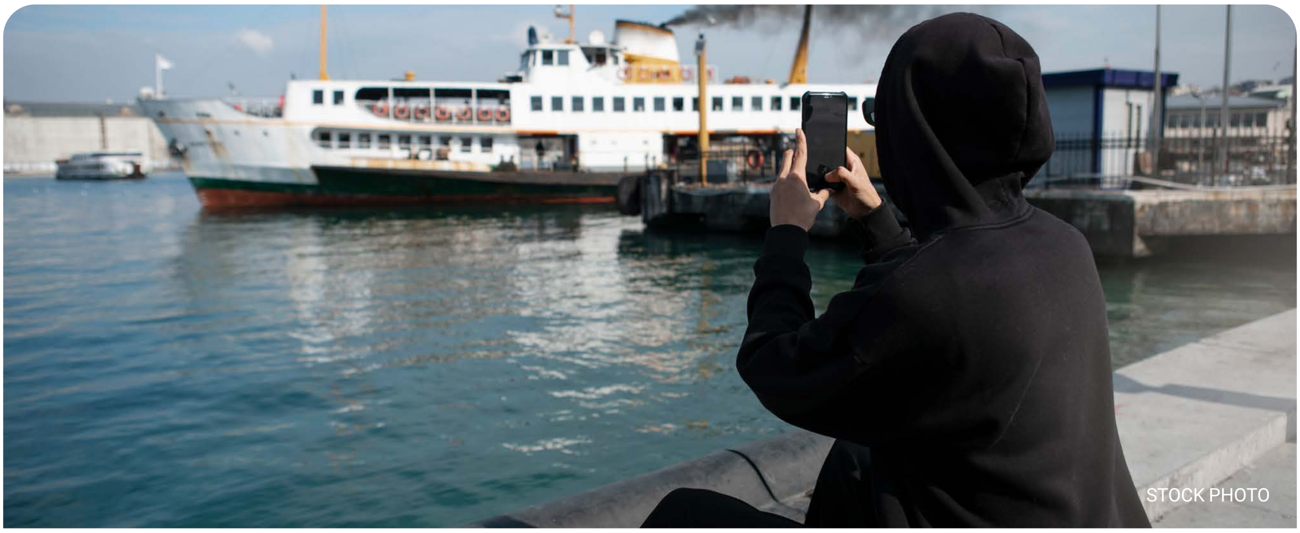
In many locations mangroves have been found to offer long-term flood protection benefits in the hundreds of thousands of US dollars per hectare (Menéndez et al 2020). In Jamaica alone, mangrove forests have been estimated to provide US$32.65 million in flood reduction benefits each year to Jamaica's built capital. It is estimated that without these mangroves, the country could suffer a 10 percent rise in the number of people exposed to flooding each year (World Bank 2019b). Other ecosystems also offer protection, for example wetlands may have reduced direct flood damage by US$625 million during Hurricane Sandy (Narayan et al. 2017)..

Coral reefs can also diminish the velocity and power of waves by producing friction against the incoming water force. As with mangroves, the extent to which coral reefs offer protection from natural hazards depends on a wide variety of factors (Figure 10). For wave hazard reduction, three key characteristics are found to be particularly important: the steepness of the foreshore slope, the rugosity (roughness) of the coral surface, and the complexity of the coral system. As each of these characteristics increases, so too does the coral's effectiveness in ameliorating waves. Some of these elements, specifically rugosity and complexity, depend on the health of coral and seem to be in decline. Further decline could occur if climate change persists.

Figure 10. Key factors in the effectiveness of coral reefs in wave reduction

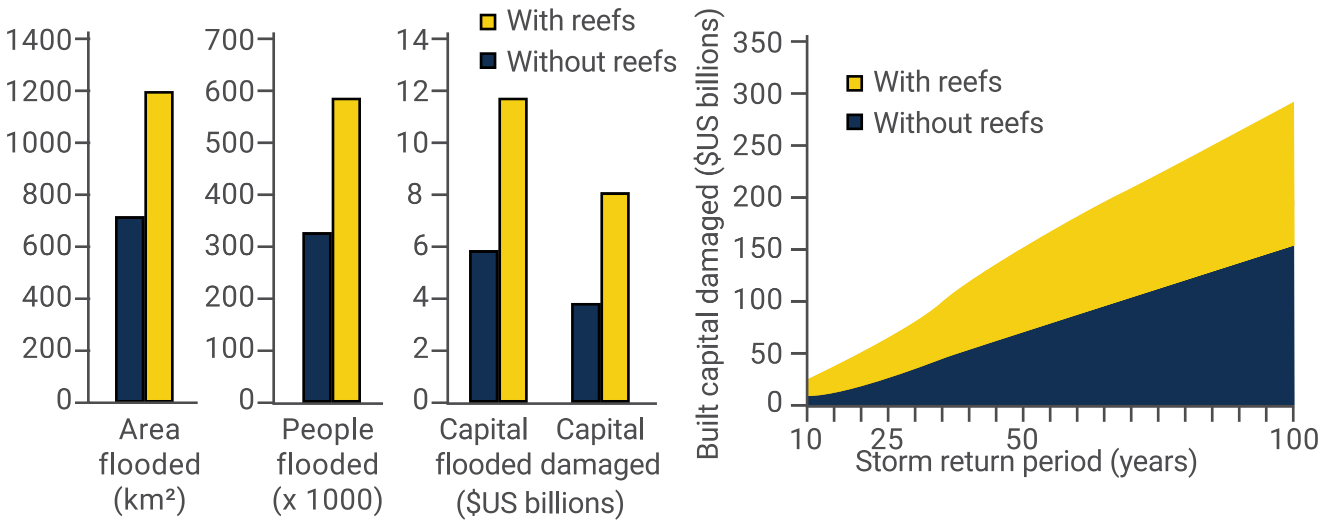


Source: Adapted from Elliff and Silva 2017.



Globally, reef coastlines have been estimated to reduce damage from storms by over US$4 billion per year on average (Beck et al. 2018). Some reef locations have long-term flood protection benefits that range from tens to hundreds of millions of US dollars per kilometer (Beck et al. 2018). Figure 11 shows the estimated global flood impacts in scenarios with and without coral reefs being present.

Figure 11. Global coastal flood impacts, with and without coral reefs



Source: Adapted from Beck et al. 2018.

Globally, reef coastlines have been estimated to reduce damage from storms by over US$4 billion per year on average (Beck et al. 2018). Some reef locations have long-term flood protection benefits that range from tens to hundreds of millions of US dollars per kilometer (Beck et al. 2018). Figure 11 shows the estimated global flood impacts in scenarios with and without coral reefs being present.

The impact of natural hazards and climate change on ecosystems

Natural hazards and climate change threaten ecosystems and the services they provide—notably the protection of local infrastructure against natural hazards. Damage to marine ecosystems caused by storm surges, hurricanes, temperature change, and other hazards reduces their ability to offer protection from future events.

Both coral reefs and mangroves are susceptible to damage by storms. Coral reefs often have the ability to self-repair and grow back (UNEP, 2024), while the situation for mangroves is less clear. Storms can damage mangroves by changing the hydrography and topography of mangrove habitat, causing shifts in sediment, or by directly damaging trees (Herrera-Silveira et al. 2022). But there is conflicting information in the peer-reviewed literature on the degree of damage inflicted on mangroves by extreme weather events. Studies do not agree on the amount of damage done by storms or on the time it takes for recovery, though there is some consensus that mangroves do recover after storms (Krauss et al. 2009; Alongi 2008). How quickly they recover depends on the mangrove species and structure, on competition, and on changes in geomorphology (Alongi 2008; Herrera-Silveira et al. 2022).

The ability of ecosystems to self-repair and recover is diminished by climate change and other human-made threats. Mangroves, corals, and other habitats such as seagrass are affected by sea-level rise, ocean acidification, and temperature changes as well as damage caused by natural hazard events. Corals, for example, can be bleached through higher sea-surface temperatures; ocean acidification causes them to become more porous, less resilient to erosion, and less able to withstand incoming wave forces. Sea-level rise is another threat. In cases where sea-level rise occurs gradually, corals are more likely to be able to keep pace and grow upward toward the light. But the extent to which corals can keep pace with sea-level rise depends on their species as well as their bathymetry. The Great Barrier Reef has been studied extensively, and recent modeling has demonstrated that various threats—increased temperature, ocean acidity, cyclone intensity, competition, predation, and chemical and sediment pollution—could cause coral reef decline in the future. Under all future climate scenarios tested, it was found that both climate and pollution pose a risk to inshore coral reefs that could result in bleaching and mortality (Mentzel et al. 2024).

Case study: Value of marine ecosystem services in the Caribbean

An illustrative exercise carried out by HR Wallingford (2024c) attempted to include the effect of marine ecosystems within disaster loss modeling. The aim was to portray how the impact of marine ecosystems (mangroves and coral reefs) might ameliorate losses causes by natural hazards. The exercise focused on The Bahamas as a case study because of the relatively developed data sets and models available for the country.

To estimate the value of ecosystems in protection, the study modeled the hazard and expected damage in scenarios with and without the ecosystem in place. The modeling occurred in five main stages: the first stage modeled the natural hazard (the source); the second stage modeled the way it physically reaches the coastal area (the pathway); the third stage modeled the direct damage inflicted (the receptor); and the fourth stage modeled the consequent financial impact (the consequences). In the fifth stage, the model accounted for events of different magnitudes and probabilities to produce an estimated average annual damage result. More detail on the methodology is below.

Stage 1. Modeling of the natural hazard (the source): Two natural hazards (hurricane surge and inundation risk) were modeled for The Bahamas, based on 10,000 years of synthetic hurricane tracks. These synthetic hurricanes were generated using statistical analysis of historical hurricanes from 1979 to 2020 inclusive (Grey, Turnbull, and Simmons, forthcoming; Grey, Liu, and Simmons, forthcoming).

