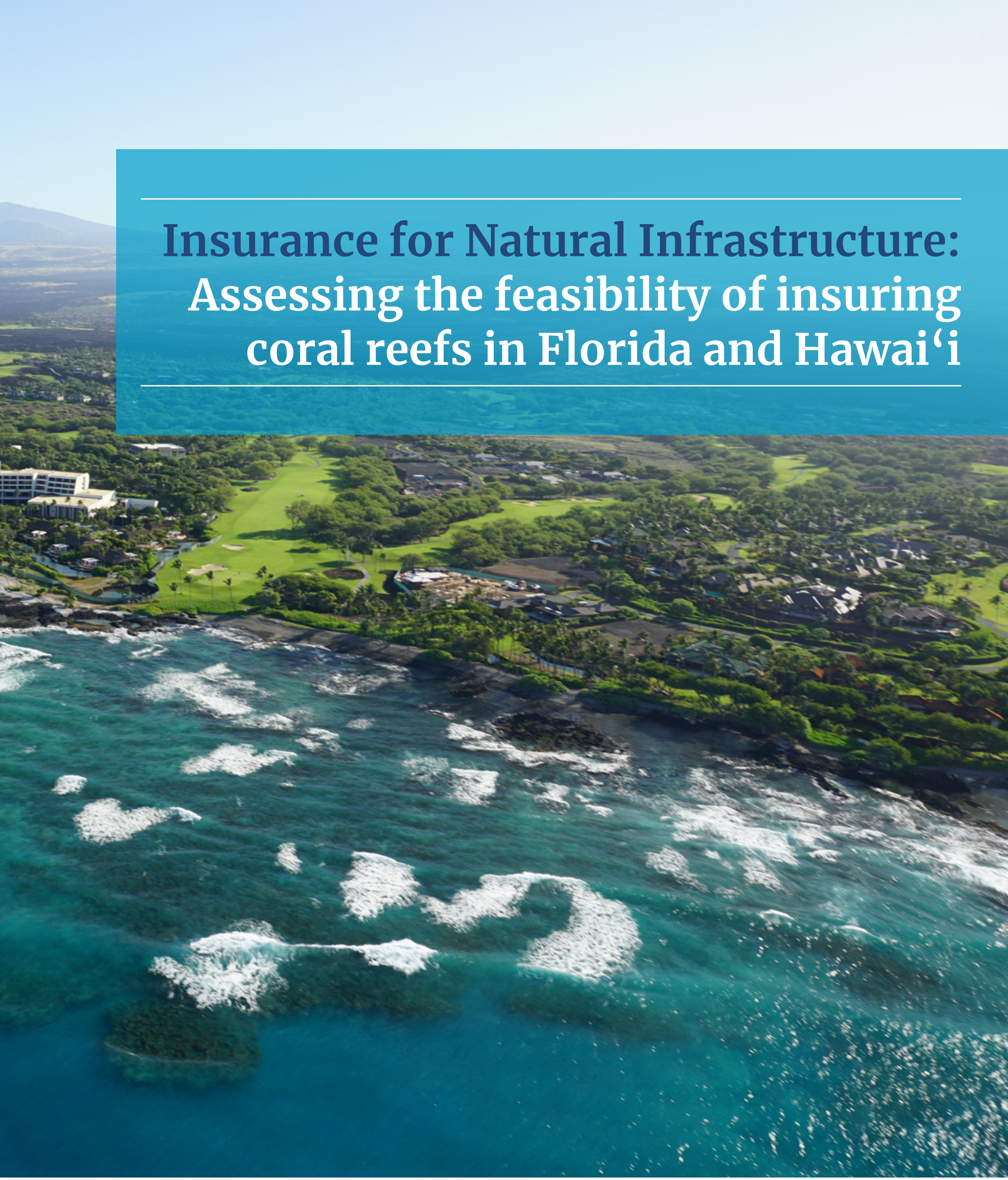
Insurance for Natural Infrastructure: Assessing the feasibility of insuring coral reefs in Florida and Hawai‘i



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Insurance for Natural Infrastructure: Assessing the feasibility of insuring coral reefs in Florida and Hawai‘i

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Photograph on the cover: Waves breaking over coral reef at beachfront resort on Hawai‘i Island’s Kohala Coast
Photo Credit: C. Wiggins

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Executive Summary

Natural infrastructure, such as coral reefs and mangrove forests, provide numerous ecosystem services to people. Healthy coral reefs can reduce wave energy by up to 97%, and large areas of mangroves can reduce wave height by up to 36% and storm surge heights by up to 75% (Ferrario et al. 2014, Narayan et al. 2016). These and other coastal ecosystems provide flood protection, food, and income from fishing and tourism to more than 600 million people globally (Neumann et al. 2015, UNEP 2006).

While coastal ecosystems clearly need to be conserved given all the benefits they provide to people and nature, funding for their conservation comes primarily from public and philanthropic sources and is limited (UN Environment et al. 2018). As such, more innovative funding models that engage the private sector are required. Insurance for natural infrastructure is one such example and is a key opportunity to generate new sources of funds to repair coastal ecosystems.

Between 2018 and 2020, The Nature Conservancy (TNC) embarked on a project with generous support from the Bank of America Charitable Foundation to assess the technical feasibility of developing parametric insurance for natural infrastructure in Florida and Hawai‘i. Parametric insurance policies provide a payout of a pre-agreed amount when a triggering event (e.g., wind-speed above X miles/hour or precipitation volume of X mm/day occurs). We asked whether such a mechanism could generate a new source of funds to support post-event reef repair to support coastal risk reduction in the two states. The assessment was modeled on a successful project in Quintana Roo, Mexico, where TNC and partners established the world's first parametric insurance policy for a coral reef ecosystem (Secaira et al. 2019). The Bank of America Charitable Foundation was also a key contributor to the Quintana Roo project.

To evaluate feasibility, we engaged reef managers, policymakers, business owners, legal experts, government agencies, hotel owners, and insurance and financial industry leaders to assess the conditions that would enable the establishment of reef insurance policies in the two states. This report synthesizes the findings of the assessment and offers considerations and recommendations on next steps to determine when parametric insurance could provide a new source of funds to contribute to the repair of coral reefs in Florida and Hawai‘i. While this assessment focused primarily on coral reefs, the methodology outlined in this report and the recommendations can also be applied to other coastal natural infrastructure. The report is designed to help stewards and beneficiaries of such natural infrastructure better understand the potential for and the conditions required to establish a parametric insurance policy, as well as the underlying funding mechanism needed to fund the insurance.

Guided by our experience in developing the Mexico reef insurance model, we answered many of the fundamental questions required to assess the feasibility of establishing reef insurance in the two states. The questions and our findings include:

Are key stakeholders interested in insurance for natural infrastructure?

Yes. In Florida and Hawai‘i, local insurance companies, government representatives, reef managers, community foundations, hotels and/or tourism associations expressed interest in insurance for natural infrastructure.

Who can legally purchase insurance?

In both Florida and Hawai‘i, public and private entities that benefit from the existence of reefs (financially or otherwise) are legally able to purchase insurance for reefs. Thus, in addition to the respective states that "own" the reefs as public goods, local governments, hotels, tour operators, and others that benefit from coral reefs' ecosystem services are also legally entitled to purchase insurance for reefs.

How valuable are the flood protection benefits of reefs and are those benefits at risk?

Each year coral reefs help to avoid direct flood damages to buildings and indirect damages to economic activity; the combined avoided damages are valued at $836 million in Hawai‘i and $675 million in Florida (Storlazzi et al. 2019).

Which risks could be insured through a parametric insurance policy?

Parametric insurance can cover reefs against the risk of hurricane damage in Florida and Hawai‘i. In Hawai‘i, marine heat waves and stormwater runoff events emerged as additional potentially insurable risks.

The term "restoration" in this report refers to ecological restoration and is defined by the Society for Ecological Restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." We use the term "repair" to refer to actions taken to hasten recovery and minimize further damage of a reef after an event to restore its flood protection benefits.

What are the potential reef repair actions and how much do they cost?

Reef repair, which is paid for by the insurance payout, is a form of restoration consisting of actions taken to minimize further damage and hasten recovery of the reef after a triggering event causes damage. It may be best to focus initial action on less intensive activities, such as removing light debris and reattaching corals. Costs can range from ~$10,000 per hectare for reattaching surviving corals on a damaged reef to ~$1,500,000 per hectare for transplantation of nursery-grown corals.

What are potential ways to fund the insurance premium in each geography?

The most feasible option to fund premiums for reef insurance in Florida and Hawai‘i are trust funds that are funded by public and/or private reef beneficiaries.

Based on the answers to these questions, the report illustrates how coastal ecosystems provide substantial flood protection benefits to people and their homes, businesses, and other essential manmade infrastructure in Florida and Hawai'i. It recognizes that the concept of using insurance to fund the repair of damage to natural infrastructure is nascent but there is broad potential for reef insurance in these two states. Additional analyses are needed to determine its suitability at specific sites. Parametric insurance does not address all drivers of coastal ecosystem decline and should be used in combination with other management tools and funding mechanisms that can enhance the resilience of these important ecosystems.

This feasibility study opens the door to explore modified versions of the Mexico reef insurance model and new approaches to fund reef repair in Florida and Hawai'i. As the cost to repair coral reefs is high, an insurance policy should focus on facilitating the most pressing repair activities needed immediately following a triggering event which can help the reef recover more quickly. Research supporting this study also highlights the pressing need for both increased repair capacity (e.g., coral nurseries, restoration practitioners) and new approaches that increase the viability and decrease the cost of repair and restoration.

The prospect of using insurance to repair reefs has proven to be an effective tool to engage a broader range of stakeholders than those traditionally involved in environmental conservation, resulting in the cross-pollination of ideas from academia, public agencies, and the tourism, finance, and insurance sectors. We will continue to develop this rich discussion in Florida and Hawai'i in order to implement tools to protect the coastal ecosystems, which provide so many vital services to people. Insurance has the potential to contribute to this goal in combination with other management tools and funding mechanisms.

Corals growing on this 'tree' in TNC's nursery at Florida's Dry Tortugas National Park will be used for restoration.
© Rachel Hancock Davis/TNC

Ecosystem services of reefs

Ecosystem services provided by coral reefs around the world include coastal protection, a cultural connection to place, recreational opportunities, fisheries benefits, food security, and tourism income. Healthy coral reefs can reduce wave energy by up to 97% to protect people and shorelines. (Ferrario et al. 2014, Narayan et al. 2016). Protection from coastal ecosystems, such as reefs can support livelihoods of 600 million people globally (Neumann et al. 2015, UNEP 2006).

Coral planting on reefs in Florida's Dry Tortugas National Park is an example of restoration
© Rachel Hancock Davis/TNC

Introduction to coastal ecosystems and their value

Coral reefs, mangrove forests, and other natural infrastructure provide numerous benefits including food, income, and flood protection to more than 600 million people (Neumann et al. 2015, UNEP 2006). Healthy coral reefs can reduce wave energy by up to 97% (Ferrario et al. 2014), and large areas of mangroves can reduce wave height by up to 36% and storm surge heights by up to 75% (Narayan et al. 2016). These coastal protection benefits also contribute to climate adaptation by reducing the impacts of more frequent and intense storms and sea-level rise.

Coral reefs are vitally important to many coastal economies. In addition to the biodiversity value that coral reefs provide, they underpin local culture, support fisheries, drive tourism, provide recreational opportunities, and act as natural breakwaters to protect coastlines from storm surge. While it is difficult to put a price tag on coral reefs that captures their full value, there have been efforts to quantify the monetary value of some of the services they provide in Florida and Hawai‘i (see Table 1).

However, coral reef and other coastal ecosystems are in peril and are disappearing at an alarming rate due to climate change and local stressors such as overfishing, coastal development, and pollution (Burke et al 2011, UNEP 2006). Over 50% of coral reefs have declined in the past 30-50 years in large parts of the world's tropical regions, and 75% of the world’s coral reefs are currently rated as threatened, a number projected to increase to almost 100% by 2050 (Burke et al. 2011, Hoegh-Guldberg 2017). The continued loss of these ecosystems will compound the impacts of climate change. For example, it has been estimated that the loss of just one meter in the height of coral reefs worldwide would more than double the annual flood damages (Beck et al. 2018). Figure 1 provides an overview of the various threats to coral reefs.

The magnitude and effect of these threats vary by geography. Within the State of Hawai‘i, for example, the main risks differ depending on the island or even the region of any given island. Reefs around O‘ahu are most threatened by overfishing, coastal development, and invasive algae, whereas reefs around Maui and Hawai‘i Island are also impacted by nutrients leaching from onsite waste disposal systems (i.e., cesspools and septic tanks) and sediments from stormwater runoff (Wedding et al. 2018). The first coral bleaching event in Hawai‘i occurred in 1996 and predominantly affected Kane‘ohe Bay on O‘ahu. Since then, four severe bleaching events have followed, affecting the Northwestern Hawaiian Islands in 2002 and 2004 and both the Main and Northwestern Hawaiian Islands in 2014, 2015 and 2019, though the impacts to specific reefs have varied widely (Couch et al. 2017, University of Hawai‘i, Social Science Research Institute 2017, Winston et al. 2020).

Florida’s reefs face many risks including bleaching, disease, degraded water quality, hurricanes, and acute impacts from fishing, diving, and boating. The long-term persistence of the reefs, and thus the future of the benefits they provide, is in question. Live coral cover has declined precipitously since the 1980s, averaging just 1.5% on reefs north of Key Biscayne and 9.7% on average on reefs throughout the Florida Keys in 2016 (NOAA 2018).

