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LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

DEPT. COMM. NO. 93

November 25, 2022

The Honorable Ronald D. Kouchi,
President
and Members of the Senate
Thirty-Second State Legislature
State Capitol, Room 409
Honolulu, Hawaii 96813

The Honorable Scott K. Saiki, Speaker
and Members of the House of
Representatives
Thirty-Second State Legislature
State Capitol, Room 431
Honolulu, Hawaii 96813

Dear President Kouchi, Speaker Saiki, and Members of the Legislature:

For your information and consideration, I am transmitting a copy of the Reef Insurance Feasibility Report, in response to Senate Concurrent Resolution 159, Senate Draft 1 of the Regular Session of 2021. In accordance with Section 93-16, Hawaii Revised Statutes, a copy of this report has been transmitted to the Legislative Reference Bureau and the report may be viewed electronically at https://files.hawaii.gov/dlnr/reports-to-the-legislature/2023/AR23-Reef-Insurance-Feasibility-Report-FY22.pdf.

Sincerely,

SUZANNE D. CASE
Chairperson

Enclosure

Report to the Thirty-Second Legislature
2023 Regular Session

REEF INSURANCE FEASIBILITY REPORT

Prepared by the

State of Hawaii
Department of Land and Natural Resources
Division of Aquatic Resources

In response to Senate Concurrent Resolution 159,
Senate Draft 1 of the Regular Session of 2021;

November 2022

Reef Insurance Feasibility Report

State of Hawai'i
Department of Land and Natural Resources
Division of Aquatic Resources

Kona, Hawai'i
Credit: Christine shepard NOAA

Report produced for the Hawai'i State Legislature and prepared by the State of Hawai'i Department of Land and Natural Resources Division of Aquatic Resources

Acknowledgements

Many thanks to all the people who shared ideas and experience for this effort, including Brian Neilson, David Sakoda, Luna Kekoa, Cathy Gewecke, Charissa Minato, Chelsea Wolke, Jesse Boord, Kim Hum, Simon Young, Colin Hayashida, Amy Wirts, Paulo Maurin, Andy McGowen, Shannon Ruseborn, Theresa Woznick, Amber Ternus, Maria Judith Amador, Katia Chikasuye, Keelan Barcina, Justine Nihipali, Makale'a Ane, Eric Conkin, Trevor Taylor, Tyler Hee, and Aarin Gross

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Executive Summary

The Ocean is an integral component of culture, tradition, economy, and sustenance in Hawai'i.

Unfortunately, the Ocean is facing unprecedented threats like climate change, dense human populations, and unsustainable practices. In response to these threats, proactive management is becoming more relevant and necessary to maintain ocean health and Hawaii's ways of life.

In 2021 the Hawai'i State Legislature adopted Senate Concurrent Resolution 159, Senate Draft 1 (SCR159 SD1), to address this need for proactive management. This concurrent resolution urges the Department of Land and Natural Resources (DLNR) to examine and consider purchasing reef insurance to support nature-based solutions to protect Hawai'i coastlines and coastal infrastructure from natural disasters. The State of Hawai'i Reef Insurance Feasibility Report has been prepared in response to this resolution from the State Senate and addresses specific topics in financing mechanisms, nature-based solutions for shoreline protection, and coral reef management through the lens of the DLNR's Division of Aquatic Resources (DAR). DAR is a state agency dedicated to working with the people of Hawai'i to manage, conserve, and restore the State's unique aquatic resources and ecosystems for present and future generations.

To best understand how reef insurance aligns with coral reef management priorities in the state, several feasibility considerations are analyzed throughout the report.

Reef insurance is a relatively new financing mechanism that provides a rapid outflow of funds for emergency coral reef restoration

A primary inhibitor in natural resource management globally is financial capacity to build robust and long term funding to address the full spectrum of threats. To build financial capacity, the insurance industry has created an innovative finance solution to insure natural assets. This insurance operates off identification of a specific damage event, and pre-agreed payouts based on specific threshold metrics. In the context of coral reefs, a few places have purchased or are investigating coral reef insurance to protect against hurricane damage, including Hawai'i. These insurance schemes are most well suited for emergency restoration actions, which are important to maintain resiliency of a reef.