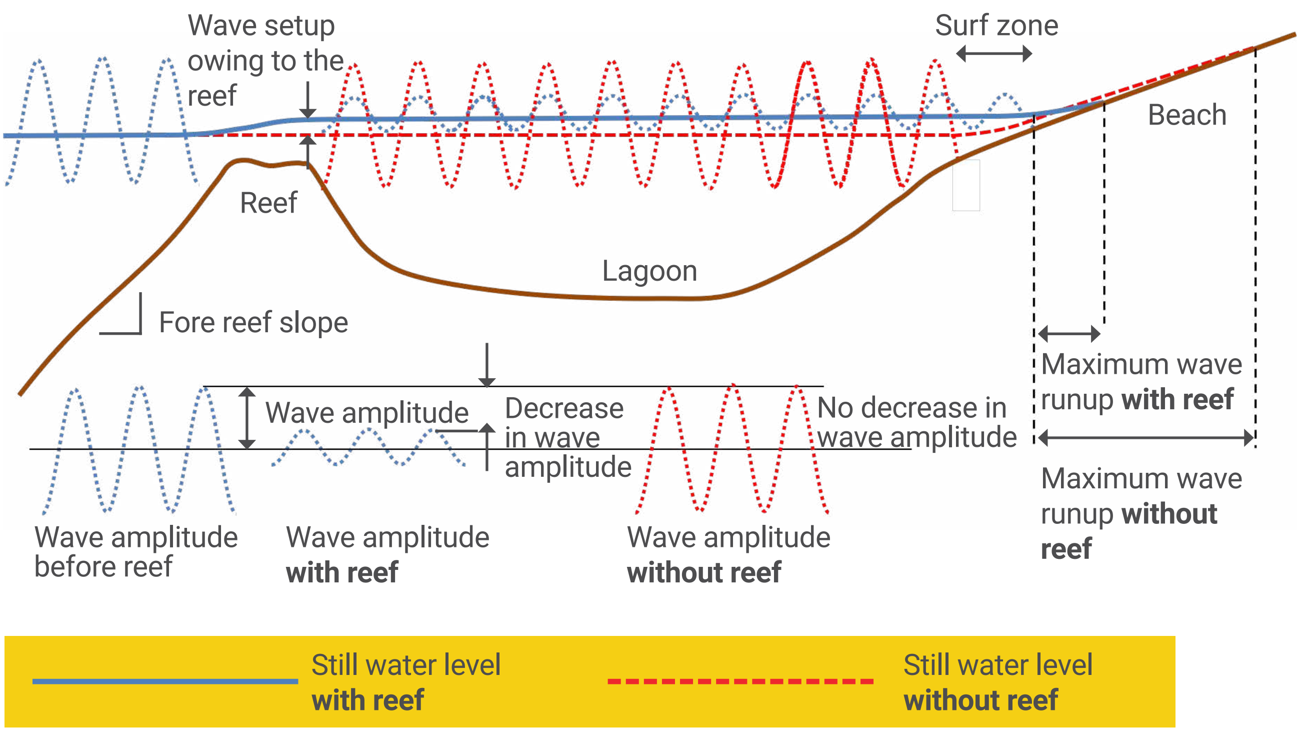
Stage 2. Modeling the propagation of the natural hazard reaching landfall (the pathway): Next, the waves and flood depths were modeled to produce estimates of the maximum onshore height reached by waves for different return periods.

Within this pathway model, the study modeled the effect of coral reefs and mangroves in ameliorating waves using the SWASH model (Simulating WAves till SHore). As described at the start of Section 2, multiple factors affect the extent to which coral reefs and mangroves ameliorate wave propagation (wave height, seabed slope, topography of coastland; density, spacing, and height of mangrove trees and leaves; the species of coral or mangrove, the structure of root systems, and the extent of the coral or mangrove area through which waves must travel). The large volume of data required for modeling these effects means that it was possible to model only seven representative cross-sections of Caribbean coast.

For coral reefs, five modeled cross-sections of coastline were chosen as representative of reef profiles found in the Caribbean. In general, the slope of Caribbean reef foreshores is steep, and for this reason, three of the five reef profiles had steep foreshores (i.e., steeper than 1 in 30). Nevertheless, as previous research (Buckley et al. 2022) had shown that the slope of the reef foreshore is an important factor in attenuating wave heights, two cross-sections with relatively shallow reef foreshores (i.e., 1 in 82 and 1 in 242) were included in the modeling. Concerning the width of the reef flat, the Caribbean tends to have reef flats of about 10–150 m (Lutzenkirchen et al. 2023). The reef flat widths modeled ranged from 10 m to 90 m. The width of lagoons behind coral reefs in the Caribbean also varies from 100 m to 1.5 to 2.0 km (Jordan et al. 1981), and the modeling included four cross-sections with lagoon widths in this range and one with a lagoon 5 km wide.

An illustration of the effect of a healthy reef on expected wave amplitude is shown in Figure 12.

Figure 12. Effect of a healthy reef on wave setup and amplitude

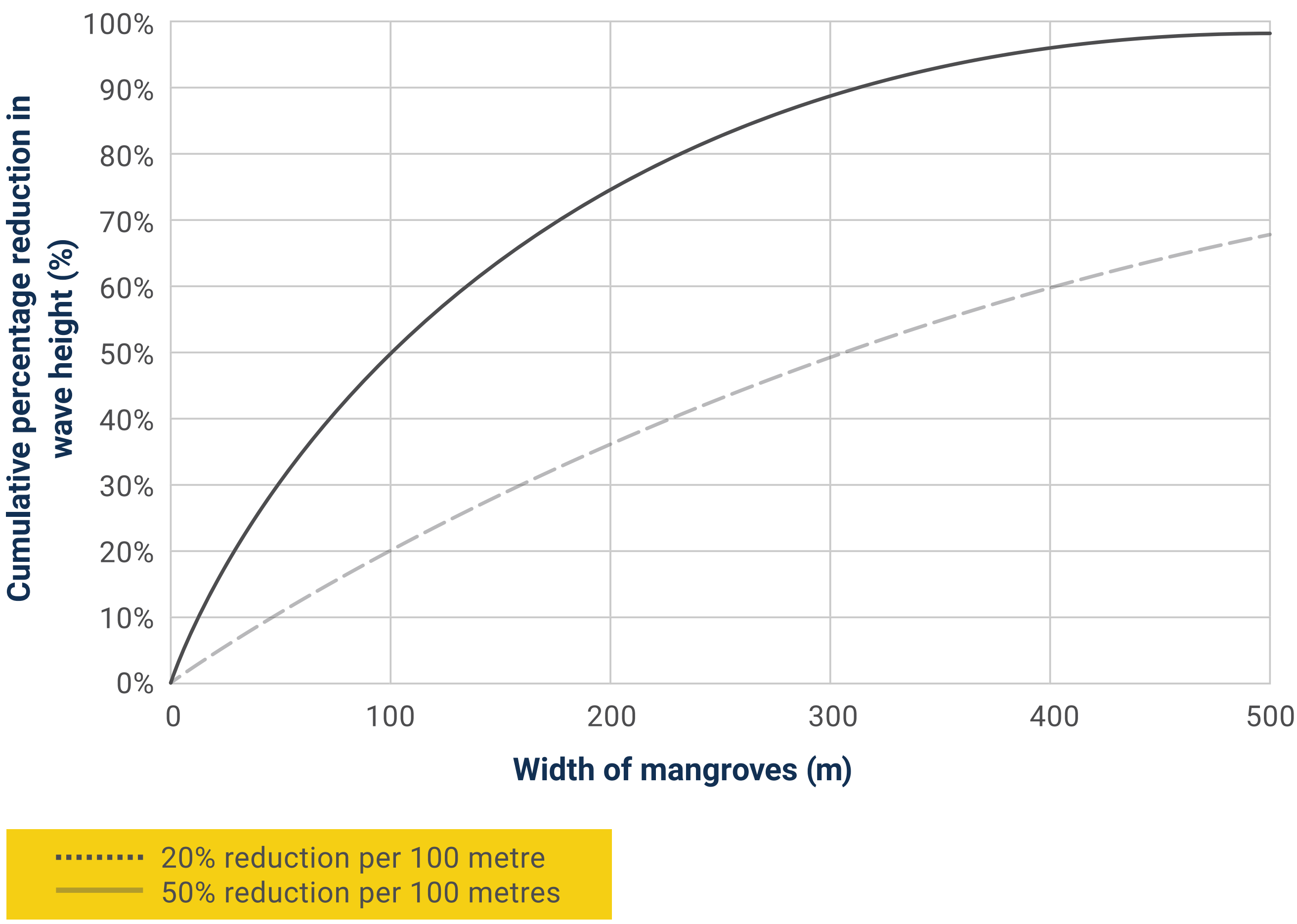


Source: Adapted from HR Wallingford, 2024c.

It should be highlighted that in cases where coral reefs are unhealthy or in poorer condition, they have less impact on wave amelioration. This is due in part both to the decline in the roughness of coral surface areas and to the decreased geometrical complexity of unhealthy coral structures. In some situations, an unhealthy reef may actually increase the wave propagation (Carlot et al. 2023).

For mangroves, two coastal areas in The Bahamas were found to be typical of the Caribbean coast— representative of the flat, shallow, intertidal areas likely to be found—and were chosen for the modeling study. A review of the literature finds that for water traveling through mangroves, the trees typically reduce wave heights by between 15 percent and 85 percent for each 100 m that the water travels (HR Wallingford, 2024a). Two scenarios were modeled; in the first, mangroves reduce wave heights by 20 percent per 100 m width of mangroves; and in the second, mangroves reduce wave heights by 50 percent per 100 m width of mangroves. The modeling estimated the benefits of mangroves in reducing expected annual damage (EAD) depending on their width. Widths of 25m to 500 m were modeled for each of the two wave reduction scenarios (20 percent and 50 percent wave height reduction per 100 m of mangrove). The modeled effect of mangroves in ameliorating wave height in is depicted in Figure 13.

Figure 13. Cumulative percentage reduction in wave height versus the width of mangroves



Source: Adapted from HR Wallingford, 2024b.

Stage 3. Modeling the direct physical damage (receptor): Modeling was based on depth-damage curves for assessing wave or flood damage. In this case, the depth-damage curves estimated the physical damage to low- and high-rise buildings depending on the magnitude of the wave event.

Stage 4. Quantifying the financial cost of direct damage (the consequences): The direct damage estimated in the receptor model was converted to monetary values (US dollars). Usually, quantification is based on local data on the characteristics and the financial value of assets, coupled with the estimates of direct damage from stage 3[6].