Emerging science indicates that coral reefs in Florida (Keys) and Hawai‘i (Maui) have transitioned to net erosion conditions of -1.5 to -4.5 mm/year and -21.0 mm/year, respectively due to anthropogenic impacts and climate change (Yates et al. 2017). Erosion of the reefs will diminish their flood protection benefits.

	Fisheries	Tourism	Flood protection
Hawai‘i	The total annual value of nearshore coral reef fisheries is estimated to be around $13.4 million, with roughly $10 million stemming from non-commercial catch (Grafeld et al. 2017)	Each year, on-reef and reef-adjacent tourism contribute $1.23 billion to the state’s economy (Spalding et al. 2017). Reefs protect beaches from erosion. Based on a perfect beach day being valued at $79 per beach visitor and 20.7 million beachgoers annually, the value of beaches translates to over $1.6 billion annually on O‘ahu alone (USACE 2018).	Coral reefs help to avoid direct flood damages worth $344 million to buildings and indirect damages of $492 million to economic activity annually (Storlazzi et al. 2019).
Florida	In 2016, Florida seafood production accounted for 3.16% of Florida’s agricultural receipts, supported nearly 4,000 jobs, and had a total economic effect of $407.6 million (FDACS 2016). Many of the species harvested rely on healthy and resilient coastal ecosystems to support critical phases of their lifecycle.	Each year, on-reef and reef-adjacent tourism contribute $1.16 billion to the state’s economy (Spalding et al. 2017). The combined annual value of recreational fishing, scuba diving, snorkeling, and glass-bottom boat rides is estimated at $174 million per year (Brander and Van Beukering 2013).	Coral reefs help to avoid direct flood damages worth $356 million to buildings and indirect damages of $319 million to economic activity annually (Storlazzi et al. 2019).

Table 1: Select economic value of coral reefs in Florida and Hawai‘i

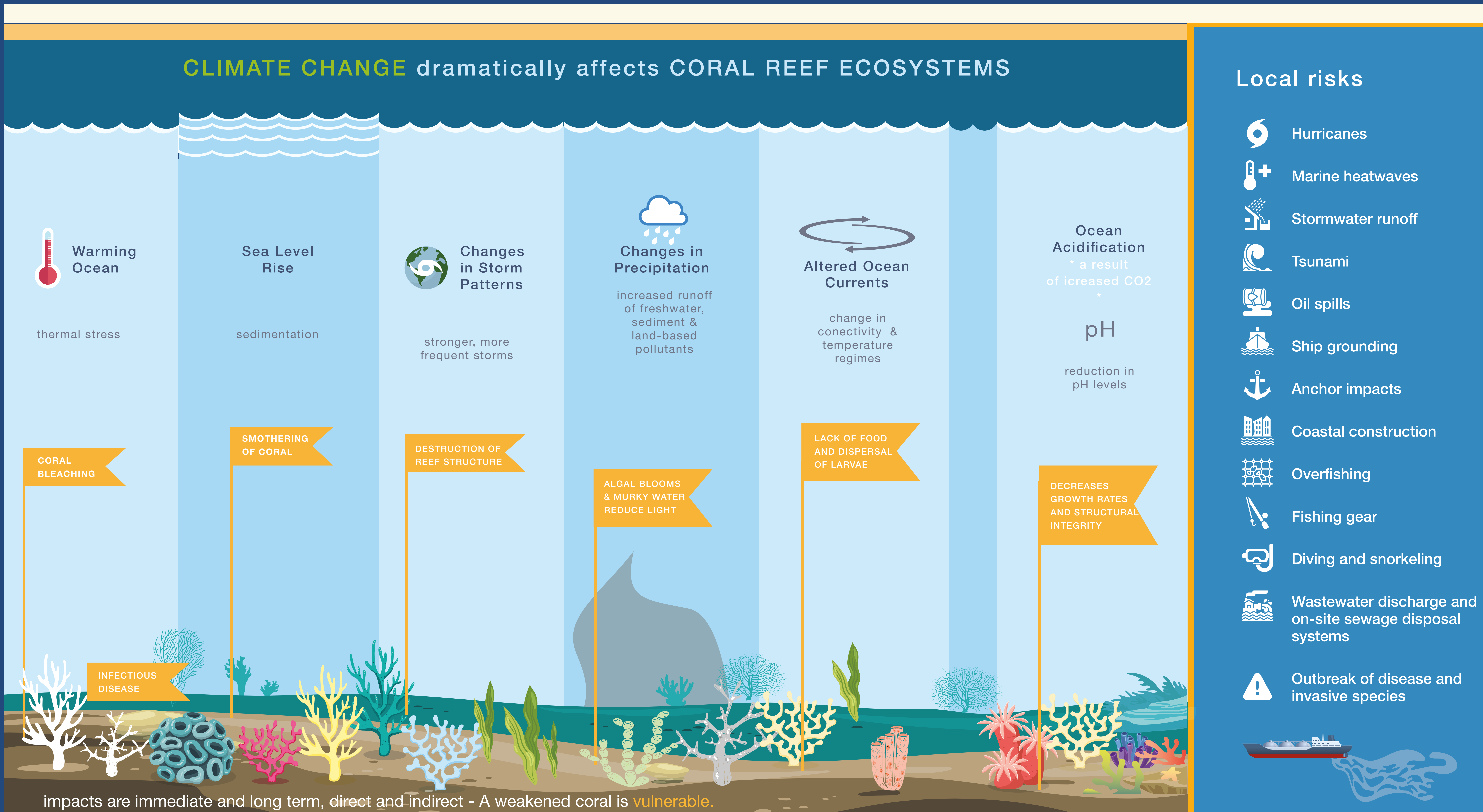


Figure 1. Threats to coral reefs. (Source: Adapted from NOAA 2018)

What is insurance for natural infrastructure?

While coastal ecosystems need to be conserved for all the benefits they provide to nature and people, funding for conservation comes primarily from public and philanthropic sources and is limited (UN Environment et al. 2018). In this respect, innovative funding models need to be considered, including private sources and insurance for natural infrastructure.

Insurance is a risk management tool used to transfer risk from the owner or manager of an asset to the insurance provider at the cost of a premium. The insurance buyer pays the premium to guarantee access to funds in case the insured asset suffers damages specified in the insurance policy (Kousky and Light 2019).

Generally, insurance is a suitable tool when:

- The cost of the expected damages exceeds the financial capacity of the insurance buyer. Otherwise, it would be cheaper to pay the replacement or repair cost than to pay an annual insurance premium (Kousky and Light 2019).
- The damaged asset is replaceable or repairable. If money cannot replace or repair the asset, there is no need for insurance (Kousky and Light 2019).
- Random events are cause of damage. If losses were certain, the insurer would not write a policy at less than the full cost to replace or repair the asset.
- Enough risk information is available to make pricing and underwriting possible. If there are no data on the geographic distribution, frequency, and/or intensity of a risk, insurers cannot calculate potential losses and, therefore, the cost of insurance.
- Risk is diversifiable. Without a large enough pool of insurance buyers, the insurer cannot diversify a risk across geographies or population segments, increasing the likelihood of having to pay many insured parties at once.
- Moral hazard risk is limited or non-existent. Moral hazard occurs when those who are insured engage in excessively risky activities knowing that an insurance payout will cover damages (Kousky and Light 2019).

The two main types of insurances are indemnity-based and parametric. Indemnity-based policies pay out an amount that equals the actual loss sustained. To make the payout, a third-party must examine the damaged item and determine the amount of loss. In contrast, parametric insurance provides pre-agreed amounts of payouts based on the occurrence and intensity of a hazard event, which serve as proxies for impact and loss, rather than indemnifying against actual loss (which is the traditional insurance approach).

Staghorn coral growing in TNC's coral nursery at Florida's Dry Tortugas National Park will be used for restoration © Rachel Hancock Davis/TNC

A triggering event must occur within a pre-defined geographic area and be recorded by a third-party using an objective parameter, such as wind speed recorded by the National Oceanographic and Atmospheric Administration (NOAA).

Parametric insurance presents advantages over indemnity-based insurance for natural infrastructure, where determining the actual loss sustained can be challenging. The focus on a hazard rather than loss creates a broad range of potential applications, which could not be served by indemnity insurance. These include protection of assets that are public goods, creating value across a broad range of actors; operability with lower data requirements than conventional insurance; and the ability to settle very rapidly, generating payouts within days, which can be applied immediately to arrest ongoing loss and facilitate early—and thus more effective—recovery (Willis Towers Watson, personal communication). Parametric insurance can also cover the economic loss caused by the interruption of services provided by the natural infrastructure, rather than being limited only to physical damage repair. However, parametric insurance is prone to basis risk, which is when damage to the natural infrastructure occurs, yet a payout may not be triggered, or a payment is triggered without damage being sustained.

The first example of a parametric insurance policy used to cover coastal natural infrastructure was implemented in Quintana Roo, Mexico, where insurance covers hurricane risk for the Mesoamerican barrier reef along a 160 km stretch of coastline. After multiple hurricanes devastated parts of the Yucatán Peninsula, local government and tourism leaders realized that hotels and beaches protected by reefs suffered far less damage than those without reefs. TNC in partnership with state and municipal governments and the tourism industry created the Trust for Coastal Zone Management, Social Development, and Security in 2018. The trust fund was designed to accept funds from multiple sources to manage beaches and reefs and to purchase hurricane insurance to protect them (see Figure 2)[1]. This parametric insurance policy is triggered when wind speeds exceed 100 knots within a predefined area around the insured reef. The rapid insurance payout allows repair activities to commence quickly following storm impacts, which is important to prevent storm debris from further damaging the reef and to reduce the mortality of corals that have been damaged or dislodged during the storm.

Insuring reefs for their coastal protection benefits provides an important and replicable model to support reef recovery and generate funds to repair damaged reefs following an event. While parametric insurance for natural infrastructure has thus far only been implemented for coral reefs, applying insurance to other natural infrastructure such as mangrove forests and other wetlands has potential as well.

1 At the time of writing, funding is provided by the State Government of Quintana Roo.

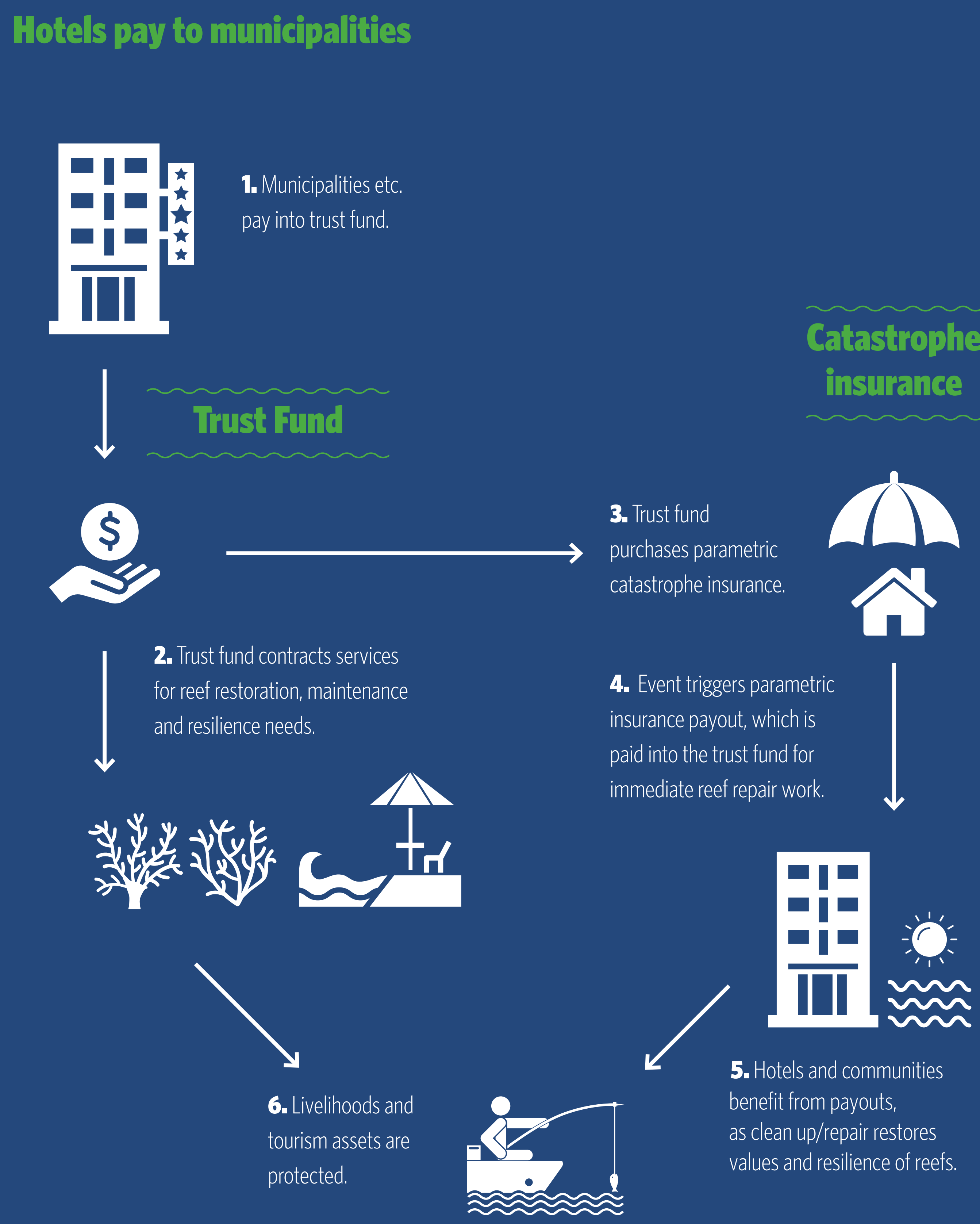


Figure 2: Schematic of Trust for Coastal Zone Management, Social Development, and Security in Quintana Roo, Mexico. (Source: Adapted from T. Zoltani 2017)

Exploring parametric insurance for coral reefs in Florida and Hawai‘i

Inspired by the successful proof of concept in Quintana Roo, Mexico, we assessed whether the reef insurance model could be replicated in Florida and Hawai‘i to repair coral reefs following damaging events. To determine this, we explored the following questions for each state:

1. Are key stakeholders interested in insurance for natural infrastructure?
2. Who can legally purchase insurance?
3. How valuable are the flood protection benefits of reefs, and are those benefits at risk?
4. Which risks could be insured through a parametric insurance policy?
5. What are the potential reef repair actions and how much do they cost?
6. What are potential ways to funding the insurance premium in each geography?
7. How might an insurance policy be structured?