Hawai'i specific considerations for reef insurance

To appropriately determine the Hawai'i specific feasibility of reef insurance, robust analysis of many factors beyond the scope of this report will be necessary. With that in mind, the following sections describe the potential considerations of feasibility in the State and topics where further consideration is necessary.

Legal feasibility

Legal feasibility was analyzed primarily to understand what are the legal roadblocks and who is eligible for ownership of a reef insurance policy. There are manageable challenges associated with procurement of funds for reef insurance premiums and allocation of payout to local reef practitioners. Importantly, many parties are eligible for reef insurance including government agencies, private entities, and public+private partnerships.

Operational feasibility

Operational feasibility of reef insurance can be divided into capacity for response and capacity to manage funds related to reef insurance. Response capacity requires a pre-determination of who will respond to these damage events, and ensuring all supplies are acquired beforehand. This also includes permitting needs at the State and Federal level (depending on project scope). To ensure fund management capacity, an insurance policy owner should determine how the funds will be distributed, to who, and how paying for the premiums will be managed.

Social feasibility

It is difficult to determine the social feasibility of reef insurance without a specific site for a policy in mind. This is because each island relies on specific regional partners to be engaged. Recommended entities that should be engaged include: community organizations, cultural practitioners, residents of Hawai'i, beneficiaries within the tourism industry, and coral reef management practitioners in the private and public sectors. Particular focus should be placed on equity of reef insurance policies, to ensure selected sites are protecting diverse needs for shoreline protection in the State.

Further considerations in economic analysis and site selection analysis

Economic Analyses

Three economic analyses must be conducted to determine if a reef insurance policy is economically feasible. These analyses must compare the costs and benefits including the of the cost of restoration actions, the cost of losses to ecosystem services with no intervention, and the benefits of ecosystem services with a payout.

Site Selection analyses

Site selection recommendations are highly dependent on specific goals outlined by the owner of the insurance policy. If the policy is focused on shoreline protection ecosystem services, then the specific sites of a policy should focus on either protection of state infrastructure, protection of private interests, protection of culturally significant sites, or vulnerable natural resources.

Alternatives to reef insurance for coral reef emergency restoration

There are few comparable funding initiatives that would provide a rapid distribution of funds for restoration after a specific damage event occurs. One of the comparable programs is the Federal Emergency Management Agency's (FEMA) hazard mitigation grant program. Hawai'i is eligible for pre and post disaster grants through HI-EMA, the Hawai'i Emergency Management Agency. Although no awards for coral reef restoration have occurred yet, this is of growing interest in Hawai'i and throughout the United States.

Governance frameworks for reef insurance

Many government agencies have responsibilities in shoreline protection in the State. This report comes at a convenient time for these agencies to determine the goals in shoreline protection such as how to prioritize nature based alternatives, how to fund these initiatives, and how to move forward collaboratively to address future challenges in shoreline destabilization.

In Conclusion

Coral reefs provide important ecosystem services for marine ecosystems that provide food and economic benefits to the people of Hawai'i. In addition, coral reefs provide essential flood and erosion protection to coastlines throughout the Hawaiian Islands. To maintain these ecosystem services and coastal protection - coral reefs need robust management to counteract degradation from storm events, ocean heatwaves, ocean acidification, and land-based source pollution. Reef insurance is a valuable financial tool that fills a specific niche in coral reef management for the State. The rapid deployment of funds for emergency coral restoration and accessibility of an insurance policy to both private and public organizations are key benefits that make this funding scheme unique and innovative. DAR would like to support future reef insurance policies by assisting in restoration site identification, and expedited permits for emergency restoration. Although reef insurance is a useful tool in financing coral reef restoration in response to damage events such as storms, other alternate financing initiatives should continue to be pursued to ensure diverse funding sources. A viable alternative to reef insurance for the purposes of shoreline protection via reef restoration is FEMA's hazard mitigation grants, which has recently grown in interest throughout the Nation.