Stage 5. Accounting for events of different frequencies and magnitudes: Models were run under different scenarios to estimate the expected damage depending on the magnitude of the natural hazard event (the source). This enabled development of a more realistic picture. Different magnitudes of natural hazard events will occur with different likelihoods; for example, larger hurricanes tend to occur less frequently (perhaps once in every 100 years), whereas smaller hurricanes occur more frequently (perhaps once in every 10 years). Running the model under different scenarios allowed a yearly average to be estimated that considers the likelihood of different events occurring in any one year.

The modeling stages described above are illustrated in Figure 14.

Figure 14. Method used for estimating the expected annual damage (EAD)

Stage 1: Modeling of the natural hazards (the source)

Stage 2: Modeling the propagation of the natural hazard reaching landfall (the pathway)

Stage 3: Modeling the direct physical damage (receptor)

Stage 4: Quantifying the financial cost of direct damage (the consequences)

Stage 5: Accounting for events of different frequencies and magnitudes

Stage 6. Estimating expected annual damage

Source: World Bank.

6- To provide a simplified example, if the total value of local assets is US$1million, and the damage-curves suggest damage of 7% of the asset value, the total value of damage would be US$70,000.

Based on the physical damage to assets estimated by the modeling, the EAD was estimated as the proportion of total tourist asset value likely to be lost due to damage in any one year. For example, if the value of expected annual damage caused by natural hazards was half the total value of tourist assets, the EAD would be 50 percent.

For coral reefs, the results of modeling run for the five different coastal areas studied are shown in Table 2 and Table 3.
The tables show the value of estimated annual damage relative to the total asset value. As an example, in table 2, comparison of the first result in the second and third columns shows that without any reef the expected annual damage as a percentage of total asset value is 10.03% (i.e. 10.03% of low-rise tourist-related building value would be destroyed), whereas the percentage of total asset value lost destroyed reduces to 4.97% when a healthy reef is present. This means that EAD for low-rise tourist-related buildings would be just over twice the size if the healthy reef is removed and no reef is present.

Table 2. Expected annual damage (EAD) for low-rise tourist buildings in the Caribbean as a percentage of the total value of asset

Cross-section	No reef EAD (as % of total asset value)	Healthy reef EAD (as % of total asset value)	Unhealthy reef EAD (as % of total asset value)
XS-E1	10.03%	4.97%	10.30%
XS-E4	11.19%	10.13%	10.95%
XS-E6	6.50%	7.02%	10.33%
XS-GA1	14.42%	13.69%	14.52%
XS-GA3	9.52%	5.33%	12.74%

Source: World Bank, adapted from HR Wallingford, 2024c.

Table 3. Expected annual damage (EAD) for high-rise tourist buildings in the Caribbean as a percentage of the total value of asset

Cross-section	No reef EAD (as % of total asset value)	Healthy reef EAD (as % of total asset value)	Unhealthy reef EAD (as % of total asset value)
XS-E1	3.98%	2.08%	4.11%
XS-E4	5.11%	4.59%	5.13%
XS-E6	2.56%	2.74%	4.16%
XS-GA1	8.00%	7.01%	8.18%
XS-GA3	3.81%	2.20%	5.86%

Source: World Bank, adapted from HR Wallingford, 2024c.

For mangroves, the results of the modeling run for the two coastal areas studied are shown in Table 4, Table 5, Table 6, and Table 7 and in Figure 15 and Figure 16. For example, in coastal location 1, assuming that the mangroves attenuate wave heights by only 20 percent per 100 m width of mangroves, then where the width of mangroves in front of the human-built assets is 100 m, removal of the mangroves could increase the EAD for low-rise tourist-related buildings by around 2.5 percent (increasing EAD from 8.01% to 8.22%). Where the width of mangroves in front of the human-built assets is 200 m, then removal of the mangroves could increase the EAD for low-rise tourist-related buildings by around 5 percent (from 7.82% to 8.22%). Where the width of the mangrove forest is increased to 500 m in front of the human-built assets, the removal of the mangroves could increase the EAD for low-rise tourist-related buildings by almost 30 percent.

Table 4. Expected annual damage (EAD) in coastal location 1, assuming mangroves attenuate the waves by 20 percent per 100 m width of mangroves

Width of mangroves	EAD for low-rise buildings (% total asset value)		EAD for high-rise buildings (% total asset value)	
	Without mangroves	With mangroves	Without mangroves	With mangroves
25	8.22%	8.17%	4.18%	4.16%
50	8.22%	8.12%	4.18%	4.14%
100	8.22%	8.01%	4.18%	4.09%
200	8.22%	7.82%	4.18%	4.01%
300	8.22%	7.65%	4.18%	3.95%
400	8.22%	7.49%	4.18%	3.88%
500	8.22%	7.34%	4.18%	3.82%

Source: World Bank, adapted from HR Wallingford, 2024c.

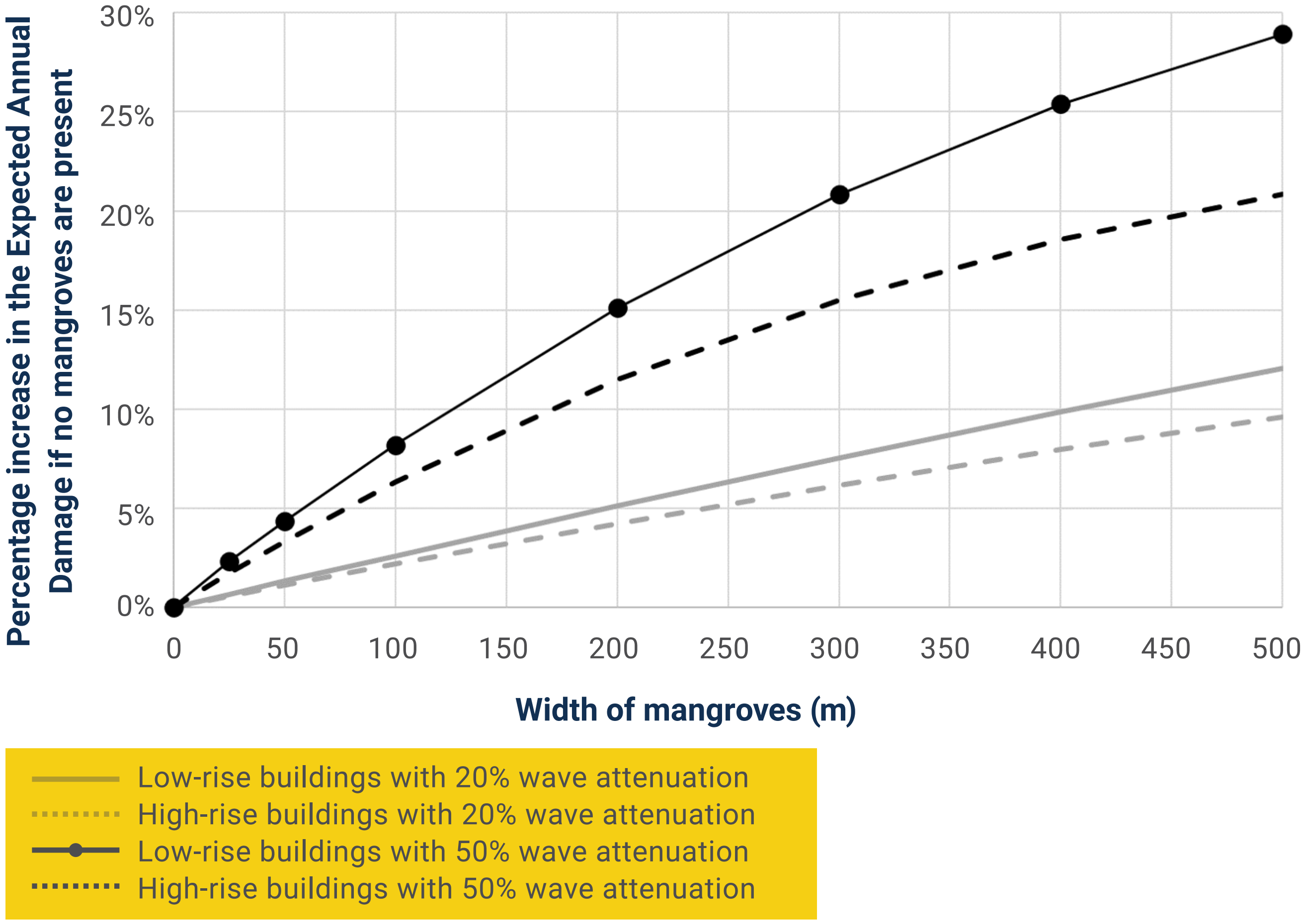
Table 5. Expected annual damage (EAD) in coastal location 1, assuming mangroves attenuate the waves by 50 percent per 100 m width of mangroves

Width of mangroves	EAD for low-rise buildings (% total asset value)		EAD for high-rise buildings (% total asset value)	
	Without mangroves	With mangroves	Without mangroves	With mangroves
25	8.22%	8.04%	4.18%	4.11%
50	8.22%	7.88%	4.18%	4.05%
100	8.22%	7.60%	4.18%	3.93%

Width of mangroves	EAD for low-rise buildings (% total asset value)		EAD for high-rise buildings (% total asset value)	
	Without mangroves	With mangroves	Without mangroves	With mangroves
200	8.22%	7.14%	4.18%	3.75%
300	8.22%	6.80%	4.18%	3.62%
400	8.22%	6.56%	4.18%	3.53%
500	8.22%	6.38%	4.18%	3.46%

Source: World Bank, adapted from HR Wallingford, 2024c.

Figure 15. Percentage increase in the expected annual damage (EAD) in coastal location 1, dependent on the width of mangroves removed



Source: Adapted from HR Wallingford, 2024c.