It is important to note that this study focused primarily on the technical feasibility of developing parametric reef insurance in Florida and Hawai‘i. While we conducted initial outreach to stakeholders including decision makers and reef beneficiaries to assess their interest in and support for reef insurance, the study did not include an exhaustive outreach component to evaluate the social and political feasibility of reef insurance.

1.

Are key stakeholders interested in insurance for natural infrastructure?

Since the concept of insurance to protect coastal ecosystems is novel, stakeholder engagement is crucial to gauge their interest. Our teams presented the reef insurance model at numerous forums and conducted outreach to local reef managers, policy-makers, business owners, legal experts, government agencies, hotel owners, insurance and financial industry leaders, and community foundations. In Hawai‘i, approximately 50 people attended a stakeholder forum where the reef insurance model was presented, and we conducted dedicated outreach to approximately 30 public and private entities we identified as key stakeholders for implementing reef insurance. In Florida, we conducted dedicated outreach to approximately 20 public and private entities, including Palm Beach, Broward, Miami-Dade and Monroe Counties in southeast Florida as well as state and federal agencies. We also presented the reef insurance model at several regional and national conferences and workshops. Throughout this engagement, stakeholders expressed clear interest in this approach.

2.

Who can legally purchase insurance?

In Florida and Hawai‘i, reefs are a public good, and therefore, "owned" by the government. Insurance statutes permit public and private entities with an insurable interest in the covered asset to purchase insurance for it. An insurable interest exists when an entity or person 1) benefits (financially or otherwise) from the asset’s continued existence, or 2) would suffer a loss from its degradation. Thus, state governments, which are effectively charged with maintaining the reefs on behalf of citizens, local governments, and industries (e.g., tour operators and hotels that derive benefits from reefs) can purchase insurance for coral reefs.

3.

How valuable are the flood protection benefits of reefs, and are those benefits at risk?

Reefs reduce wave energy and storm surge, which reduces flooding during a storm event. Each year coral reefs help to avoid direct flood damages to buildings and indirect damages to economic activity; the combined avoided damages are valued at $836 million/year in Hawai‘i and $675 million/year in Florida (Storlazzi et al. 2019). Any risk that affects the health of coral reefs in the short- or long-term will diminish the flood protection benefits that the reefs provide (Ferrario et al. 2014).

Different reef characteristics are likely providing the flood reduction benefits in the two geographies. With Florida’s reefs being sponge and soft coral dominated and low in hard coral cover, the flood protection benefits are likely a function of historic coral reef formations. Hawai‘i‘s reefs, in contrast, are dominated by hard corals, which are presumed to be providing the bulk of flood protection benefits.

Coral reefs provide protection from flooding valued at $836 million/year in Hawai'i (Storlazzi et al. 2019) © C. Wiggins

4.

Which risks could be insured through a parametric insurance policy?

Coral reefs provide enormous benefits and face numerous risks, and some risks meet the criteria to be insurable. To design a parametric insurance cover, two conditions must be met in addition to those outlined above (see: What is insurance for natural infrastructure? on page 14). First, a hazard parameter that would trigger a payout must be correlated to the risk of interest. That parameter must be monitored by an independent and reliable data source in near-real time and have a historical data record associated with it. Examples of such parameters are wind speed for hurricanes and precipitation volume for extreme rainfall. Second, it must be possible to set a threshold for the parameter at which an insurance payout would be triggered. This threshold is set based on data demonstrating a correlation between the parameter and damages to the insured asset. In most cases, the trigger is not a single parameter value but a continuous relationship allowing for a more intense hazard to provide higher payout amounts from the parametric insurance instrument, for the reef insurance in Quintana Roo, Mexico, windspeeds of 100 knots would trigger a payout equivalent to 40% of the amount of cover, and windspeeds of 160 knots, or more, would trigger payout equivalent to 100% of the amount of cover.

Based on interviews conducted with several insurance industry experts, we divided risks facing reefs in Florida and Hawai'i into two categories: those considered insurable and those currently not insurable. Additional considerations to design a parametric insurance cover are listed for each risk in Table 2. Of the insurable risks, we focused on hurricanes in Florida, and hurricanes, marine heatwaves, and stormwater runoff in Hawai'i.

The following sections describe the relevance of the three risks to Florida and Hawai'i, their impact on coral reefs, and expected changes in their frequency based on climate projections.

Shoreline along Miami Beach, Florida © Pixabay

Insurable Risks

Hurricanes

Parameter: Wind speed
Threshold: Correlation between parameter and coral damage has been established for the Caribbean only. For other regions, this correlation needs to be confirmed.

Marine heatwaves and cold-water anomalies

Parameter: Sea surface temperature
Threshold: Correlation between high sea surface temperature and likelihood of bleaching, measured by Degree Heating Weeks, has been established. For cold-water anomalies, this correlation needs to be established.

Stormwater runoff

Parameter: Precipitation volume
Threshold: Correlation between precipitation volume, sediment load on reef, and coral damage needs to be established.

Tsunami

Parameter: Wave height
Threshold: Correlation between wave height and coral damage needs to be established.

Uninsurable Risks

Coastal construction; damages from anchors, fishing gear, diving and snorkeling; overfishing; wastewater discharge

Not insurable for one of the following reasons: Risks are directly caused by humans; it is difficult to construct parameters; there is risk of moral hazard, meaning that with insurance cover there may be little or no incentive for the responsible party to minimize risk.

Oil spills and ship grounding

Insurance is available but not on a parametric basis. In Florida, the Florida Coral Reef Protection Act (Florida Statute 403.93345) addresses coral reef impacts from ship grounding.

Outbreak of coral disease/invasive algae/ crown-of-thorn starfish, ocean acidification

Risks lack scientifically demonstrated correlations between an external parameter and the event, and/or coral damage.

Table 2: Risks to coral reefs that are considered insurable with parametric insurance in Florida and/or Hawai‘i and those which are uninsurable in either state.

Hurricanes

The coast of South Florida is exposed to hurricanes forming in the eastern and mid-tropical Atlantic, usually starting off the west coast of Africa. Atlantic-crossing hurricanes tend to dominate the core part of the annual Atlantic hurricane season, which is most common between mid-July and mid-October, though storms in the coastal waters off Florida can occur from April to December.

Hurricanes threaten Florida's coastline regularly. Five hurricanes have traversed Miami-Dade County since 1950 (see Figure 3) and 17 have hit the region extending from Martin to Monroe counties during the same period (NOAA 2020).

The frequency of hurricanes historically reaching Hawai‘i has been low with only eight named storms impacting the islands between 1979 and 2010. While hurricane frequency is projected to remain relatively low in Hawai‘i, even a slight increase in frequency could have substantial impacts on coral reefs as the intensity of hurricanes is projected to increase globally (Murakami et al. 2013, National Academies of Sciences, Engineering, and Medicine 2016, Widlansky et al. 2019).

The extent to which hurricanes (tropical cyclones with wind speed greater than 74 miles per hour) can impact coral reefs is proportional to their strength and duration (Jaap 2000). While this impact can be beneficial and reefs have historically withstood such impacts, hurricanes can also negatively impact the live coral cover of reefs. Reef damage from hurricanes is of increasing concern. North Atlantic hurricanes have increased in intensity, frequency and duration since the early 1980s, and predictions indicate that hurricane intensity and associated rainfall will increase as the climate continues to warm (Walsh et al. 2014). Hurricanes, of course, cause direct physical damage such as erosion of the reef framework, dislodgement of massive corals, coral breakage, and coral scarring by debris, but they also cause indirect damage due to increased flooding and terrestrial runoff which carry nutrients and sediments into reefs (Fabricius et al. 2008, Silbiger et al. 2018).

A correlation between hurricane wind speed and coral damage has been established for the Caribbean, which may serve as a basis to consider suitable insurance coverage for locations in Florida and Hawai‘i (Pérez-Cervantes et al. 2020). This information should be supplemented with additional evidence gathering in each state.

Projections of the potential impacts of global warming on regional hurricane activity are challenging due to multiple sources of uncertainty and different assumptions in models. However, the intensity of hurricanes around the world is projected to increase (National Academies of Sciences, Engineering, and Medicine 2016).

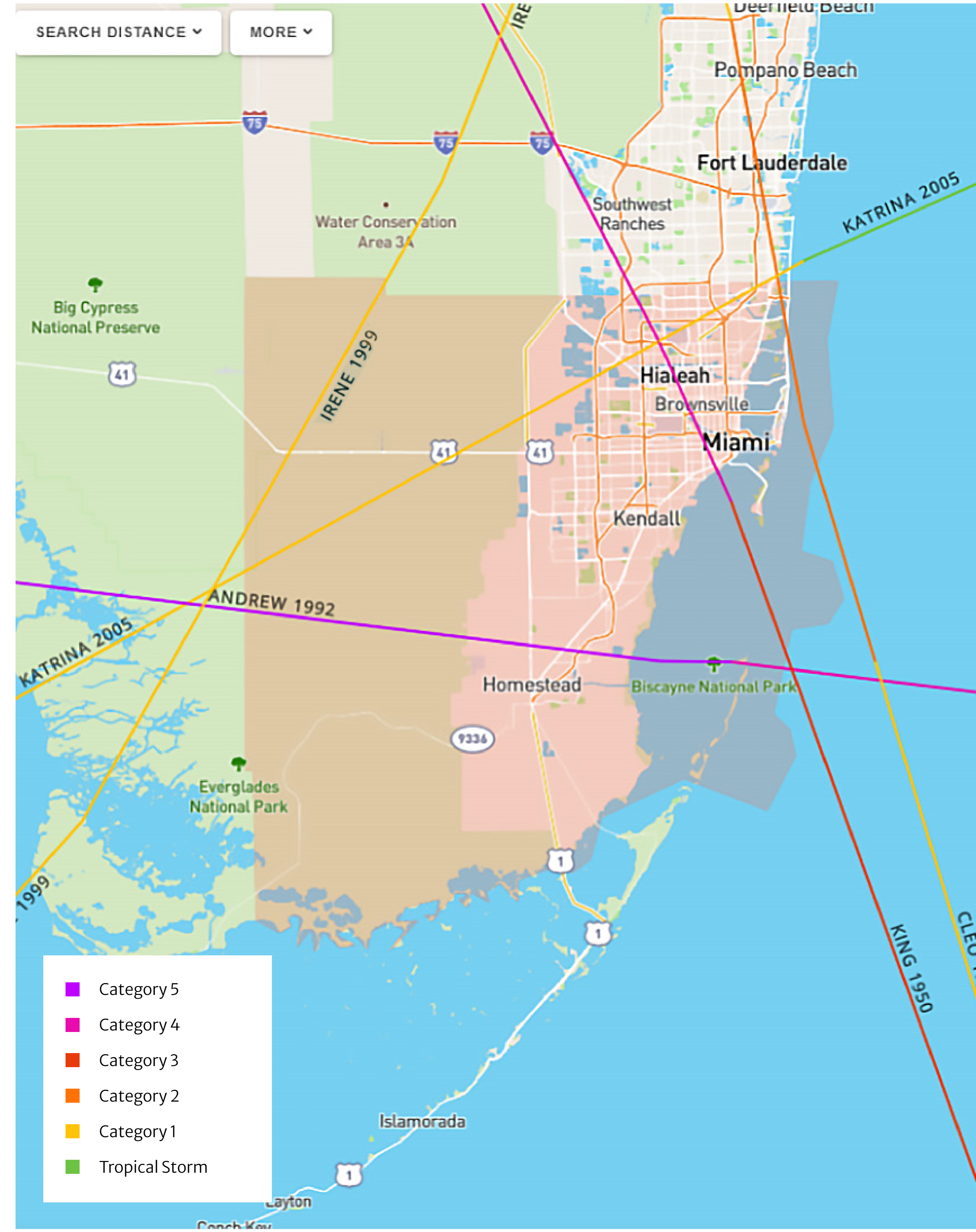
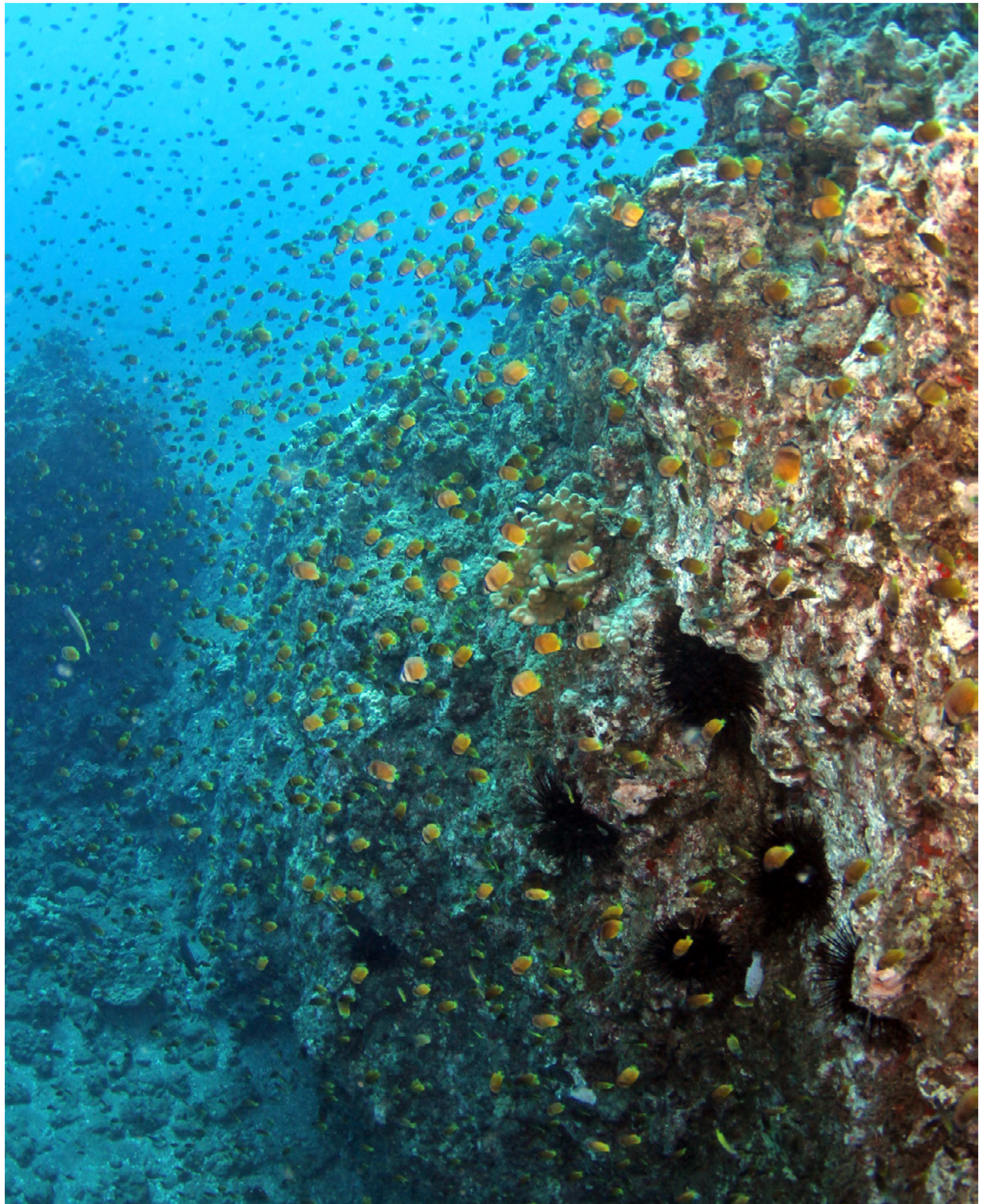