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Section One

The next section provides background on shoreline destabilization and shoreline protection tactics in the state of Hawai'i

Kealakekua Bay, HI
Credit: Bert Weeks

As human use, global change, and natural processes occur, Hawai'i coastlines are becoming more vulnerable and destabilized resulting in coastal erosion and flooding. These vulnerabilities are consistent throughout the state, with 70% of beaches on Kaua'i, O'ahu, and Maui experiencing long-term and chronic erosion, with 13 miles of beaches already lost (Romine & Fletcher, 2013). In addition to erosion, estimations of coastal flooding under a projected 3.3 feet of sea level rise will put at risk 6,500 cultural sites, 38 miles of major roads, and $19 billion in assets at risk. These threats are imminent, with sea level rise continuing to exacerbate king tides and increase the frequency of severe storm events, which will in turn worsen coastal erosion and flooding (Hawai'i Sea Level Rise Vulnerability and Adaptation Report, 2017). Increased erosion and flooding will disrupt coastal businesses, destroy homes, impact recreation opportunities, damage critical infrastructure such as roads and public buildings, disrupt cultural and traditional practices, and disrupt people's unique relationship with the natural environment.

In response to these threats, Hawai'i has taken two approaches to combat shoreline destabilization: hardened structures and nature-based alternatives. Hardened structures fortify the shoreline and inhibit erosion. Some examples include t-groins, seawalls, sandbags, and bulkheads. As the popularity of hardened structures has grown globally, so have the critiques. Coastal resource managers are now realizing that these structures reduce nursery habitat for marine species, degrade water quality, increase erosion processes on beaches to either side of the hardened shoreline, and are cost inhibitive because they require continual maintenance. Recent efforts to quantify the negative impacts of hardened structures in Hawai'i show an overall narrowing of 10.7 miles due to hardened structures. On O'ahu alone, beaches have been narrowed by 6.4 miles due to shoreline hardening, which is ~24% of the 71.6 miles of originally sandy shoreline on the island (Hawaii Coastal Erosion Management Plan - COEMAP, 1999). Due to these concerns, the State of Hawai'i is moving towards nature-based alternatives.

House threatened by erosion on North Shore of O'ahu.

(Credit: NOAA)

Nature-based alternatives

Nature-based alternatives supply coastal protection without many of the negative side effects associated with hardened structures. In the context of shoreline protection, nature-based alternatives are incorporated in three ways: 1) restoration or creation of natural habitats, 2) incorporation of organic materials in coastal protection projects, and 3) utilization of natural features in combination with hardened structures (also referred to as green-gray infrastructure). Real-world application typically consists of beach renourishment, removal of invasive species, and restoration of coastal ecosystems such as estuaries, coral reefs, and dunes. This next section will discuss the merits of nature-based alternatives in greater depth as this is a focused direction for shoreline stabilization efforts in the State of Hawai'i and a request of the SCR159, SD1.

Specific habitats identified with shoreline protective services in mind naturally produce wave attenuation, storage of floodwater, reduction in erosion of sediment and soils, and reestablishment of native flora and fauna (Bridges et al., 2021). These services all contribute to the dissipation of wave energy interacting with the coastline and therefore reduce flood and erosion damages.

It is difficult to determine what is the most efficient nature-based alternative for coastal protection, because there are many factors that must be considered based on:

- site specific threats will primarily guide nature-based solution implementation
- site specific goals
- community buy-in of projects and prioritization of projects based on available funds and state priorities
- impacts of nature-based solutions on nearby ecosystems
- Cost of project and cost of maintenance of nature-based solution
- Prioritization of potential co-benefits such as recreation use, culture, tradition, and aesthetic

On a national scale, beach nourishment and dune restoration efforts are the most well documented and most often deployed nature-based coastal protection measures. FEMA values hazard mitigation potential of beach and dune projects at $300,649/acre/year. Comparatively, coral reef hazard mitigation potential is valued at $7,120/acre/year and wetland hazard mitigation potential is valued between $8,171-$8,955/acre/year (FEMA Ecosystem Service Value Updates, 2022). It is important to keep in mind these metrics represent national valuations of coastal protection services and are not specific to Hawai'i.