Table 6. Expected annual damage (EAD) in coastal location 2, assuming mangroves attenuate the waves by 20 percent per 100 m width of mangroves

Width of mangroves	EAD for low-rise buildings (% total asset value)		EAD for high-rise buildings (% total asset value)	
	Without mangroves	With mangroves	Without mangroves	With mangroves
25	15.59%	15.33%	7.38%	7.29%
50	15.59%	15.08%	7.38%	7.20%
100	15.59%	14.58%	7.38%	7.03%
200	15.59%	13.63%	7.38%	6.70%
300	15.59%	12.75%	7.38%	6.41%
400	15.59%	11.94%	7.38%	6.15%
500	15.59%	11.19%	7.38%	5.91%

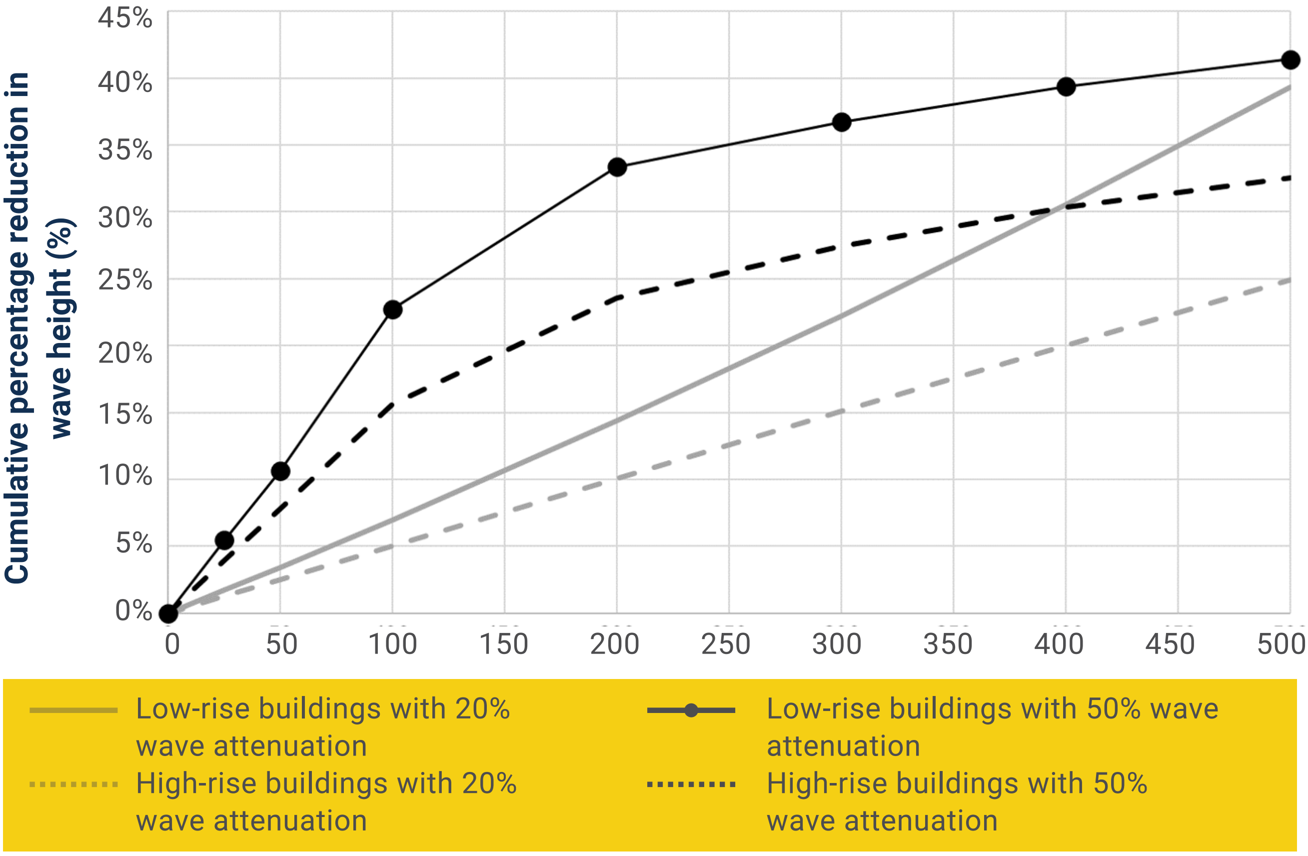
Source: World Bank, adapted from HR Wallingford, 2024c.

Table 7. Expected annual damage (EAD) in coastal location 2, assuming mangroves attenuate the waves by 50 percent per 100 m width of mangroves

Width of mangroves	EAD for low-rise buildings (% total asset value)		EAD for high-rise buildings (% total asset value)	
	Without mangroves	With mangroves	Without mangroves	With mangroves
25	15.59%	14.78%	7.38%	7.01%
50	15.59%	14.88%	7.38%	6.84%
100	15.59%	12.70%	7.38%	6.38%
200	15.59%	11.69%	7.38%	5.97%
300	15.59%	11.40%	7.38%	5.79%
400	15.59%	11.18%	7.38%	5.66%
500	15.59%	11.02%	7.38%	5.57%

Source: World Bank, adapted from HR Wallingford, 2024c.

Figure 16. Percentage increase in the expected annual damage (EAD) in coastal location 2, dependent on the width of mangroves removed



Source: Adapted from HR Wallingford, 2024c.

Modeling case study conclusions and caveats

The study found that corals and mangroves can provide significant value in reducing the damage caused by sea wave hazards.

The modeling suggests that for certain locations, healthy corals could halve the expected annual damage to certain tourism assets, though in other areas their impact is more limited. In one coastal location studied, unhealthy coral reefs actually have a slight negative impact and increase the EAD by 7 percent relative to a situation without reef presence; this result reflects the finding by Carlot et al. (2023) that unhealthy coral reefs may increase the EAD to infrastructure in certain situations. In reality, unhealthy corals are expected to increase expected damage relative to the absence of any reef only in very specific situations. But an unhealthy reef is expected to provide less protection than a healthy reef. These results highlight how crucial ecosystem health is for the well-being of the tourism industry and the wider society and economy.

Results suggest that mangroves could reduce damage to tourist assets, depending on the width of mangroves and site location. For coastal location 1, assuming that the mangroves attenuate wave heights by only 20 percent per 100 m of mangroves, the modeling shows that where the width of mangroves in front of the human-built assets is 200 m, removing the mangroves could increase the EAD for low- and high-rise tourist-related buildings by around 5 percent. If the mangrove forest width was increased to 500 m, removing the mangroves could increase the EAD for low-rise tourist-related buildings by almost 30 percent. In coastal location 2, assuming that the mangroves attenuate the wave heights by only 20 percent per 100 m of mangroves, where the width of mangroves in front of the human-built assets is 200 m, removing the mangroves could increase the EAD for high- and low-rise tourist-related buildings by between 10 percent and 15 percent. As the width of mangroves increases, the damage reduction rises, reaching almost 40 percent for low-rise tourist-related buildings.

As this is new work, the following caveats apply and should be kept in mind for future studies:

» **Research requires highly localized data and site-specific modeling.** It is possible to estimate the potential value of marine ecosystem protection in terms of damage reduction from natural hazards where highly localized data are available and site-specific modeling can be carried out. That is, for modeling to accurately reflect expected damage, it is necessary to have highly specific ecological, topographical, bathymetrical, and geographic data. As with all models, the results depend heavily on the assumptions used, and consequently validation of the model and its results is key.

» **The models' limited scalability creates high barriers to market entry for the insurance industry.** The need for highly localized data on a large number of variables means that risk models cannot be extrapolated to serve larger geographical areas. This constraint limits the potential market size that any one model could be used for, and makes a significant return on investment in modelling less likely.

BENEFITS FOR THE INSURANCE INDUSTRY

The insurance sector can protect the assets they underwrite by developing insurance products that help maintain marine ecosystems. Reductions in ecosystem services can impact the financial system through credit, market, and underwriting risk (see Financial Stability Board [2024] for an overview). The financial sector is increasingly aware of risks to their balance sheets posed by natural hazards and in response has created organizations such as the Network for Greening the Financial System and the Taskforce on Nature-Related Financial Disclosures, which help guide action in this space.[7]

By reducing risk and expected losses, insurers save money, and they can pass on these savings to their clients in the form less expensive premiums. Accounting for risk mitigation is common practice in primary insurance policies throughout developed insurance markets (including in insurance regulation), with both premium reductions and incentives for taking measures to protect property and businesses. Exploring the success of promoting such resilience investments (successful at primary insurance levels, but notably less so at larger scale) and how that could be used to support eco-system resilience would be beneficial. Insurance can thus play a part in climate change mitigation and adaptation by incentivizing risk reduction through these ecosystem maintenance activities.

Moreover, the insurance industry has opportunities to expand its markets by insuring marine ecosystems themselves. Coral reefs alone are estimated to produce US$36 billion for the global tourism industry (Souter et al. 2020), yet the Intergovernmental Panel on Climate Change considers them one of the most vulnerable marine ecosystems (Gattuso et. al 2014). Businesses as well as governments have a motivation to protect this key income source and may be willing to purchase insurance to maintain it.

7- See NGFS (2023) and the TNFD website at https://tnfd.global/.

Insurers also have opportunities to develop new products by harnessing the power of new technology. New technology could help fill knowledge gaps—not only about how events affect human-made assets, but also about events affect ecosystems and their ability to protect against hazards and offer other services to society. This new information can help inform risk models developed for parametric insurance. For example:

- **Satellite monitoring data across time and seasons could be compiled to build up more granular maps of climate and hazard impacts in specific areas.** Satellite imagery is being used to monitor ecosystems' extent (area covered) and in some cases condition. Models can be produced to identify the ecosystem types (habitat) based on satellite and airborne images (Iglseder et al. 2023). In the UK, experts are also investigating methods to assess woodland condition by verifying Sentinel-2 satellite data with on-the-ground monitoring. This work aims to improve the assessment of ecosystem (habitat) condition by refining the satellite-derived indices used—that is, by ground-truthing satellite-based assessments with ecologists' observations on the ground (Biological Recording Company 2024).
- **Various technologies could be used to collect data for assessing ecosystem services provided in different locations (Schirpke et al. 2023).** Mobile data are being used in citizen science projects (for example, to identify ecosystems with high numbers of visitors); virtual reality technologies are being used to assess the intangible benefits derived from natural assets (e.g., cultural value of a woodland). Evidence of this type could be harnessed to help estimate the value of Caribbean marine ecosystems.
- **Machine learning could be used to draw together the massive volumes of data required for risk models that account for ecosystem changes.** By combining different data (geographic, ecological, and economic), there might be the potential to build "dirty but cheap" models of risk. These could then be used to highlight areas standing to benefit most from ecosystem insurance so that resources could be channeled to improve modeling in these locations.