Figure 3: Hurricanes hitting Miami-Dade County since 1950 (Source: NOAA 2002)



Coral reef with black-lipped butterfly fish at the Puʻu Olai Volcanic Cinder Cone, Makena State Park, Maui © Pauline Fiene

Marine Heatwaves

The first severe heat-induced mass-bleaching events in the Main Hawaiian Islands occurred in 2014 and 2015, followed by a less severe bleaching event in 2019 (Bahr et al. 2015, Rodgers et al. 2017). The marine heatwaves of 2014 and 2015 resulted in extensive coral loss, especially in West Hawaiʻi (49.7%) and Maui (20-40%) (University of Hawaiʻi, Social Science Research Institute 2017). The 2019 marine heatwave, caused the highest percentage of live coral cover bleached (42.8%) in Oʻahu, followed by Maui (30-33%), and Hawaiʻi Island (18-20%) (Winston et al. 2020).

Corals experience heat stress when sea surface temperatures exceed 1°C (1.8°F) above the maximum summertime mean and the stress worsens as the marine heatwave persists. Degree Heating Weeks (DHWs) is used as a measurement of the cumulative amount of heat stress corals experience in a certain location by adding up any temperature exceeding 1°C (1.8°F) above the maximum summertime mean during the previous three months. When DHWs reaches 4°C-weeks (7.2°F-weeks), significant coral bleaching is likely, and when DHWs is 8°C-weeks (14.4°F-weeks) or higher, widespread bleaching and mortality is likely to occur, although bleaching response can vary widely within a reef. Given the well-established correlation between sea surface temperature, DHWs, and coral damage, DHWs may be used to trigger an insurance payout in some locations.

Climate change is causing oceans to become warmer. Global average sea surface temperature has already increased by 0.63°C compared to 1850-1900, and model projections estimate that under a business-as-usual carbon emission scenario, sea-surface temperature will increase by 2.58°C by 2100 relative to 1986-2005 (Abram et al. 2019). In addition to long-term ocean warming, short-term marine heatwaves, during which extremely high ocean temperatures persist for days to months over thousands of square kilometers, have become more frequent, extensive, and intense. In tropical reef systems globally, the average interval between marine heatwaves and associated coral bleaching events has decreased steadily from 1980 to 2016, from once every 28 years to once every 6 years (Collins et al. 2019). Under a business-as-usual carbon emission scenario, Hawaiʻiʻs coral reefs are predicted to experience annual mass bleaching by about 2050 (van Hooidonk et al. 2016).

Reef in Key Largo Florida © Rachel Hancock Davis/TNC

Stormwater runoff

Sediments can kill corals by smothering them and by blocking sunlight, which impedes the ability of symbiotic algae within corals to photosynthesize (Fabricius 2005). Our focus in Hawaiʻi is on stormwater runoff that results in streams carrying large amounts of sediments into the ocean, and not on urban runoff. This type of runoff causes localized sediment plumes in the ocean and is common even during small storm events (Wedding et al 2018). While many studies have measured sediment discharge from streams in Hawaiʻi, no quantitative data is available to correlate precipitation volume to sediment loads on reefs, and in turn, sediment loads on reefs to coral damage. Thus, additional data gathering would be beneficial, but the structuring of a parametric product may still be possible without it. In Florida, making this correlation would be very difficult due to the complex and intensively managed stormwater management systems, including the Central and Southern Florida Flood Control Project.

Climate change is expected to impact global precipitation patterns, and extreme precipitation events are projected to become more intense and frequent (Collins et al. 2019, National Academies of Sciences, Engineering, and Medicine 2016). The frequency of extreme precipitation events has changed between 1960 and 2009 in Hawaiʻi, but the trend varies depending on the location within the state. Such events have become more frequent on Hawaiʻi Island, but less common on Oʻahu and Maui. A positive relationship was found between precipitation extremes and the El Niño Southern Oscillation (ENSO) index, implying greater extreme events during La Niña years and the opposite during El Niño years (Chen and Chu 2014).

Sediment runoff in Honolua Bay, Maui © Bill Rathfon

Coral bleaching on the west coast of Hawaiʻi Island © David Slater

5.

What are the potential repair actions and how much do they cost?

As part of this assessment, we compiled a list of repair activities that could support reef recovery following threat events. Table 3 provides an overview of such repair activities that are either currently feasible or were deemed likely feasible with modifications to existing technologies. For hurricanes, the activities are based on the post-hurricane response protocol developed to support the Mexico reef insurance model (Zepeda-Centeno et al. 2019). For marine heatwaves, coral transplantation was identified as a potential repair activity. However, we acknowledge that it will be extremely challenging to replace bleached corals on a reef scale, and heat-resilient corals suitable for transplantation still need to be identified. For stormwater runoff, the repair activities are similar to those proposed for hurricanes, except that sediment instead of debris will need to be removed. While there are currently no effective methods to remove sediment from reefs, existing methods to remove sediment from fishponds could be explored and possibly adapted.

Prior to conducting work on coral reefs, including the proposed repair activities, several regulatory authorizations and permits would need to be obtained. Table 4 groups various repair activities into three categories based on the level of intensity required. For each group, the table lists the federal and state permits and licenses and consultation and review processes that are potentially relevant to the activities in each category. Depending on the location and specific repair activity, not every consultation or permit listed below will necessarily apply.

Repair activities	Description	Hurricane	Marine heatwave	Stormwater runoff
Damage assessment	Diver teams assess damage using scientific methods	✓	✓	✓
Intervention design	Plan repair activities based on damage assessment	✓	✓	✓
Debris/rubble removal	Remove debris/rubble that can be moved by divers using lift bags and small vessels	✓		
Sediment removal	Adapt existing fishpond sediment removal technologies			✓
Reattach broken corals	Reattach hard corals or other sessile biota that have broken off or become dislodged by placing in reef crevices or using drills and epoxy	✓		
Coral transplantation	Use mechanical fasteners and adhesives to attach corals from nearby nursery sites	✓	✓	✓

Table 3: Repair activities for potential hazard events

While waiving permitting requirements and fees[2] is a common response following emergencies, no precedent was found where permitting requirements for reef repair activities were waived following hurricanes and emergency declarations. To repair reefs following threat events, it may be best to focus on

2 In Florida, to remove hard or stony corals, a Special Activity License is required, which involves a payment of a non-refundable processing fee of $25.

Category 1: Requirements for reattaching, collecting and transplanting coral	
Federal	• National Oceanic and Atmospheric Administration (NOAA): Essential Fish Habitat Consultation; National Marine Sanctuary Permit; Consultations and permits for work affecting endangered species including coral and marine mammals. • Any federal permitting agency: National Environmental Policy Act (NEPA) review, potentially resulting in an Environmental Assessment or Environmental Impact Statement.
State of Hawaiʻi	• Department of Land and Natural Resources: Conservation District Use Permit; Permit for work in Marine Life Conservation Districts (issued by the Division of Aquatic Resources); Special Activity Permit (issued by the Division of Aquatic Resources). • Office of Planning; Coastal Zone Management Program: Federal Consistency Certification.
State of Florida	• Fish and Wildlife Conservation Commission: Special Activity License.
Category 2: Requirements for removing debris, sediment, and rubble and stabilizing rubble (in addition to those listed under Category 1 above)	
Federal	• NOAA: Consultation and authorization for work that might harass or harm any marine mammals. • United States Army Corps of Engineers (USACE): Dredging and filling permits under CWA §401, 404; Construction permits under Rivers and Harbors Act §10. • Any federal permitting agency: consultation with the Advisory Council on Historic Preservation.
State of Hawaiʻi	• Department of Health: National Pollutant Discharge Elimination System Permit, Water Quality Certification. • Any state permitting agency: Consultation with Department of Land and Natural Resources, State Historic Preservation Division.
State of Florida	• Department of Environmental Protection: Environmental Resource Permit; National Pollutant Discharge Elimination System Permit. • Any state permitting agency: Consultation with Department of State, Division of Historical Resources.
Category 3: Requirements for construction activities (in addition to those listed under Categories 1 and 2 above)	
State of Florida	• Department of Environmental Protection: General Permit for the Construction of Artificial Reefs.

Table 4: Permits, licenses, consultations and review processes for various reef repair activities

less intensive activities, such as removing light debris and reattaching corals, because more intensive activities that include construction will increase the number of permits required. Completing consultations and obtaining permits for pre-agreed response activities in advance of emergencies would enable swifter implementation.

To determine the necessary amount of insurance cover that will allow a meaningful level of reef repair, we estimated the cost of the repair activities outlined in Table 3. This was particularly challenging, as coral restoration to date has been limited to only a few small-scale projects and branching coral species. In addition, coral restoration costs are rarely reported and the limited data that is reported is shared in an inconsistent manner (Bayraktarov et al. 2019). Similarly, reef repair activities and associated costs are based on data from smaller scale physical disruptions, such as ship groundings or anchor drags. Finally, data on the extent of coral damage caused by hurricanes, marine heatwaves, and stormwater runoff is limited, presenting an additional challenge when attempting to estimate repair costs following threat events, where repair activities would need to be carried out on a reef scale and involve many coral species.

Despite these limitations, rough order-of-magnitude reef repair costs for Florida and Hawaiʻi were estimated based on a literature review, cost estimates for the post-hurricane response protocol developed to support the Mexico reef insurance model (Zepeda-Centeno et al. 2019), and discussions with reef restoration practitioners.

The cost to repair a reef will vary greatly depending on the extent of damage and types and magnitudes of repair actions undertaken. Recent literature found coral reef restoration costs to range from ~$10,000 per hectare for harvesting of coral colonies from a donor site and their transplantation to a restoration site, to ~$1,500,000 per hectare for transplantation of nursery-grown corals (Bayraktarov et al. 2019). This is within the same order of magnitude as our analysis using information from literature, discussions with reef restoration practitioners, and an estimate provided by a marine contractor. Damage assessment, intervention design, and debris/rubble/sediment removal are estimated to cost tens of thousands of USD per hectare. If corals are also reattached or nursery-grown corals transplanted, the cost estimate increases to a few million USD per hectare.

This information should be used with caution as scaling-up repair actions and associated costs from small sites to regional or reef scale efforts introduces a high level of uncertainty. The results also highlight the need for additional research and capacity building to enable reef scale repair, identification of multiple funding sources, and exploration of sustainable funding mechanisms (Section 6). Regardless, these orders-of-magnitude cost estimates were useful for developing potential insurance policies for each geography (Section 7).