He'eia National Estuarine Research Reserve, O'ahu, Hawai'i. (Credit: NOAA)

Nature-based alternatives for coastal protection in Hawai'i

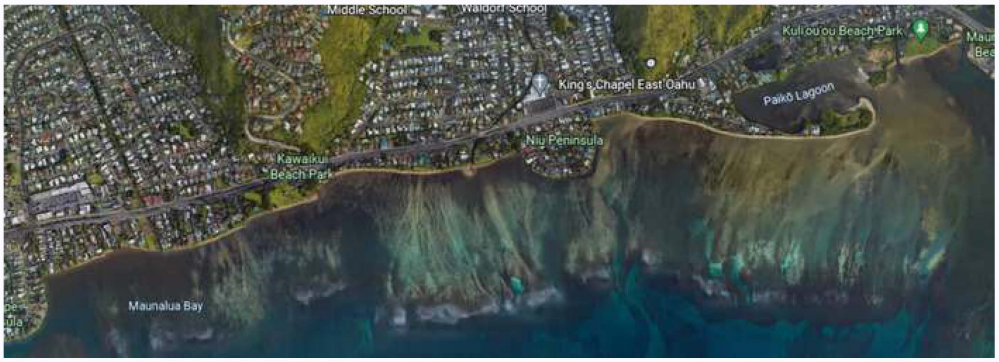
There are many projects occurring throughout out the state, below are a few examples:

Wetland Restoration	Sand Renourishment	Green-Gray Infrastructure
Demonstrating the interconnectedness of culture, food resiliency, and sustainable agricultural practices, partners Kako'o 'Ōiwi, Paepae o He'eia, and the He'eia National Estuarine Research Reserve utilize traditional management practices including agroforestry, lo'i kalo (wetland taro), and loko i'a (marine fishponds) while increasing biodiversity of native flora and fauna. These restoration projects improve wetland resilience to storm surge events and flooding inundation (Hastings et al., 2020).	To mitigate the impacts of sea level rise and increasing coastal erosion, the State of Hawai'i and the Kā'anapali Operations Association, Incorporated have developed a plan to protect Kā'anapali Beach Park, that includes both beach restoration and berm enhancement (Lands).	The Moku o Lo'e Marine Laboratory refuge is implementing green-gray infrastructure practices by restoring a seawall with concrete designed to recruit coral larvae and promote coral growth on the seawall. This will improve the structure's resilience and improve the wave attenuation benefits through coral restoration (need to find citation).

Although there is high interest in nature-based alternatives for shoreline protection in the state of Hawai'i and clear examples of successful projects, further investigation is needed to better understand Hawai'i's specific challenges. For example, the coastal composition of much of the state's coastlines lacks wetlands. There are wetlands present throughout the islands but are often concentrated inland. In addition, the high wave energy impacting beaches throughout Hawai'i requires careful consideration in potential beach and dune renourishment projects. If a beach with continual high wave energy undergoes sand renourishment, the long-term impacts could be negligible and require frequent renourishment to provide shoreline protection benefits.

It is important to investigate natural barriers that are plentiful in the state and provide a consistent benefit in the reduction of wave energy. For Hawai'i, this means coral reefs. Although coral reefs receive considerable investments in time and capacity, their role as natural barriers for coastal protection is at a crucial moment in history, and coral reef managers are beginning to investigate this relationship more than ever.

Coral Reefs as a natural barrier



Reef Structure protecting coastal infrastructure on South Shore of O'ahu.

(Google Earth, retrieved 2022)

Studies show that coral reefs can dissipate as much as 97% of incident wave energy, dispersing the wave's power and lessening its impact on the shoreline. Reefs can function in this way because they act like low-crested breakwaters, breaking up the energy of a wave and acting like a natural barrier between the ocean and land (Storlazzi et al., 2019). This wave attenuation service is applicable for both low wave energy days (typical days) and high energy days (like hurricanes and large storm cells) (Ferrario et al., 2014). In addition to wave attenuation functions, coral reefs naturally produce and trap sand, which collects on nearby beaches and combats coastal erosion (Woodhead et al., 2019).