STOCK PHOTO

SUPPORTING BLUE-GREEN INVESTMENT

Insurance can protect conservation funds by ensuring they are not diverted after a disaster. Often, when public finances cannot cover the cost of post-disaster recovery activities, governments divert funds from other areas to fill urgent spending requirements. This tendency can put other planned spending—such as economic development projects, social programs, or nature conservation—on hold or jeopardize it completely. Where assets are insured, however, less public finance is required, and conservation funds are safer.

Quantifying the value offered by marine ecosystems makes it possible to attract green finance to support them; both before and after disasters occurring. Coastal ecosystems have been estimated to produce US$15 billion in tourism, recreation, fisheries, and carbon sequestration each year. This includes services from mangroves and seagrass (valued at US$6.7 billion a year) and coral reefs (US$6.2 billion a year). Carbon sequestration by mangroves alone is estimated at over US$6.5 billion per year (Heck et al. 2019). Information like this encourages investment in healthy ecosystems, which benefits the investors (who buy "green credits" or similar), the nature conservation community, and the local areas that benefit from the marine ecosystem services.

Insuring green-blue investments, such as carbon offsetting projects, is a recent innovation by the insurance industry. Insurance for carbon credits has recently been pioneered by Howden Insurance Group. The product insures green investors' purchase of carbon credits with the Mere Plantations teak reforestation project in Ghana (Howden 2024). Carbon offsetting investments do not always produce benefits, whether due to poor design or simply the failure of well-designed activities to achieve the expected results. Standards have been established in an attempt to improve the value provided by carbon offsetting projects; these include additionality (sequestration above what would have occurred without investment), permanence (sustainability in the face of climate, natural hazards, and other forces), and quantification (sufficient data collection to assessment how much carbon is sequestered in scenarios with and without the project). Data produced from monitoring these green investments can be harnessed to inform ecosystem insurance.


STOCK PHOTO

The challenges in developing insurance for marine ecosystems

This section explores issues found important for developing insurance products and finance for ecosystems. Experience with existing relevant products points to challenges in assessing and securing financial requirements (e.g., through risk modeling), in assessing the costs and benefits of ecosystem restoration, and in implementing practical and institutional requirements (Beck et al. 2019; Secaria et al. 2019; The Green Finance Institute, 2024).

COMPLEXITY OF INTEGRATING MARINE ECOSYSTEMS WITHIN DISASTER RISK ASSESSMENTS AND LOSS MODELS

A major challenge for efforts to develop insurance for marine ecosystems is integrating these ecosystems within risk assessments and loss models. To understand why this is so, some background on catastrophe loss modeling is helpful and provided below.

For insurers to accurately price products covering disaster losses, they must be able to estimate the likely magnitude and frequency of payouts. On the other side, potential buyers (such as governments and businesses) want to know the expected size and magnitude of payouts when assessing the potential benefit of purchasing coverage. To forecast the likely losses that insurance would cover, risk models are required to estimate the likelihood and magnitude of different disaster events, along with their likely impact in terms of damage and losses. Nevertheless, there are multiple challenges in developing risk models able to incorporate the effect of ecosystems.

3- For details see EM-DAT: The Emergency Events Database, Université catholique de Louvain, Belgium, https://www.emdat.be/.

Disaster risk assessments, particularly within insurance, rely heavily (but not solely) on catastrophe loss models to quantify risk and to price insurance based on the impact of extreme events. Catastrophe loss models were first developed in the late the late 1980s following a series of major natural catastrophe events and insolvencies among undercapitalized insurers. They are sophisticated tools that draw on scientific disciplines to estimate the financial impacts of rare/extreme events. Within the property insurance markets, catastrophe loss models are a primary mechanism for estimating risk.

The basic approach of all catastrophe models is to develop a large catalogue of synthetic hazard footprints with physically realistic spatial resolution that cover the geographical extent of the model. Each event in the catalog will have an associated probability of occurrence so that the user can generate tens or hundreds of thousands of years of physically realistic simulations of the peril in question. Thus, risk can be assessed based not only on the limited historical records available, but on a very extensive simulation of catastrophe events that are physically realistic and plausible and that expand beyond observed history to include much more extreme events than those that may actually have occurred.

The spatially resolved nature of the events allows these models to explicitly capture correlations between any set of locations; models can thus develop location risk analytics and also quantify the risk to a portfolio of assets. Catastrophe loss models are often multi-peril, i.e., they include some or all of the sub-perils associated with a given event, such as wind, surge, and rainfall from a tropical storm, or ground motion, landslide, liquefaction, and tsunami from earthquakes. Catastrophe loss models include multiple hazard-damage "vulnerability" relationships that translate a hazard experienced at a location to a damage estimate for different types of property, assets, or infrastructure. These hazard-damage vulnerability relationships are often called damage curves. Catastrophe loss models also include a financial model that translates damage to property, assets, or infrastructure to a financial consequence.

However, catastrophe loss models do have limitations:

» **They are extremely costly to develop and maintain.** Few companies have the internal capacity to develop models, and the market is dominated by a few third-party vendors or solutions developed by large international brokers.
» **Their development has been focused on core property and casualty insurance markets,** so that the coverage, options, and quality of models in markets like the Caribbean can be limited.
» **Their development has prioritized the key drivers of building or property insurance—i.e.,** wind over water for insurance in the United States.
» **Their validation is very challenging.** All risk modeling should provide transparency on the assumptions used and should compare the overall output of the model to historical experience; but when integrating ecosystems into catastrophe risk modeling, the ecosystem-linked resilience must be treated as a separate component with its own validation before it is integrated into the risk modeling chain.

Consequently, even when models are available, they typically fall short:

» **They do not model the impact of hazard directly on ecosystems such as coral reefs or mangroves.**
» **They do not consider nonlocal or**

downstream consequences, such as indirect loss or business interruption. Although the most sophisticated models do approximate business interruption impacts, these impacts are typically estimated based on physical damage having occurred at that location. They do not consider wider effects on society or the economy. New approaches to quantify wider impacts such as trade disruption and indirect losses are emerging, but the modeling is in its infancy.

» **They do not consider the effect of ecosystems in ameliorating damage.** Where protective mitigations or measures are in place, models typically consider only hard protection (such as seawalls), standards of protection quantified by national agencies, or local measures specific to individual properties (such as elevated ground floors or hurricane shutters).

Studies such as that undertaken by HR Wallingford (2024a, 2024b, 2024c) are valuable in highlighting the complexity of integrating nature-based solutions into disaster risk assessments and catastrophe loss models.

Challenges in quantifying the impact of natural hazards on the ecosystem and on its ability to provide protection

The large number of factors affecting ecosystems and the protection they provide, and the complexity of untangling their impacts, makes modeling challenging and inherently more uncertain than other components of risk assessment. Not only is the underlying scientific evidence on these relationships limited, but modeling also requires a large volume of site-specific data, which increases the cost of producing risk models.

Part of the difficulty lies in the ability of some ecosystems to repair themselves. As described in Section 2, coral reefs damaged by storms do have the ability to self-repair and offset erosion by growing back (UNEP 2024). At the same time, the ability of coral reefs to self-repair is diminished in the face of other threats such as increases in ocean temperature and ocean acidity. Regarding mangroves, the peer-reviewed literature differs both on the amount of damage caused by storms and on the time it takes for recovery. Factors affecting recovery time include mangrove species, structure, competition, and changes in geomorphology (Alongi 2008).

Challenges in quantifying the physical effects of marine ecosystems in ameliorating risk

The degree to which marine ecosystems provide protection against climate and natural hazards varies depending on a wide variety of factors and hence requires a large volume of different types of data. But the data collected by research studies is often deficient, in part because studies do not always record the full range of factors that influence natural hazard reduction. The result is that there are not sufficiently robust metrics to use in risk modeling. To help overcome issues with data in future, studies should collect data not just on the natural hazards (e.g., wave height and energy attenuation rate), but also on other influencing factors such as the species composition of the ecosystem, physical structure of the ecosystem, and the hydrodynamics of the marine environment.

Challenges in quantifying the monetary value of protection provided by ecosystems

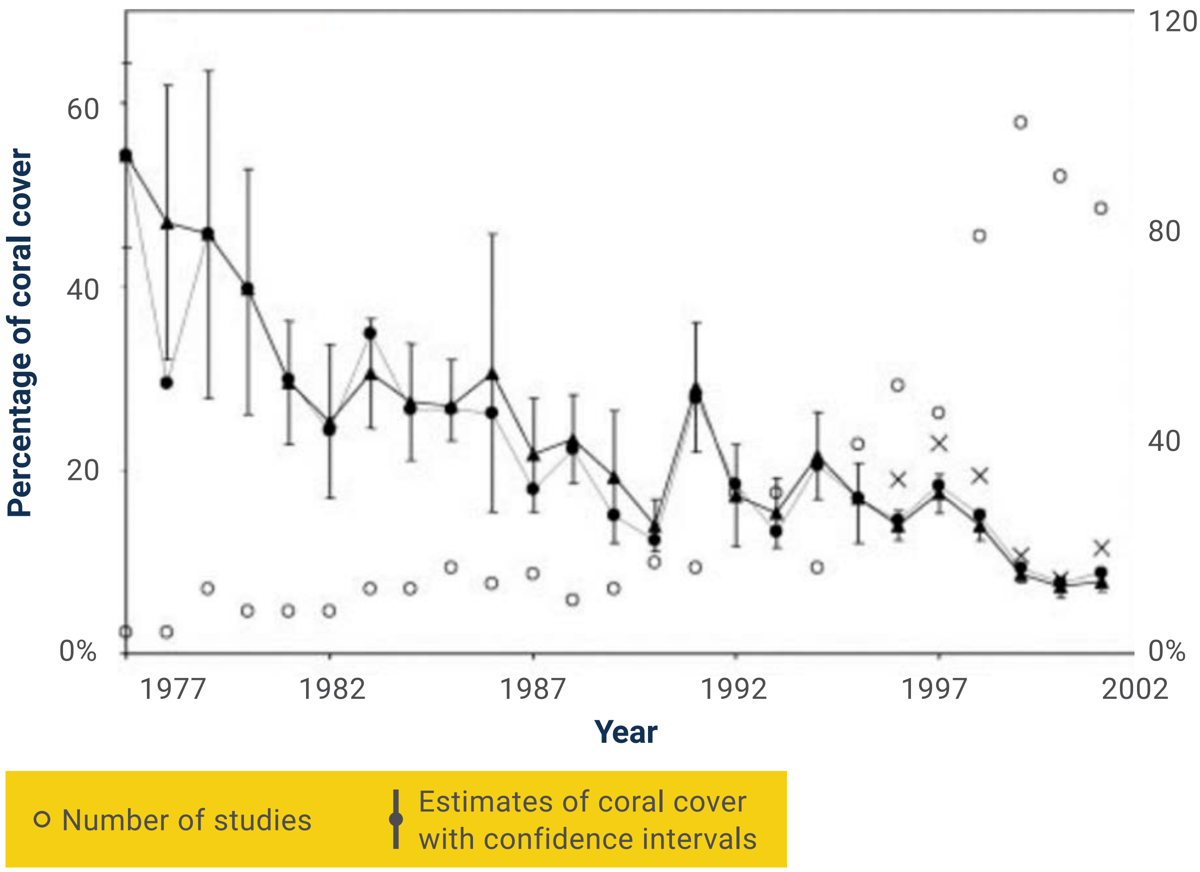
Quantifying the economic consequences of disaster, such as business interruption and lost revenue, is important but challenging. In the Caribbean, for example, the tourism industry relies heavily on transport and infrastructure for its operation, with almost all clients requiring sea or air travel. Businesses also need local infrastructure and transport for restocking and other vital activities. Some 45 percent of firms report that if power infrastructure was disrupted for one day, their daily revenue would drop by 50 percent or more (Erman et al. 2021); for longer disruptions, the share of businesses experiencing a halving of revenues would increase. Difficulties in quantifying the monetary value of business interruption due to different disaster events relate to data collection; calculations require site-specific survey data and local economic data (for example local business revenues collected by municipalities) that are not always available.