Coral reef at Molokini crater, Hawaiʻi © Pauline Fiene

6.

What are potential ways to fund the insurance premium in each geography?

One of the primary challenges of insuring this natural infrastructure is finding entities that are able and willing to pay the insurance premiums to cover the cost of reef repair, which can be wide-ranging. Similarly, any funding for insurance should be coupled with funding for the ongoing management and protection of the reef between events which cause an insurance payout. Many stakeholders in both geographies expressed interest in using insurance to protect reefs and wanted to know how insurance premiums could be funded.

Government funding is the most viable initial source to cover an insurance premium, and it will be faster and easier to adapt an existing funding source than to develop a new source of funding. Unlike in Quintana Roo, Mexico, Hawaiʻi does not collect taxes or fees for commercial use of beaches. Implementing such a tax or fee would require discussions with many stakeholders and could be time-consuming. While Florida counties may collect taxes to finance beach park facilities and other system (e.g., channel, estuary and lagoon) improvements, existing public funding sources (e.g., Hawaiʻi Transient Accommodation Tax, Florida Tourist Development Tax) do not have the legal structure to pay for an insurance premium and re-appropriating these taxes would require complex negotiations.

Table 5 lists public funding sources in Florida and their potential to be used to purchase a reef insurance premium, along with necessary legislative changes assessments for revenue generating capability, and overall feasibility. Any new user fee or penalty could be worthy of consideration, however, establishing such a system would likely take time because pricing guidance and collection models would need to be set up. Therefore, the most feasible option to fund premiums for reef insurance in Florida and Hawaiʻi may be through trust funds that are capitalized by public, and possibly private, reef beneficiaries. Although the overall feasibility of new insurance funding mechanisms today is considered low to medium, this may change as support for reef protection increases and the economic climate improves.

In Florida, a national insurance broker began to socialize the concept of a privately capitalized trust fund to explore potential revenue-generating mechanisms that can significantly advance the protection of coastal ecosystems. In this capacity, the brokerage firm contacted approximately 65 insurance companies to survey their interest. Approximately 10 carriers responded with a handful of companies expressing interest in the concept of using a voluntary contribution based on commission gained from flood insurance business to repair coral reefs as well as other natural coastal ecosystems, suggesting that this concept should be explored further.

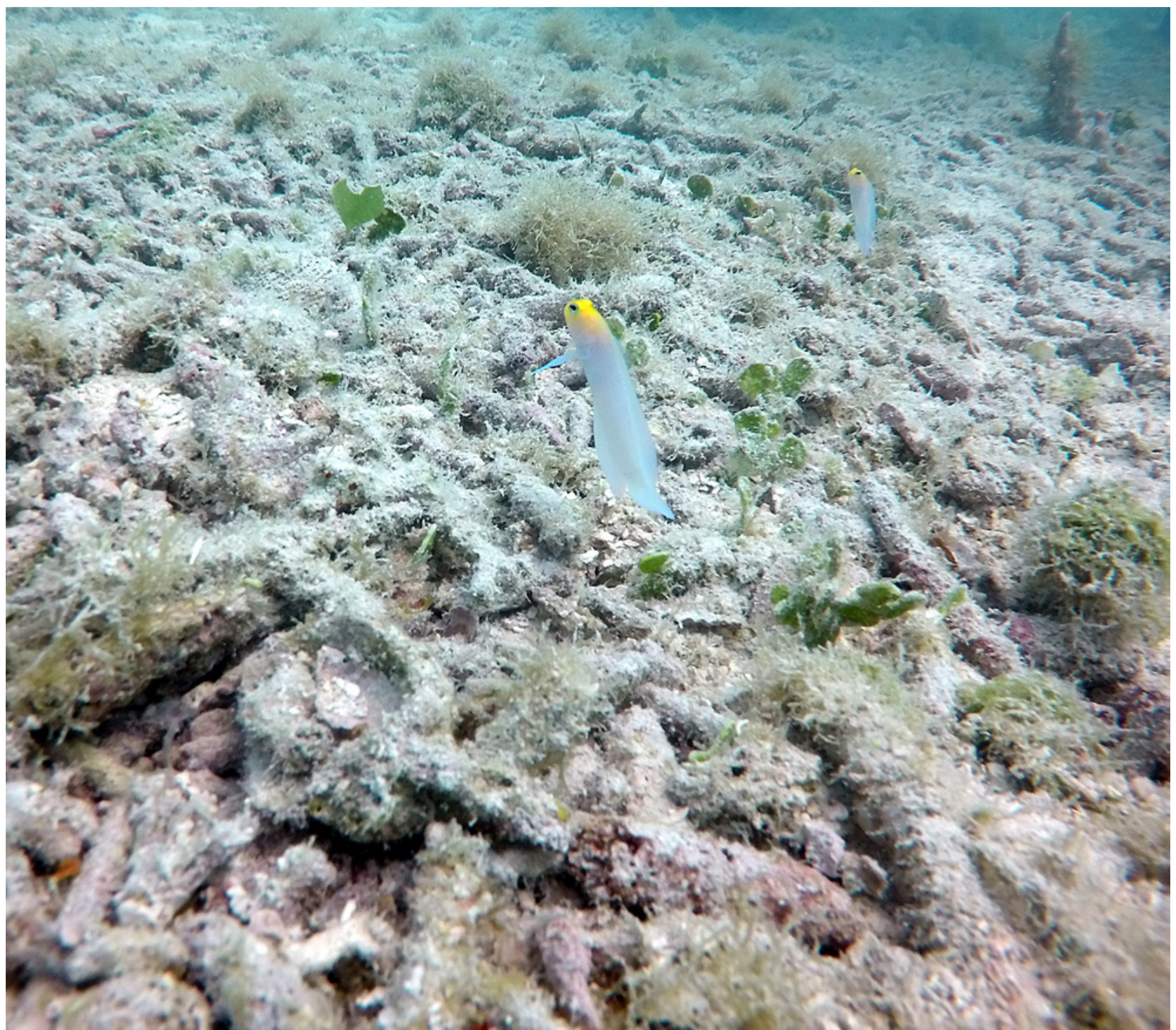
Revenue option	Source currently used for coral reef restoration?	Legislative change required for use of revenues to purchase coral reef insurance?	Type of local authorization required	Revenue generating capability	Overall feasibility
Vessel registration fees	✗	Yes—would require specific authority for state to buy reef insurance with proceeds.	Would require approval by the local government if any revenue sharing/local option funds are used.	Low—without increase in base vessel registration fees.	Low
Coral reef protection act	✓	Yes—would require Florida Department of Environmental Protection to use civil penalty proceeds to purchase insurance	None	Low—funding dependent on sporadic collection of civil penalties.	Low—does not create reliable funding stream
Tourist development taxes	✓	Yes—would require legislative authority to use funds for insurance purchase	Referendum approval required for levy of surtax. Would require local tourist development authority to approve within annual plan.	High	Low/Medium–too many competing uses (e.g., advertising, beach nourishment, etc.)
Local government infrastructure sales tax	✗	Yes—would require legislative change to allow funds to be used for insurance.	Referendum approval required for levy of surtax.	High	Low–too many competing uses
Interlocal entity	✗	To be determined–may be possible to do under existing authority.	Would require local governments to enter interlocal agreement.	Medium—as requires local government contribution of funding or issuance of bonds.	Medium

Table 5: Potential public funding sources in Florida for reef insurance premium

7.

How might an insurance policy be structured?

Based on findings from our assessment, we offer two examples to show how a parametric reef insurance policy could be structured in Florida and Hawai'i.



Degraded reef with jawfish at TNC's coral nursery in Florida's Dry Tortugas National Park

Example 1: Single-peril hurricane insurance for reefs in Miami-Dade County

This sample site is located of the City of Sunny Isles Beach, where average live coral cover on the offshore reefs ranges from 1 to 5% (NOAA, 2018).

Like the Mexico model, it would use funding from a parametric insurance policy to repair coral reefs damaged by a hurricane. The design of a parametric insurance policy for Florida must balance the potential for significant impact on the reefs against the frequency of storms that might cause that impact. Though selecting a large area of reef and a low wind speed will trigger more frequents payouts, it will also increase the premium cost. In contrast, setting a tight boundary around the reef and a high wind speed to trigger the insurance payout might result in not receiving a payout when reefs are damaged. The limited global experience shows that significant damage to reefs requires peak storm intensity at hurricane force or above within a few of kilometers of the reef. Historical hurricane records (track points and intensity) dating back to 1851 are available in the public records, which form the basis for the risk analysis. Hurricane risk for this stretch of the Florida coastline is high, with hurricane-force winds expected within 100 km of the site at least once every 5 years. The coverage design below seeks to balance the need for the coverage with the cost of the insurance. The stepped trigger payout approach outlined in Figure 4 and Table 6 would help to keep the insurance premium affordable (Willis Towers Watson. 2020).

The annual protective value of the reefs and cost of insurance premium should factor into a decision on purchasing reef insurance. For example, modeling shows that the 4.5 km^2 of coral reefs located off the City of Sunny Isles Beach in Miami-Dade County (see Figure 5) reduces flood damage. Insurance experts estimate the insurance premium for a reef insurance policy for the Miami-Dade County region would be approximately 11% (plus or minus 2%) of the maximum insurance cover. This constitutes an annual premium cost in the range of $90,000 to $130,000 per million dollars of coverage (Willis Towers Watson. 2020).

Hurricane category	Payout amount (% of limit) at given circle radius		
	25 km	50 km	75 km
1	20%	10%	5%
2	40%	20%	10%
3	60%	40%	20%
4	80%	60%	40%
5	100%	80%	60%

Table 6: Potential payout for hurricane parametric coverage for the Miami-Dade County sample site (Source: Willis Towers Watson. 2020).

When determining the appropriate amount of insurance cover, it is important to consider reef beneficiaries' willingness to pay and the desired amount (e.g. light debris removal versus coral transplantation). It is also important to keep in mind the limited restoration capacity and availability of cost-effective techniques to conduct reef restoration at scale. Currently, based on the limited amount of available data, the cost of reef repair is estimated to be high, and covering the full cost of repair through insurance may be cost prohibitive. However, an immediate response (damage assessment, light debris removal, stabilizing dislodged corals, and reestablishing in-water coral nurseries) following a hurricane is vital, and the quick payout of parametric insurance to fund this response could be extremely beneficial to initiating reef repairs.

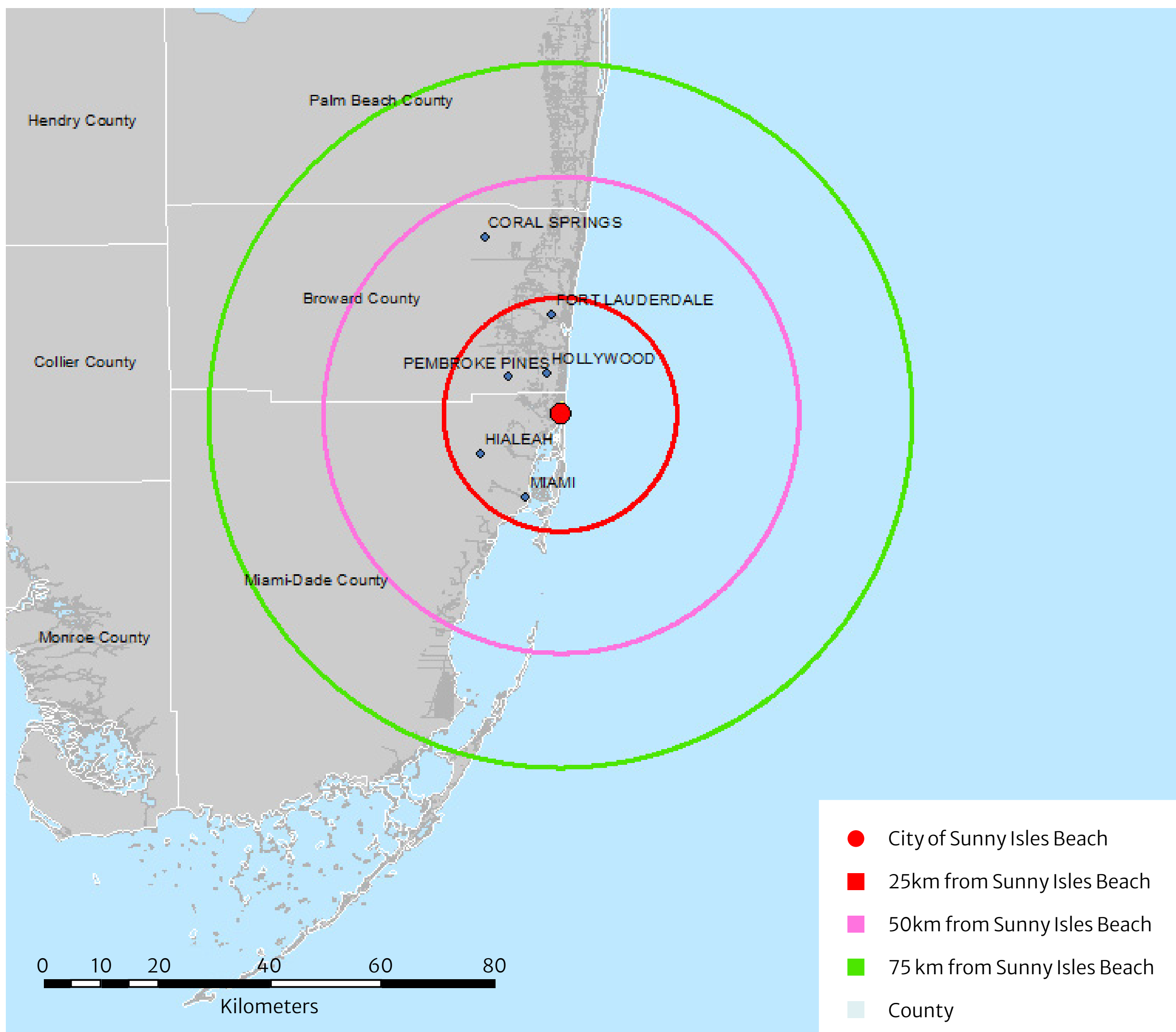


Figure 4: Example of circle radii used to determine payout amounts in Table 6.