Challenges in quantifying changes due to climate change and other time-varying factors

Changes in marine ecosystems due to climate change (and other time-varying factors) are well documented, as described below, but difficult to quantify.

Globally, coral reefs are in decline due to climate change. Corals are at risk of bleaching, disease, overfishing, and pollution (Webster and Schindler 2024). Research that models future changes in coral forecasts a low abundance of living coral until the climate stabilizes (McManus et al. 2021). Analysis by Gardner et al. (2003) finds a decline in the absolute coral cover in the Caribbean between 1977 and 2001, with a fall in coral cover from about 50 percent in the 1970s to about 10 percent in 2001 (Figure 17).

Figure 17. Decline in Caribbean coral between 1970 and 2001



Source: Adapted from Gardner et al. 2003.

Mangroves have also been affected by climate change, as well as population encroachment and sea-level rise, so that the area covered by mangroves in the Caribbean has declined in recent decades (for details see HR Wallingford, 2024c). As of 2007, the Caribbean region had experienced the second highest loss in mangrove area relative to other global regions, with around 24 percent of mangrove area lost between 1980 and 2005 (FAO 2007). Mangroves can adapt to sea-level rise by migrating inland and by accreting sediments (Blankespoor et al. 2017; Krauss et al. 2014). But they become more vulnerable to sea-level rise in areas of low-relief islands, where there is a reducing elevation in sediments and new sediment supply is limited (Alongi 2008), and where there is restricted area for landward migration (Gilman et al. 2008). There is less evidence on how mangroves respond to other climate change threats such as rising carbon dioxide concentrations and temperature change (Alongi 2008; Gilman et al. 2008).

Aside from climate change, mangroves are also affected by coastal development and aquaculture as well as deforestation, diseases, and pollution (Akram et al. 2023). These factors can directly cause mangrove loss and can limit the extent to which mangroves cope with changes in the environment.

As living ecosystems, both coral and mangroves also experience seasonal changes and other changes over time, which affect their structure and ability to ameliorate natural hazards. For models to accurately quantify damage reduction value from ecosystems, they must be based on timely data, such as up-to-date topography and bathymetry data (Beck et al. 2018). Although high-resolution coastal elevation (topographic) data are becoming more available, in many countries data are still limited. Accurate nearshore bathymetry data can be even more sparce (Beck et al. 2018).

Summary of information deficiencies

In summary, improved risk modeling requires more evidence in several areas:

- **The extent to which ecosystems reduce the impacts of natural hazards.** Studies must collect data not just on the extent to which ecosystems ameliorate hazards (e.g., reduce wave height) but also on other influencing factors, such as the species composition of the ecosystem, species' structures, and the characteristics of the hazards (e.g., wind speed, hydrodynamics, land gradients, etc.).
- **The amount of damage to ecosystems caused by natural hazards, and the time it takes them to recover,** in particular in the face of climate change and other human pressures (e.g., pollution).
- **Local infrastructure characteristics and capacity to withstand natural hazards** (e.g., waves), with and without marine ecosystems present. There is a need for granular data on building type and location, as well as studies that provide more detailed damage curves that include a larger number of risk factors (e.g., building structure, materials, etc.).
- **The extent to which local livelihoods and businesses suffer financial losses after events.** In particular, information regarding business interruption and other indirect effects is needed.

The data collected on the value of ecosystem protection against natural hazards will also be valuable for other important purposes, such as the development of National Environmental Economic Accounts.[9] Many Caribbean countries are advancing their system of environmental and ecosystem accounts, which quantify benefits that society and the

9- United Nations, "System of Environmental Economic Accounting," https://seea.un.org/es/ecosystem-accounting.

economy derive from nature each year, and where possible estimate a monetary value for these benefits.[10] As stated repeatedly above, ecosystems provide a wide array of benefits and services (water and oxygen supply, food, genetic resources, areas for recreation); quantification of these via the national accounts would ensure that these vital services are not overlooked in decision-making and that they can continue to provide benefits to society into the future. In the Caribbean, ecosystem service quantification has focused on the value of protection from natural hazards, the value of providing spaces for tourism and recreation, and the value of fisheries, food, and other marketable produce. Nevertheless, the data that form the basis for the National Environmental Economic Accounts are still relatively limited and could be strengthened by more recent and comprehensive studies.

The many challenges involved in integrating ecosystems in disaster risk and insurance modeling are not insurmountable, however. New technologies could improve modeling and meet some of these challenges (as described in the subsection entitled "Benefits for the insurance industry" in Section 2). Use of parametric products could also overcome some of the modeling complexities outlined above, since it does not require robust modeling of physical effects. For example, if global evidence suggests that coral reefs protect against storm surges and provide ecosystem services to a community, and that coral reefs are damaged by Category 1 storms that pass nearby, all the building blocks of a parametric policy are already in place without hard quantification of all those aspects for the specific location. The unknown risk of damage to assets can still be mitigated by placing a parametric policy with agreed payouts, limited only by the budget of insurance purchasers who must pay the insurance premiums.

COMPLEXITY OF IMPLEMENTING MARINE ECOSYSTEM INSURANCE PRODUCTS THAT COULD SUPPORT TOURISM

The value of new products to insure marine ecosystems, including even parametric products (which could be developed despite limited data on ecosystem protection values under different circumstances), may be difficult to demonstrate to potential buyers. If it is not possible to model the value of ecosystem protection from natural hazards, buyers in the tourism sector will not be able to estimate the expected benefit that would accrue to them from purchasing insurance for funding ecosystem restoration efforts. There also remain additional challenges in assessing the likely costs and benefits of ecosystem restoration after events.

Assessing cost-effectiveness of restoration and maintenance activities

To develop ecosystem insurance products that disburse funds for ecosystem restoration activities after disaster events, it is necessary to assess how much these activities will cost, and the extent to which they will successfully restore nature so that it continues to reduce risk. Not all marine sites will require the same types of restoration. Different species of plants and animals are suited to different environments, and different types of activities (for example, replanting, dredging to restore hydrographical characteristics) have been shown to produce different outcomes.

There is some evidence on both the cost of implementing restoration activities, and the extent to which these activities provide benefits. The evidence for mangroves and corals is summarized below.

10- As indicated by Belize's national strategy ("Strategy 1: Incorporate environmental sustainability into development planning"), the government plans to introduce natural resource accounting into GDP (Barnett et al. 2011).

For the Caribbean, Menéndez et al. (2022) found that the median cost of mangrove restoration was US$23,000 per hectare, except in The Bahamas, which was studied separately and had higher median restoration costs (US$35,955). These estimates were based on collating data from previous reviews to provide a larger number of restoration projects on which to base cost estimations.[11] The type of restoration required will have significant bearing on costs; planting of small mangrove saplings can be relatively cheap, while hydrological restoration is more expensive. Maintaining the project after the initial restoration is also found to be an important factor in project cost (Narayan et al. 2019), and projects costs tends to be lower for larger restoration projects, where there can be economies of scale for one-off fixed costs (such as land permitting, project design, monitoring).

For corals, Bayraktarov et al. 2016 have evaluated the cost and feasibility of marine coastal restoration. The meta-analysis showed that coral reefs tended to have a relatively good survival rate, compared to survival of other restored ecosystems (64.5 percent). Median cost of coral reef restoration projects varied between US$11,717 per hectare, for activities involving coral reef fragments being transplanted to the degraded reefs. The costliest coral reef restoration was US$2,879,773 per hectare, and used transplantation in addition to other activities (stabilizing substrates). The costs and success rates of restoration depend on the type of restoration and the country or location where they are carried out. Another review found that there can be positive feedback loops between different marine ecosystems; for example, nearby seagrass can reduce disease in corals (McLeod et al. 2019).

Regarding cost-effectiveness in the Caribbean region,[12] estimates have assessed that mangrove and reef restoration can be cost-effective for flood reduction in over 20 countries (Beck et al. 2022). A hectare of restored ecosystem is forecast to provide US$100,000 in flood protection benefits on average (Beck et al. 2022).[13] Over 3,000 km of coast were identified as having the potential for cost-effective mangrove restoration investment (Cuba, The Bahamas, and the US had the most study units with positive investment opportunities), and over 1,000 km of shoreline were expected to provide areas where coral restoration would be cost-effective (particularly in Cuba and Jamaica). Even where restoration costs are relatively high, it can still be worth investing given the high returns expected.