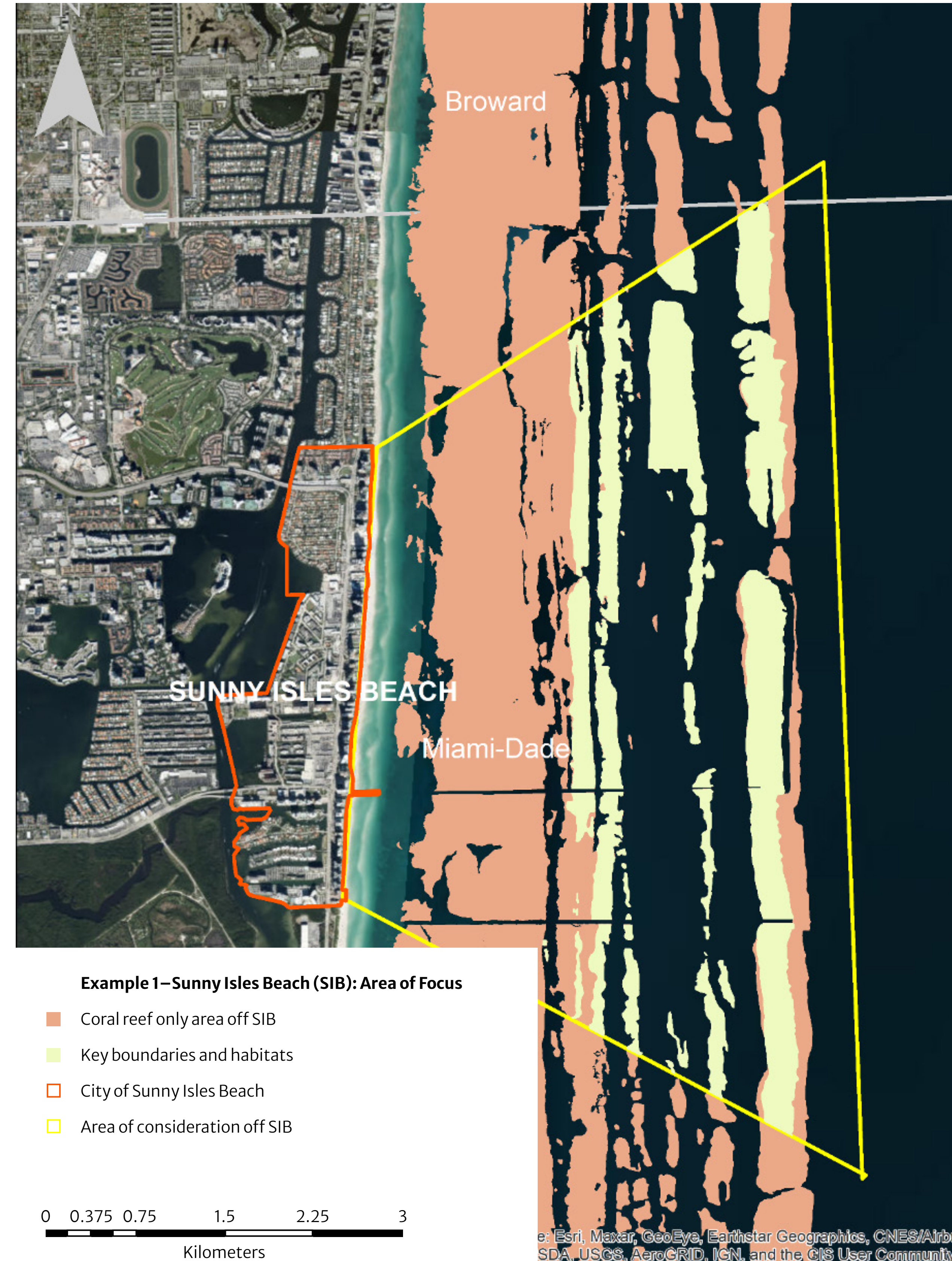


Figure 5: Coral reefs and Hardbottom Areas Off City of Sunny Isles Beach (SIB)

Example 2: Multi-peril insurance against hurricanes and marine heatwaves for reefs between Waikiki and Maunalua Bay, O‘ahu, Hawai‘i

This site spans the southeastern shore of the island of O‘ahu from Waikiki to Maunalua Bay, where average live coral cover on the offshore reefs is 5-10% (Franklin et al. 2013). Hurricane risk is currently relatively low in Hawai‘i (Figure 6), and the cost of hurricane insurance would likely be higher when it is designed as a stand-alone policy than when it is included in a multi-peril policy. Accordingly, a combined hurricane and marine heatwave insurance product should be considered.

Similar to the Florida example, the hurricane policy is designed to trigger higher amounts of payout as wind speeds increase, while at the same time reducing the payout with increasing distance from the center of the insured area. Historical hurricane records dating back to 1876 are available in the public records, and these form the basis for the risk analysis (Willis Towers Watson. 2020). Table 7 outlines the proposed amounts of payout depending on hurricane strength (Willis Towers Watson. 2020).

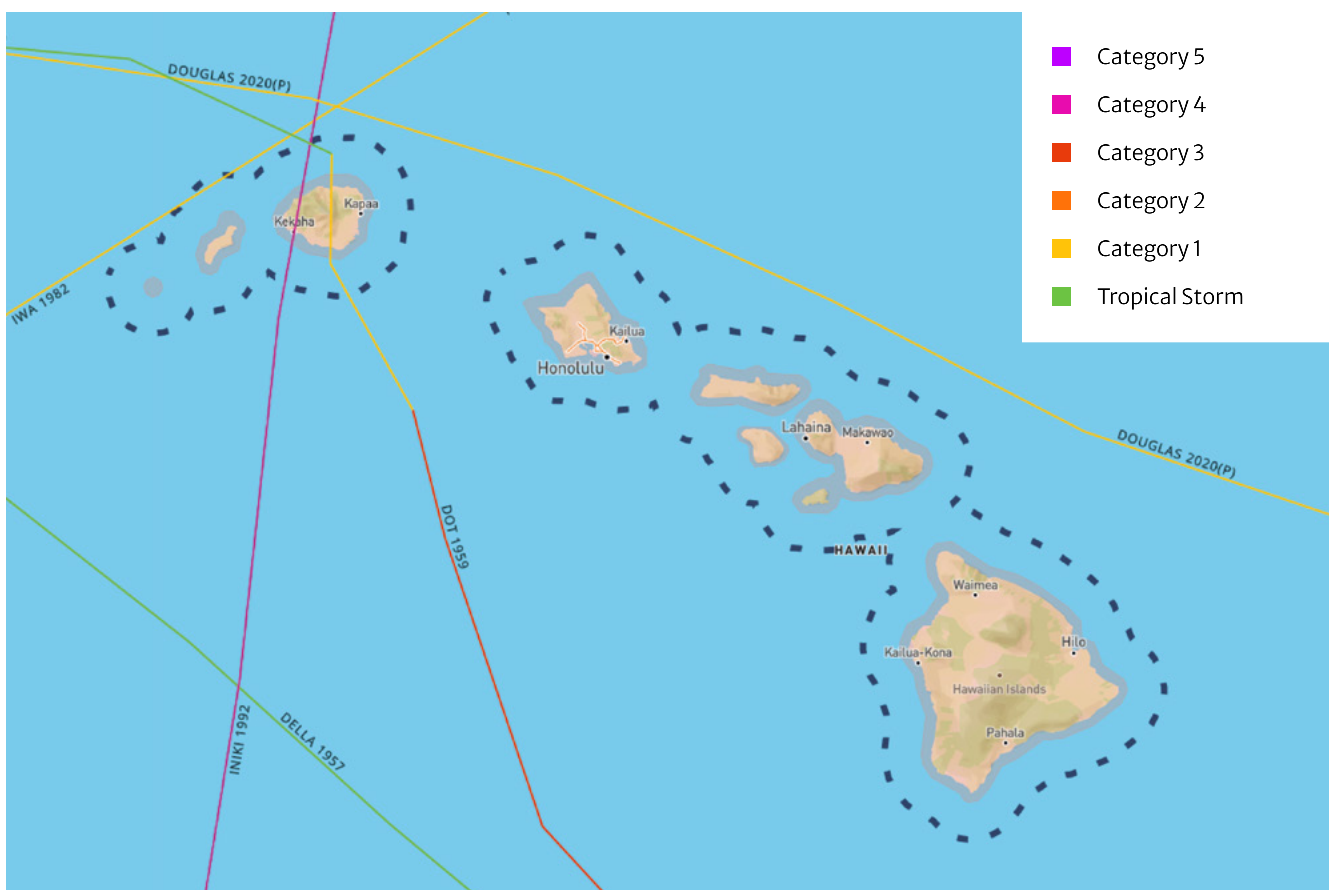


Figure 6: Hurricanes and tropical storms near Hawai‘i since 1950 (Source: NOAA Historical Hurricane Tracks)

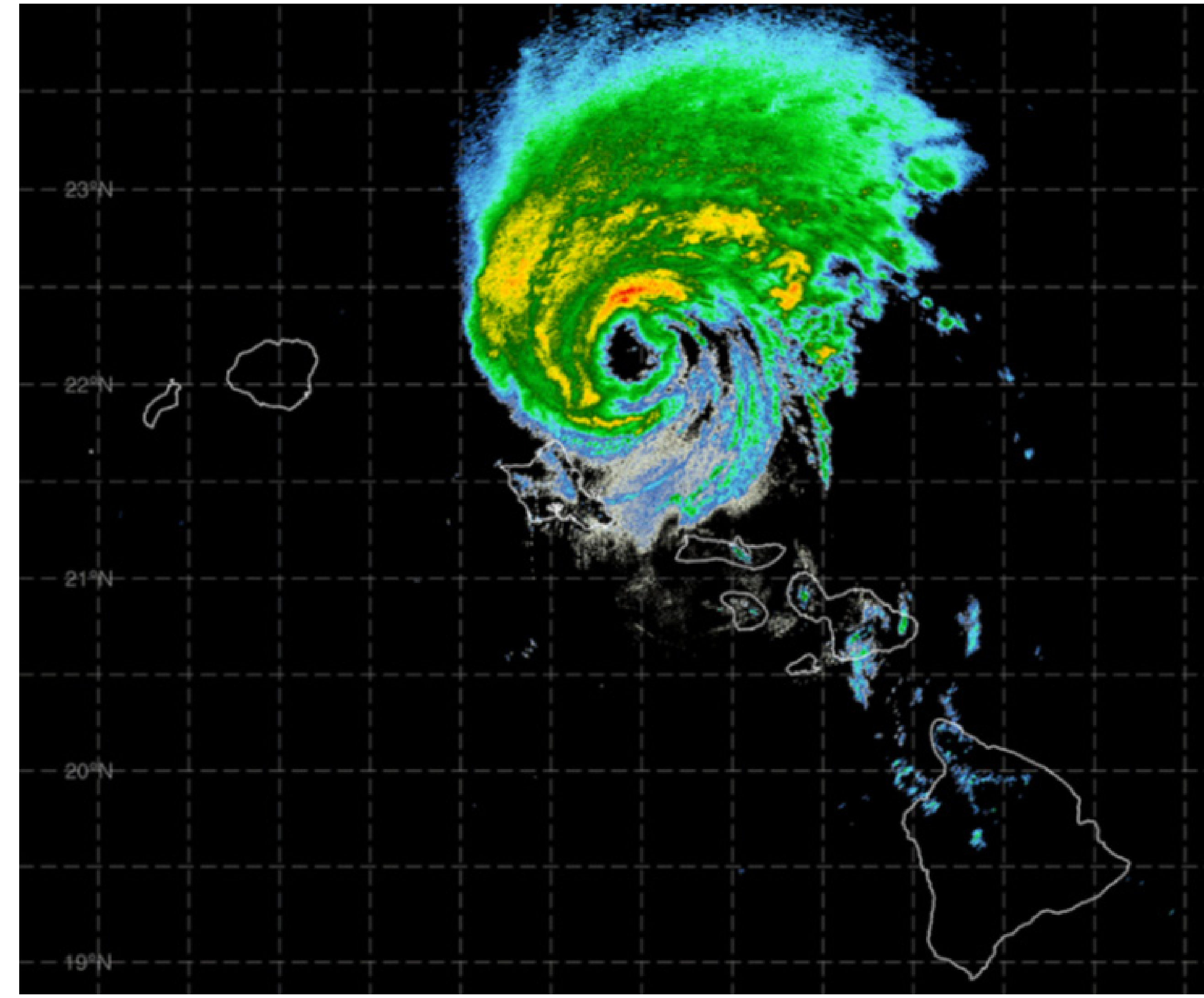


Figure 7: Radar image of Hurricane Douglas at 3:34am on July 27, 2020 as the storm was clearing O‘ahu. (Source: National Weather Service via Mark Nissenbaum/Florida State University)

Hurricane category	Payout amount (% of limit) at given Circle Radius		
	50 km	75 km	100 km
1	20%	10%	5%
2	40%	20%	10%
3	60%	40%	20%
4	80%	60%	40%
5	100%	80%	60%

Table 7: Table 7: Potential payout for hurricane parametric coverage for the Waikiki - Maunalua Bay sample site (Source: Willis Towers Watson. 2020).