With more robust evidence on the cost-effectiveness of conservation interventions, investors will be able to target high-return activities and channel funding toward them. For this to happen, it is necessary for ecologists and conservationists to gather better information on the optimal type of restoration and implementation techniques for use in different circumstances. A review of coral restoration projects (documented in the literature and through practitioner surveys) identified that 60 percent of projects reported less than 18 months of site monitoring (Boström-Einarsson et al. 2020). This limits the extent to which success can be assessed and highlights the need for studies to improve monitoring and evaluation of restoration projects.

11- Herrera-Silveira (2022) assessed the cost of mangrove restoration based on a review of case studies and literature, and Narayan et al. (2019) assessed 72 projects in the Caribbean.
12- Assessments included areas of the United States, Mexico, and other countries within the Caribbean region.
13- This value is the average value that each hectare of restored ecosystem will provide across the lifetime of the restoration project.

Limited scalability of financial products (localized nature of events and heterogeneity in risk across Caribbean Island countries)

There are high barriers to entry for insurers seeking to develop products that integrate ecosystems into risk models. Modeled-loss insurance, which bases payouts on risk models for events of different intensities and forecasts the expected losses incurred, requires models to accurately predict damage. Modeling wave hazards requires site-specific data on the hydrological profile of the coast, physical geography, and assets that could be damaged. In addition, factoring in the role of ecosystems in damage reduction, as well as how the hazard could affect this, requires a further level of detail. As discussed, the ability of ecosystems to provide protection depends on a variety of factors (e.g., their structure, condition, extent).

All these requirements limit the extent to which risk models can be used over larger geographical areas, and in consequence the market scalability. There exists a trade-off between area covered and accuracy; low-resolution models can be used over larger areas but are less accurate, while higher-resolution models can more accurately predict risk but are confined to a smaller area.

Affordability of insurance product

To be viable, an insurance product must be affordable for both the client and the insurer. For insurance clients (asset owners), it is not optimal to insure all assets against all risks. Where insurance is expensive relative to the expected value of losses covered, purchasing insurance is less attractive. In cases where businesses predict relatively small losses from disasters, they choose to use other means of managing risks. Even in cases where it would make sense to insure, the multitude of other financial pressures faced by asset owners can make putting aside funds for insurance premiums difficult or impossible. Most Caribbean tourist firms without insurance reported the cover was "too expensive" (Erman et al. 2021).

Insurers also need the product to be affordable—that is, the premiums they receive must adequately cover their future losses and payouts. Where insurers face high uncertainty about expected losses, they are forced to increase the price of insurance in order to cover the potential for large-scale, unforeseen losses. For example, the recent price increases in the insurance sector have been partially explained by economic uncertainty (Congressional Research Service 2023). Faced with higher uncertainty over their expected losses, insurers must increase their financial reserves and either increase premiums or simply not offer coverage for certain events.

Uncertainty over risks diminishes as risk models improve. With access to more and better information and data, models are better able to predict losses, and the probability of errors decreases. Thus, stronger modeling, including incorporation of aspects relating to natural ecosystems, is vital.

Practical issues in setting up insurance contracts

The legal and regulatory aspects of issuing an insurance policy must be considered when setting up an insurance scheme. Thought must also be given to practical processes to help overcome hiccups that could affect success after rollout. Some important aspects are highlighted below.

There should be agreement on the insured entities as well as the entities responsible for ecosystem maintenance. For an insurance product linked to ecosystem conservation to be viable, it is necessary to define not just the legal “purchaser” of the insurance product (e.g., the local tourism business or government entity that takes out insurance to cover risk) but also the “owner” of the marine ecosystem that is responsible for its restoration or conservation (e.g., governments, local municipalities, communities). There must be arrangements to ensure that the owner responsible for ecosystem maintenance continues to provide the services over time, notwithstanding changes in priorities or challenges faced. Additionally, thought must be given to the value of the ecosystem to the business; a dive operator, for example, could not operate if the reef was lost, and therefore has a vested interest in conserving the reef.

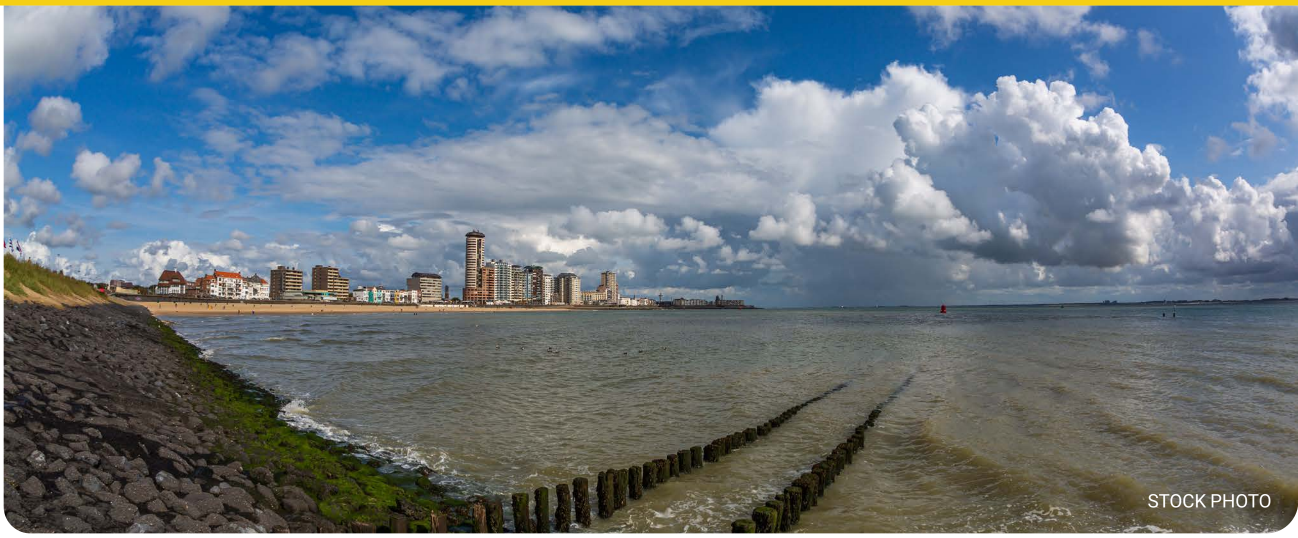
In setting up products to insure marine ecosystems, care must also be taken to avoid a “tragedy of the commons.” This is the scenario in which ecosystems are degraded and overexploited because individual actors have an incentive to use them (catch as many fish as possible, visit a beautiful beach often, lead many tour groups) without contributing to their maintenance; as long as some users are not paying, all users will resist doing so lest they allow “free-riders” to benefit. In this scenario, no private actor has an incentive to own an ecosystem or contribute to the cost of insuring or maintaining it, because its benefits are available free of charge. A way to overcome this issue that has proved successful for other similar products is the formation of trust funds, whereby local actors agree to jointly fund insurance with the understanding that this will benefit everyone. Private actors pay into the trust fund, which purchases insurance and oversees ecosystem restoration activities on their behalf. This solution was used by products such as the Quintana Roo Reef Protection insurance, which developed the Trust for Coastal Zone Management, Social Development, and Security (see Figure 3).

Another issue to be considered in setting up insurance products is the trade-off between the benefits provided by restored ecosystems and the potential disruption or loss of business they create. Tourism companies might be reluctant to support mangrove restoration projects, for example, because they could be disruptive to their business; indeed, given the public’s perception of mangroves as unsightly, a company might judge that mangrove restoration was not beneficial and have little incentive to fund restoration activities.

Mechanisms for disbursement of funds should be also be carefully considered. In practice, disbursing insurance payouts can be a challenge in situations where numerous small local businesses or community organizations are the insured entities. In the Caribbean, the tourism industry includes various businesses with potential incentives to purchase cover (hotels, restaurants, sports, eco-recreation tours, etc.), and many will be small and micro businesses. Insurers may have to offer products that pool risk through a local government or other entity that acts as an intermediary in order to reduce their administrative costs.

Monitoring of ecosystem maintenance is required. For insurers to have faith in the value of the ecosystem services being provided, they will need assurance that effective maintenance is being undertaken. The teams of ecologists and conservationists going out into the field to implement coastal ecosystem recovery may be required to provide progress updates and periodic monitoring, which will increase the administrative costs of offering these products.

Key findings and areas for future research



Travel and tourism is a vital part of economies in the Caribbean, but natural hazards and climate change pose risks to the economy and tourism sector. Natural assets and ecosystems can provide protection against the risks posed by natural hazards through the ecosystem services they provide. One of the vital services provided by ecosystems is coastal protection from hazards such as storm surge waves. However, marine ecosystems can suffer in the process of protecting against various natural risks. Natural assets that suffer direct damage during a hazard event (e.g., from wind and waves) are then less able to provide future protection and other ecosystem services to society. Climate change and human pressures can add to their decline.

It is possible to restore and conserve ecosystems so they continue to provide vital ecosystem services, but these activities—and investment in ecosystems more generally—require finance, which insurance can provide. Insurance offers a way to access funds after hazard events occur that could be beneficial to tourism operators as well as the ecosystem conservation community. Insurance coverage reduces the risk that funding designated for strengthening ecosystems will be pulled away after a disaster and redirected toward other urgent financial pressures (e.g., human asset restoration and recovery).

Research has highlighted the challenges in developing ecosystem-linked disaster insurance. A particular challenge is developing risk models that incorporate ecosystem effects in disaster risk quantification. These are required for modeled-loss insurance and indemnity insurance products, and can also serve to identify locations that could most benefit from insurance for restoring and maintaining ecosystems.

The linkages between marine ecosystems, the extent to which these systems ameliorate natural hazard events, and the way that climate change influences both factors are not well understood, and as a result accurate inclusion of ecosystem effects in risk modeling is limited. More evidence is also needed on the cost and benefits of ecosystem restoration activities.

These benefits are not limited to damage reduction and recreation and tourism value; other relevant ecosystem services include benefits to fishery stocks.

Because many localized, situation-specific factors influence ecosystems and losses from natural hazards, certain insurance products may have a limited potential client base for each risk model they develop. To account for the complexity of ecosystems and interactions with disaster losses, risk models require use of large volumes of many types of data. Consequently, it is often not feasible to extrapolate or generalize risk models for use over large geographical areas. This constraint limits the return on investment for insurers—that is, the costs of modeling local risk are high, while the potential markets that products can serve are small.