During late July 2020, Hurricane Douglas passed close to the north of main Hawaiian Islands as a Category 1 storm (see Figure 7).

Applying the parametric insurance structure described above and in Table 7, the event was at Category 1 status while passing through the 100 km circle for the sample site Waikiki – Maunalua Bay (see Figure 8) and would have triggered a 5% payout of the maximum cover.

In the case of a second peril, coral bleaching is well correlated to the cumulative amount of heat stress corals experience in a certain location, measured in DHWs. NOAA's Coral Reef Watch (CRW) has been providing daily satellite-derived sea surface temperature estimates and DHWs at 5 km resolution since 2000. Breaching of a DHWs threshold in any one of the 5 km-CRW cells in the immediate offshore area of Waikiki - Maunalua Bay is used as the insurance trigger, and the proposed amounts of payout are outlined in Table 8 (Willis Towers Watson. 2020). It is important to note that the bleaching response of corals can vary greatly within a reef. Furthermore, it will be extremely challenging to replace bleached corals on a reef scale, and heat-resilient corals suitable for transplantation still need to be identified.

Due to the highly innovative nature of a parametric bleaching cover, it will only be possible to confirm the cost of insurance at the time of purchase. However, in discussions with insurance industry experts, it has been estimated that purchasing a multi-peril (hurricane and marine heatwave) policy at this location on Oʻahu could cost approximately $100,000 per million dollars of coverage. If the multi-peril policy were structured to cover different sites across Hawaiʻi, there may be relative pricing benefits for the purchaser.

The cost of a policy to cover hurricane risk only in Hawaiʻi would be lower than that of the multi-peril cover mentioned above. However, due to the current low risk presented by hurricanes and minimum cost requirements of insurance companies, it would seem relatively expensive compared to the multi-peril cover. Industry experts estimate that such a policy would cost approximately $20,000 per million dollars of coverage, assuming that an annual loss limit across multiple sites were implemented. Conversations with the industry confirmed that it would not be problematic to find companies willing to offer this hurricane-only policy.

Coral reef and fish at Kaʻūpūlehu, Hawaiʻi Island © Bryce Groark

The 2.7 km^2 of offshore coral reefs between Waikiki and Maunalua Bay are vital to Oʻahu's tourism industry and are estimated to prevent $135 million in flood damages annually. The flood protection benefits of reefs were calculated based on data from a recent United States Geological Survey report (Storlazzi et al. 2019) and using the Federal Emergency Management Agency's Flood Assessment Structure Tool. Expected flooding for various storm return periods (i.e., storms occurring once every 10, 50, 100, and 500 years, where rarer storms are more intense) at current reef levels and with 1 meter of reef loss were modeled. The flood zones were then overlaid with a building value database to arrive at the expected damages to buildings and their contents. The difference in expected damages between current reef levels and with one meter of reef loss is the protective value of reefs. Sample maps showing expected damages at current reef levels and with 1 meter of reef loss are provided below (see Figures 9 and 10).

As in Florida, reef beneficiaries' willingness to pay and the desired level of response should also be considered when determining the appropriate amount of insurance cover. While covering the cost of full reef repair may be prohibitive, a parametric insurance payout can provide funds necessary to implement the most pressing repair activities needed immediately following a triggering event which can help the reef recover more quickly.

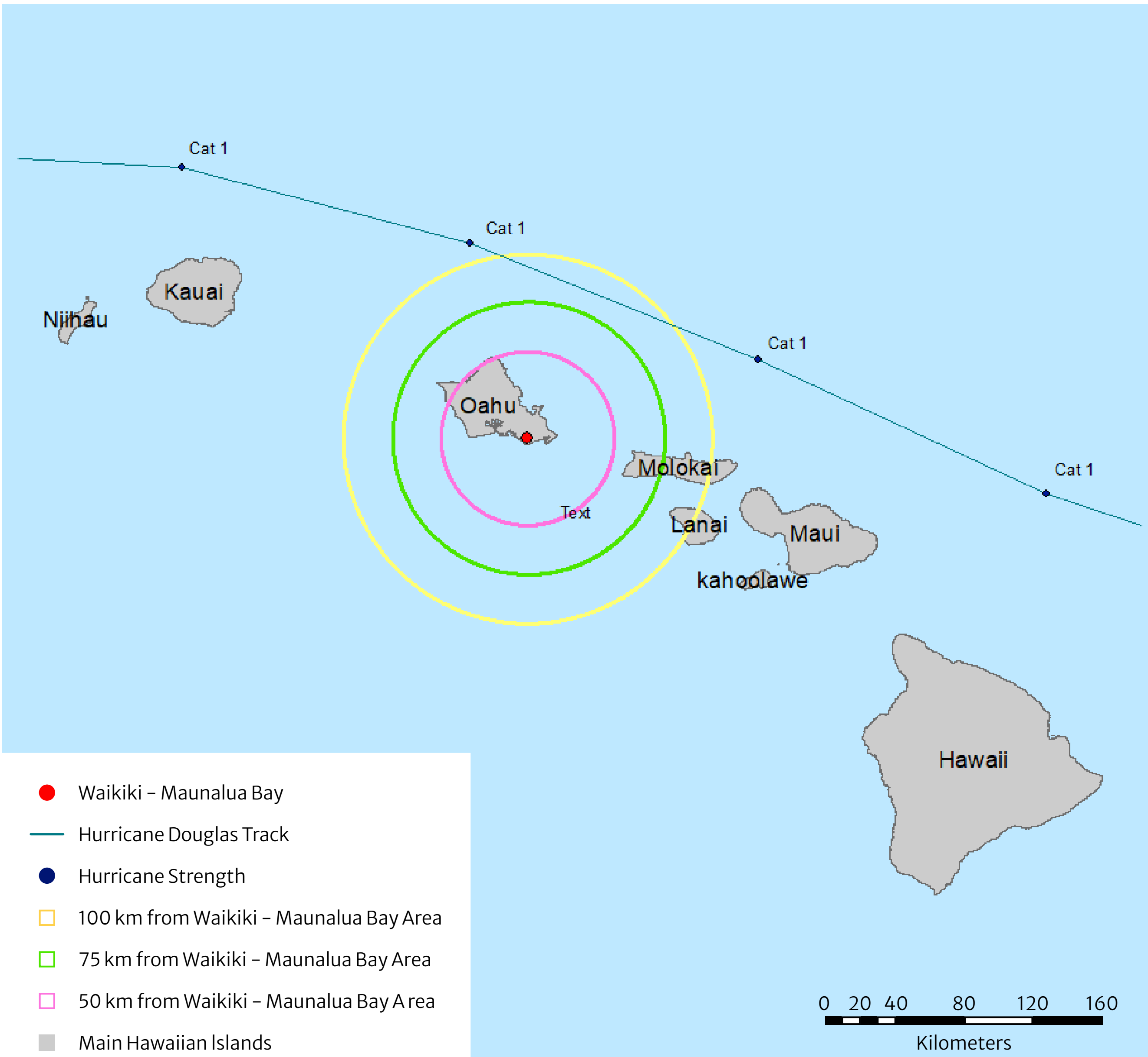
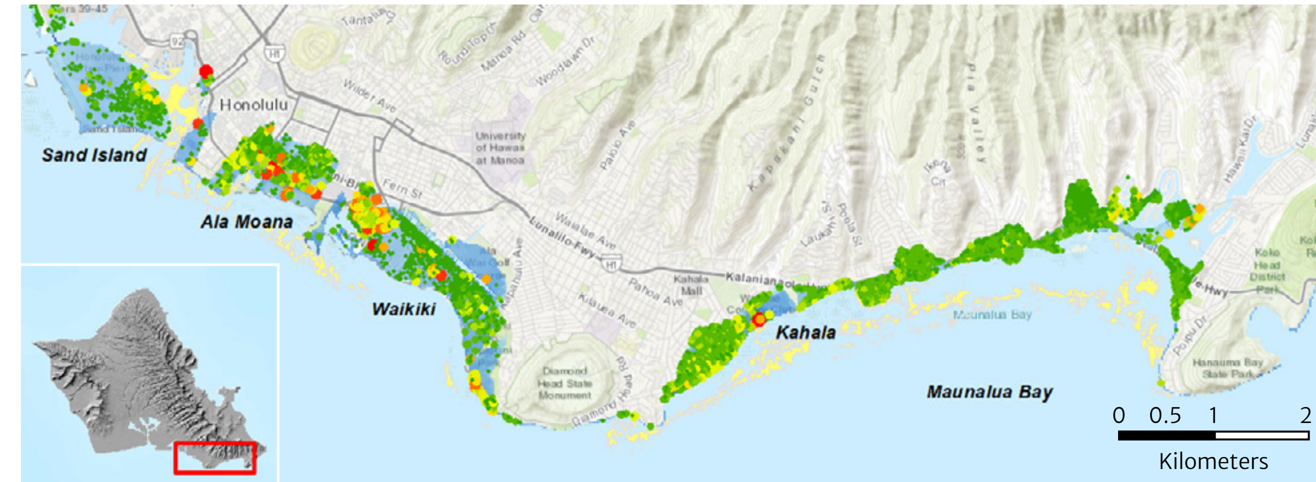


Figure 8: In 2020, Hurricane Douglas passed through the circle radii used to determine payout amounts in Table 7. (Source: Basemap with hurricane data, National Hurricane Center, NOAA.)

Max DHW (rounded to 1 decimal place)	Payout amount (% of limit)
4.0	20%
4.1 – 7.9	20% + (DHW – 4) x 20%
8.0	100%

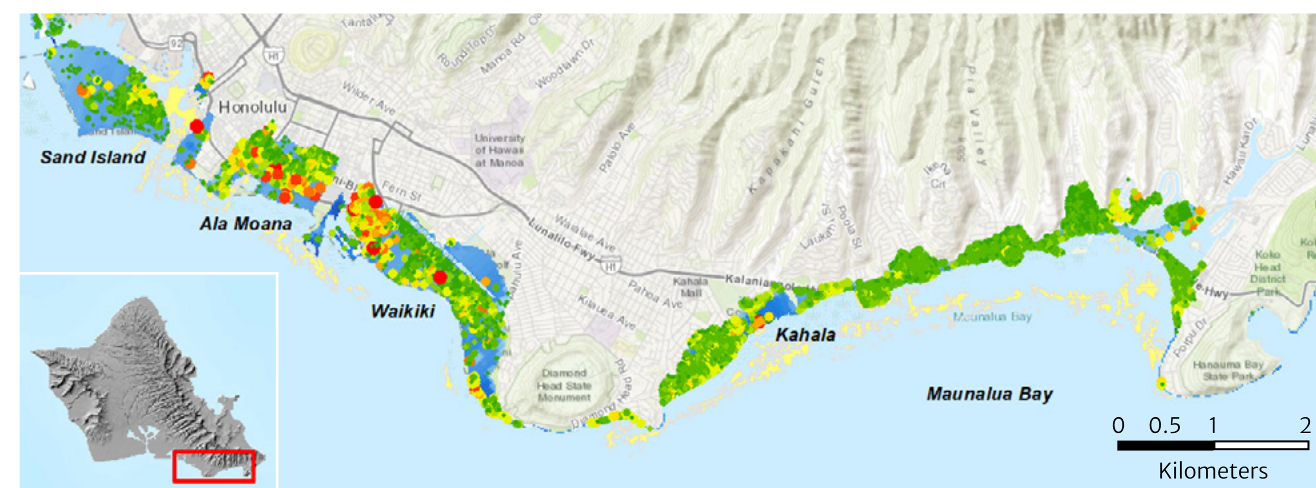
Table 8: Potential index function for marine heatwave parametric coverage for the Waikiki - Maunalua Bay sample site (Source: Willis Towers Watson. 2020).



Total Loss ($USD)

- 0.0 – 31,000
- 32,000 – 66,000
- 67,000 – 110,000
- 120,000 – 180,000
- 190,000 – 340,000
- 350,000 – 610,000
- 620,000 –1,100,000
- 1,200,000 – 1,900,000
- 2,000,000 – 3,800,000
- 3,900,000 – 20,000,000
- Coral–Algae cover
- High: 13.9ft
- Low: 0.15ft

Figure 9: Expected losses in the Waikiki - Maunalua Bay area from damages to buildings and their contents in a flood event expected to occur once every 100 years at current reef levels.



Total Loss ($USD)

- 0.0 – 31,000
- 32,000 – 66,000
- 67,000 – 110,000
- 120,000 – 180,000
- 190,000 – 340,000
- 350,000 – 610,000
- 620,000 –1,100,000
- 1,200,000 – 1,900,000
- 2,000,000 – 3,800,000
- 3,900,000 – 20,000,000
- Coral–Algae cover
- High: 13.9ft
- Low: 0.15ft

Figure 10: Expected losses in the Waikiki - Maunalua Bay area from damages to buildings and their contents in a flood event expected to occur once every 100 years with 1 meter of reef loss.

Conclusions

Coral reefs are highly valuable to coastal communities in helping to reduce the impacts of storm surge and coastal erosion. Considering the range of benefits that coral reefs provide, there is strong stakeholder interest in using parametric insurance to raise funds to repair reefs after a damaging event. Based on the findings from the six questions above, this section provides eight key conclusions about the potential of using parametric insurance to support reefs and communities that depend on them for coastal protection and economic well-being. This section also identifies opportunities for further exploration with stakeholders in Florida and Hawaiʻi.