This report points to several opportunities and ways forward for developing ecosystem insurance. Despite the challenges facing efforts to develop such insurance, advances are possible and could benefit both the insurance sector and Caribbean tourism industry.

1. Use new technology

New technologies could help overcome the challenges of modeling an ecosystem's interaction with natural hazards. This interaction is highly site-specific, and thus increases the model's data requirements and limits its use over larger geographical areas. But satellite-imagery, mobile data, and machine learning offer powerful tools that could address this problem. They could fill gaps in knowledge—not only about how events affect human-made assets, but also about how events affect ecosystems and the extent of their ability to protect against hazards and offer other services to society.

Governments and relevant institutions could take specific actions to promote and facilitate improved data collection within their localities, and could also share the data so they can be fully harnessed. The insurance and technology sectors could collaborate to improve data collection, dissemination, and use by highlighting existing data gaps and technology solutions that should be prioritized. Several data gaps are identified in this report: the extent to which ecosystems reduce impacts of natural hazards; the amount of damage to ecosystems caused by natural hazards and the time it takes them to recover; granular data on local infrastructure characteristics and its capacity to withstand natural hazards, with and without marine ecosystems; and the extent to which local livelihoods and businesses suffer financial losses after events.

2. Explore possibilities for insurance design

Appropriate insurance design offers another way to overcome modeling complexities. While both modeled-loss insurance and indemnity insurance require a robust quantification of likely losses and risk reduction to ensure that they are efficiently and fairly priced, parametric insurance does not. Pricing of parametric products is based solely on the expected occurrence of a pre-agreed event and a pre-agreed payout if the event occurs. Consequently, parametric insurance can be an option even in situations where neither the physical effects of the marine ecosystems nor the impact of natural hazards on them can be robustly modeled. At the same time, it is still necessary to communicate the value of disaster insurance to buyers. Risk modeling and forecasting of expected losses can provide motivation to buyers, as well as highlight to the insurance industry which areas could benefit most from insurance offerings.

Parametric and modeled-loss products may be suitable when the timeliness of post-disaster restoration is critical as is the case for some ecosystems. More broadly, the more quickly an ecosystem can be restored after an event, the sooner it can return to providing the full range of ecosystem services to society—including protection from hazards, food provision, and areas for tourism and recreation.

To account for the disaster risk mitigation benefits of ecosystems in the design of insurance and premiums, existing insurance product design offers relevant approaches. Accounting for risk mitigation is a common and successful practice in primary insurance policies throughout developed insurance markets (including in insurance regulation); insurers offer premium reductions for risk mitigation and incentives for protecting property and businesses. It would be helpful to explore how these approaches could be used to support ecosystem resilience. The practical issues raised in this report—about setting up insurance contracts and agreeing on the insured entities and the entities responsible for ecosystem maintenance—require attention in this context.

Governments can also take action to explore new insurance designs. Governments can conduct initial assessments to identify regions or localities that depend heavily on ecosystems (such as areas with high revenues from coastal and eco-tourism, areas with important agriculture or fisheries economies), so that these could be targeted for financial protection against natural disasters. Areas identified as both highly important for the economy and highly dependent on ecosystems would be most likely to benefit from financial protection against disasters.

3. Promote collaboration between the insurance industry and environmental stakeholders.

The insurance industry could act as a catalyst for ecosystem insurance products by collaborating with environmental stakeholders, including development institutions. Such collaboration could promote investment in ecosystem resilience activities as part of programs focused on ensuring livelihoods, economic development, and sustainable tourism. For example, Munich Re and The Nature Conservancy recently designed a method to combine community-based insurance along the Mississippi River with ecosystem maintenance activities that improve flood prevention (Munich Re and The Nature Conservancy 2021). Initiatives like this one, or like the Quintana Roo Reef Insurance, could be explored for the Caribbean and could leverage regional entities such as CCRIF SPC and the Caribbean Biodiversity Fund.

Going forward, the insurance industry could promote ecosystem insurance products by drawing on its experience in developing products for other purposes. Although modeling the disaster risk reduction benefits of marine ecosystems is still a novel area, there has been more experience of modeling and financing wider disaster risk reduction investments and incorporating them into insurance product pricing. Lessons might be learned from the insurance, risk modeling, and engineering worlds to help guide this agenda. Other experts (e.g., in technology or data science) could offer complementary solutions to aid in advancing risk modeling. Once improved risk models are developed, other key players (governments, businesses) could be vital partners in product development. These collaborative efforts should learn from relevant existing insurance products, and in particular be guided by how successfully they were implemented. Governments and interested organizations could assess financial insurance products in use in their localities to understand what elements worked well, what elements worked less well, and

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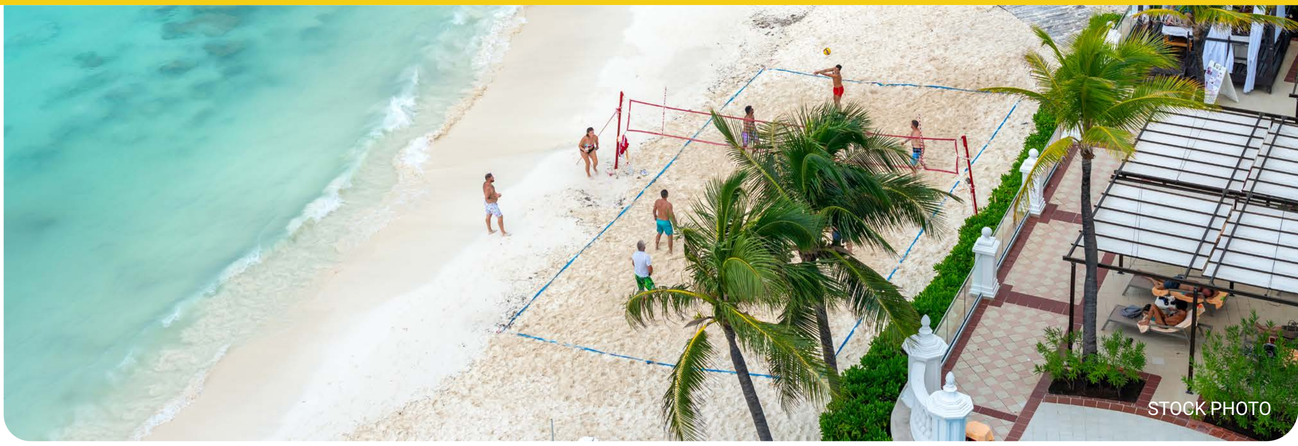

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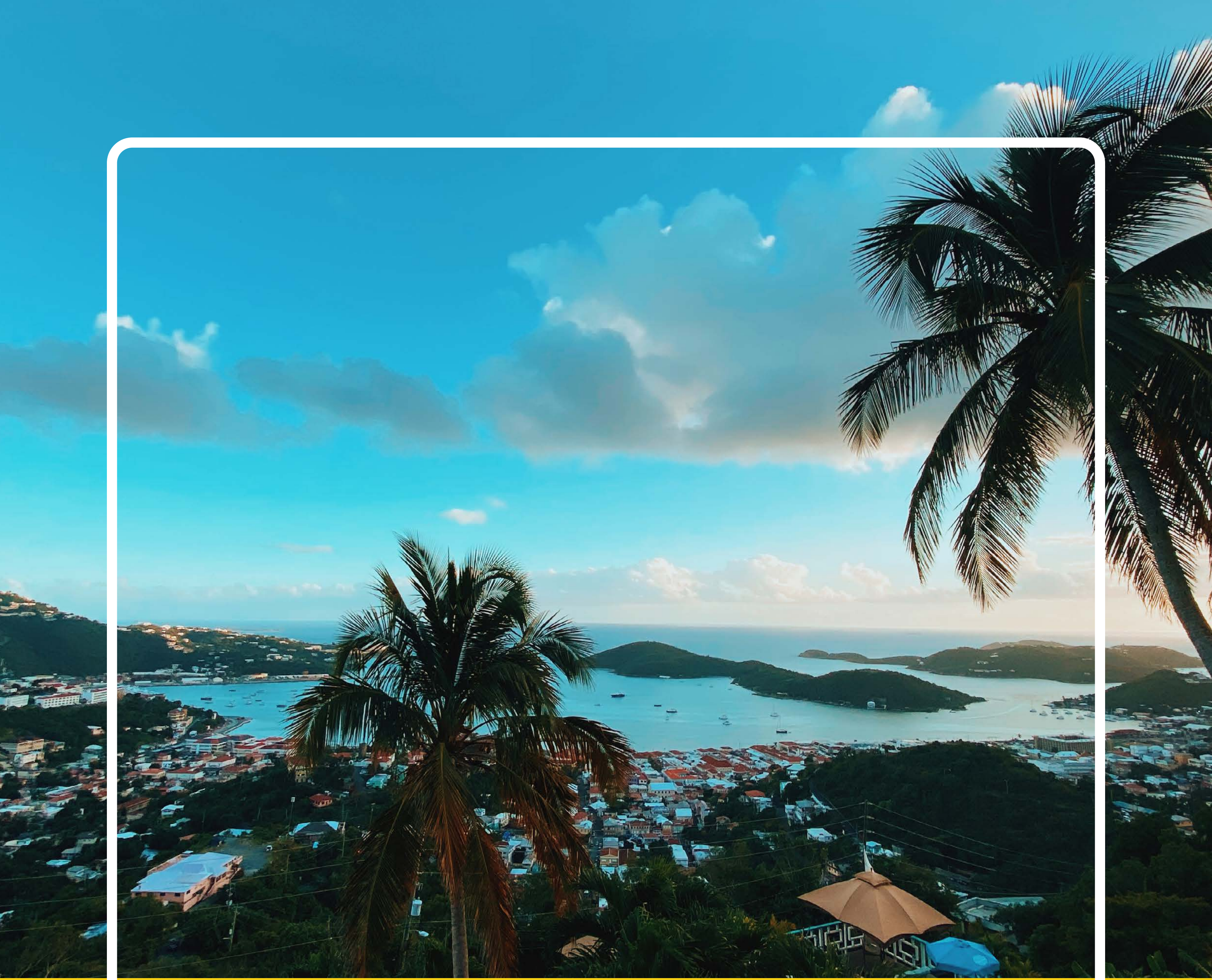

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