Dive boat moored above coral reef in Key Largo, Florida © Rachel Hancock Davis/TNC

Conclusions for Florida and Hawaiʻi

1. Though the concept of insuring natural infrastructure is new, the assessment confirmed interest and broad potential for insuring coral reefs at statewide levels. However, additional analyses are needed to determine its suitability at specific sites within each state.
2. Parametric insurance for coral reefs is legally and technically feasible in Florida and Hawaiʻi and can provide funds to repair coastal ecosystems after they are damaged by insured events. However, it does not address the drivers of coral reefs decline and should be used in combination with other management tools and funding mechanisms to enhance the resilience of these ecosystems in the long term.
3. Parametric insurance for coral reefs can play an important role in their protection by facilitating private sector engagement and catalyzing funding from beneficiaries to protect and repair coral reefs from the increasing risks of climate change.
4. In Florida and Hawaiʻi, reefs provide valuable ecosystem services and face a multitude of risks, some of which are technically insurable through parametric insurance. In addition, many public and private entities have an insurable interest in reefs and are, therefore, legally entitled to purchase insurance. This feasibility study opens the door to explore modified versions of the Mexico reef insurance model and new approaches to fund reef restoration and repair in Florida and Hawaiʻi.
5. Since the cost to repair coral reefs is high, an insurance policy should focus on the most pressing repair activities needed immediately following a triggering event. An insurance payout could be combined with other funding sources (e.g., post-disaster recovery funds) to cover the full cost of repair. For full-scale reef repair, both increased repair capacity (e.g., coral nurseries, restoration practitioners) and new approaches that increase the viability and decrease the cost of repair need to be identified. Insurance could be used to cover some of the costs of these investments.
6. Identifying funding sources to cover the insurance premiums is essential. Existing sources of public funding in Florida and Hawaiʻi, which are already stretched thin, would likely require legislative changes to allow payment for insurance premiums. This highlights the need for new funding sources and models involving the private sector.

Elkhorn coral on reef in Key Largo, Florida © Rachel Hancock Davis/TNC

Additional considerations for Florida

7. With the rapid decline in live coral cover and deterioration of overall reef height and surface roughness, a holistic approach is needed in Florida. Investment should be focused on restoring coral reef health and recovery from disease as well as other stressors to preserve the current level of ecosystem benefits reefs provide. Insurance could be a valuable tool to protect the investment made to conduct this work and could be of interest for specific stretches of reef that are in better condition and provide more protection and a richer set of additional services.
8. Due to the high risk of hurricanes in Florida, insurance to cover this risk is understandably more expensive than in areas with lower frequency of hurricanes. Therefore, obtaining coverage to fully repair reefs may be cost prohibitive, highlighting the need for multiple and diverse funding sources and mechanisms.

Outlook and Opportunities

Reef insurance has proven to be an effective tool to engage a broader range of stakeholders than those traditionally involved in environmental conservation, resulting in the cross-pollination of ideas from academia, agencies, and the tourism, finance and insurance sectors. This has led to the identification of several opportunities to adapt the Mexico reef insurance model to Florida and Hawai‘i.

Building on the findings of the feasibility studies in the two geographies, we will continue discussions with local stakeholders to further explore opportunities that were identified and develop funding models that align interests of natural infrastructure beneficiaries with protection and repair of coral reefs and other ecosystems to enhance coastal resilience. Below are opportunities that could be further explored.

Coral reefs protect coastal homes and infrastructure on Hawai‘i Island's Kohala coast © C. Wiggins

Protecting investments in coral reef restoration

Parametric insurance for coral reefs can play an important role by providing a source of revenue to contribute to the repair of these valuable ecosystems after they suffer damage or cover costs of investments made to restore ecosystems. For example, an insurance policy might be designed to provide cover for a part or all of the planned investment in the seven iconic reef sites within Florida Keys National Marine Sanctuary. It could be used to repair in-water coral nurseries which are essential to reef restoration and highly exposed to hurricane damage. Assuming catastrophic loss of a single average-sized nursery, we estimate a cost of $165,000 in labor, supplies, and boat time to fully replace the infrastructure and stock the nursery with corals from other existing nurseries.[3]

Considering Resilience Insurance

Parametric reef insurance, which covers the reef itself, is used to provide funds to repair and jump-start recovery following damage to the reef by a triggering event. However, many reefs (and other ecosystems) have been degraded by manmade and/or natural events and require both pre-disaster restoration to reestablish the reef's full resilience capacity and ongoing management to maintain resilience capacity thereafter. In such cases, a concept called resilience insurance could be used to incentivize upfront investment in restoration that would reduce the risk posed by degraded natural infrastructure and enhance resilience pre-disaster, thus preventing or minimizing future economic losses. For example, a beachfront hotel adjacent to a degraded reef pays annual premiums for standard insurance to repair or replace its assets when a storm damages the hotel. The hotel could invest funds to restore the degraded reef, which would increase the capacity of the reef to protect the hotel from flood damage (i.e., decrease the potential for economic loss from flooding). A third-party evaluator would quantify the flood protection benefits provided by the restored reef and the benefits would then be translated into reduced annual insurance premiums for the hotel, amortizing part of the cost of the upfront reef restoration over time. Similarly, resilience insurance could incentivize investments to improve the resilience of other natural infrastructure, such as restoring oyster reefs, mangroves forests, or dune systems that could provide enhanced flood protection benefits after restoration. The extent to which this premium reduction would amortize the upfront investment cost, will differ depending on the size of the restoration project and its actual cost. Should there be a funding gap, with restoration costs above the maximum possible premium savings, additional funders would need to be brought on board.

3 This was estimated based on information from both our experiences and those of our partners, with assumptions that an average nursery has about 200 structures that cost between $35 and $100 each to replace, and that a team of four can reasonably install 20 structures per day and fill 5 structures with 100 corals each, per day. This estimate could differ outside of the United States.

School of manini (*Acanthurus triostegus*) on reef at ʻĀhihi-Kīnaʻu Natural Area Reserve, Maui © Jim Petruzzi

Resilience insurance could be a particularly appropriate tool in Florida to help improve the condition of its coral reefs. It is important to note, however, that an immediate and quantifiable risk reduction from restoration activities must be realized for the insurance provider to offer a premium reduction. In the case of coral, this means not merely transplanting it, but also building a structure to which it can be attached. In the short term, the premium reduction will come from the risk reduction benefit of the structure, and over time, the coral will increase this benefit. While a restoration and management strategy aimed at flood risk reduction may require consideration of these hybrid structures, there is debate over the benefits to the ecosystem and appropriateness of such structures in Florida.

Soft corals in Boynton Beach, Florida © Rachel Hancock Davis/TNC

Exploring alternative funding models

All levels of government in both Florida and Hawaiʻi are strongly committed to protecting their coral reefs. The State of Florida confirmed its commitment in 2020 by including $10 million in its budget for coral reef restoration. Reef insurance may be to be an appropriate mechanism to protect this investment from hurricane damage. The State of Hawaiʻi is committed to effectively managing 30% of Hawaiʻi's nearshore waters by 2030 and is developing a coral reef restoration and artificial reef plan, which includes hybrid reefs. In a recent public survey, 72% of respondents said they were concerned about the islands' coral reefs dying. However, more resources are needed for ongoing management and restoration of reefs to prevent further degradation and to ensure that they continue to provide flood protection, and cultural, tourism, and fishery benefits.

Therefore, alternative funding models should be explored that include opportunities for private sector beneficiaries to contribute towards restoring natural infrastructure that protects them, regardless of a threat event.

What does your organization consider to be the top three threats to coastal areas (choose three)?

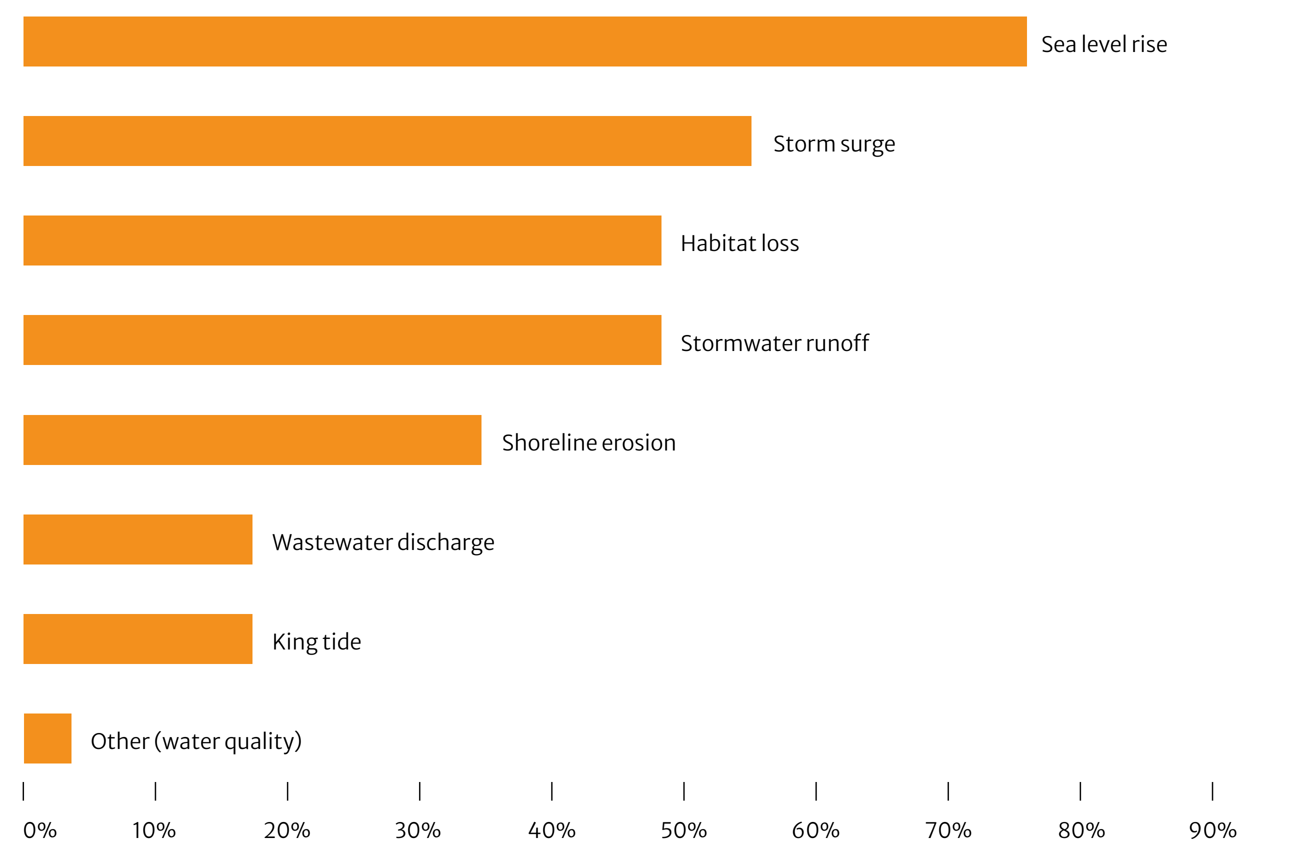


Figure 11: Survey of Florida public sector resilience and natural resource practitioners' organizational views on the top three threats to coastal areas.

Expanding to coastal ecosystems other than coral reefs

In Florida, a survey was sent to 46 public sector resilience and natural resource practitioners and agency decision makers to better understand which natural infrastructure they were most interested in protecting from a risk reduction perspective. According to the 29 responses it was found that:

1. The top four risks to coastal areas are identified as sea-level rise (76%), storm surge (55%), stormwater runoff (48%) and habitat loss (48%).
2. Respondents were most interested in exploring mangroves (89%) and coral reefs (69%) to reduce these risks.
3. The natural infrastructure considered most important to protect the coast were natural areas (72%), beaches (66%), public infrastructure (55%) and public parks (48%).
4. A vast majority (83%) of respondents were interested in participating in a TNC-led forum to further explore alternative funding models to protect natural coastal infrastructure and the protective benefits it provides. The survery indicated interest in various natural coastal infrastructure, such as mangroves and dunes. These systems are less costly to repair and may be well-suited to the parametric insurance approach or to resilience insurance and should be further explored. TNC and partners recently published a report on the potential to use insurance to protect mangroves.

Filling data gaps and strengthening the science

Filling data gaps will enable the development of additional insurance-for-nature models, as well as other funding mechanisms to protect and restore coastal ecosystems. Some of the key data gaps include the degree of loss of ecosystem benefits (e.g., flood protection, tourism, fishery) from a single event, feasibility and cost of large-scale ecosystem restoration, effective repair activities, and the timeframe for ecosystem benefits to be fully restored following such repair activities.

School of ‘ōpelu (mackeral scad, *Decapturus* spp.) swimming over coral reef on Hawai‘i Island’s west coast © Jim Kilbride

In recent decades, scientists have developed a better understanding of the ecosystem services provided by coral reefs around the world. These services include coastal protection, a cultural connection to place, recreational opportunities, fisheries benefits, food security, and tourism income. Recent studies quantifying the value of these services clearly demonstrate that their loss would be both an ecological and economic disaster. An unprecedented coordinated global effort among the public, private, and philanthropic sectors will be required for reefs to survive beyond the end of this century. While insurance cannot address many of the drivers of reef decline, including pollution, overfishing, and acidification, it can provide essential post-event funding to repair reefs after suffering damage from other significant risks they face today and into the future.

Bayfront properties in Miami, FL © Pixabay

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