Based on coral reef risk reduction services, the United States Geological Survey (USGS) and partners can quantify the value of coral reefs based on the flood reduction services provided. USGS did this by quantifying hazards to the shoreline, the role of coral reefs in reducing flooding, and the averted economic and social consequences. This research proposed a benefit that coral reefs help to avoid direct flood damages worth:

- $1.1 billion total value of economic activity protected by coral reefs from 100-year storm intervals in Hawai'i
- $836 million worth of coastal infrastructure protection from flooding annually; (Curt paper)
- 9,251 people protected by coral reefs from flooding based on 100 year storm models for Hawai'i (Storlazzi et al., 2019)

This wave attenuation service is increasingly sought after in long-term coral reef restoration projects in Hawai'i. An example of this is the Department of Defense's Reefense project. This project is funded through Defense Advanced Research Project Agency (DARPA) and will engineer reefs with coastal protective services for national defense infrastructure particularly at risk to sea level rise due to proximity to coastlines. These projects will be self-sustaining, man-made, and promote reef-like coastal protective services. In Hawai'i specifically, the University of Hawai'i will partner with DARPA to create concrete structures that mimic fringing reefs near some coastal military bases. This project is on a 5-year timeline and will be divided into three phases that address structural engineering of biohybrid materials, techniques to promote ecosystem engineering, and adaptive biology of corals for resilience in future ocean conditions (DARPA, 2020).

Co-Benefits of Coral Reefs in Hawai'i

Coral reefs provide additional services critical to the people of Hawai'i, in addition to the protection of shorelines. In Hawai'i, coral reefs are vital in the preservation of biodiversity, as they provide nursery habitat for culturally and economically important fisheries. Annually, coral reef fisheries provide 7 million meals, of which about 5 million are sourced from non-commercial catches (Grafeld et al., 2017). In addition, coral reef associated tourism contributes $1.23 billion to the State's economy (Spalding et al., 2017). Furthermore, coral reefs support an intrinsic value and identity to communities rooted in culture, tradition, and recreation.

In Hawai'i, coral bleaching, water quality degradation from sedimentation and nutrient-rich runoff, unsustainable fishing practices, and human-use of the ocean (via touching, kicking, standing on, or dragging gear) all impact overall reef health and therefore affect the ability of the reefs to provide coastal protective services.

Corals in Kāne'ohe Bay demonstrated a range of bleaching responses during the 2019 heat stress event. (Credit: Chuck Babbit Photography, NOAA)

Funding for coral reef management

As these threats become more apparent and damaging, a consistent challenge is financial capacity. Currently, funding initiatives for coral reef management projects come from federal and state agencies providing management and oversight, private entities that mitigate planned and unplanned damages (like harbor improvements and ship groundings), academics conducting coral reef-based research, and not-for-profits mitigating land-based and in-water threats. To focus on DAR the state agency in Hawai'i managing aquatic resources including coral reef ecosystems, most operational funding for coral reef management is from federal grants, state general funds, and ship grounding litigation. Other entities, like not-for-profit organizations and academia, fund coral reef management projects primarily through private beneficiaries, state grants, and federal grants. Funding through donors, as well as state and federal funds will always be necessary monetary streams in coral reef management but lack the ability to meet the growing costs of maintaining coral reef health and associated ecosystem services (Gross & Hicks, 2020).

There is a need to diversify funding streams and target industries that benefit from coral reef ecosystem services but are not directly contributing monetary support to coral reef management. To address this need, the Conservation Finance Alliance identified financing tools for use in coral reef management outside of traditional funding mechanisms. These nontraditional and novel funding mechanisms include entrance fees, taxes and levies, payment for ecosystem services like visitor fees, biodiversity offsets, bonds and impact bonds, debt for nature swaps, conservation enterprise incubators, conservation trust funds, and market and impact investing. The Finance Tools for Coral Reef Conservation: a guide has additional information and case studies associated with each listed finance tool (Iyer et al., 2018).

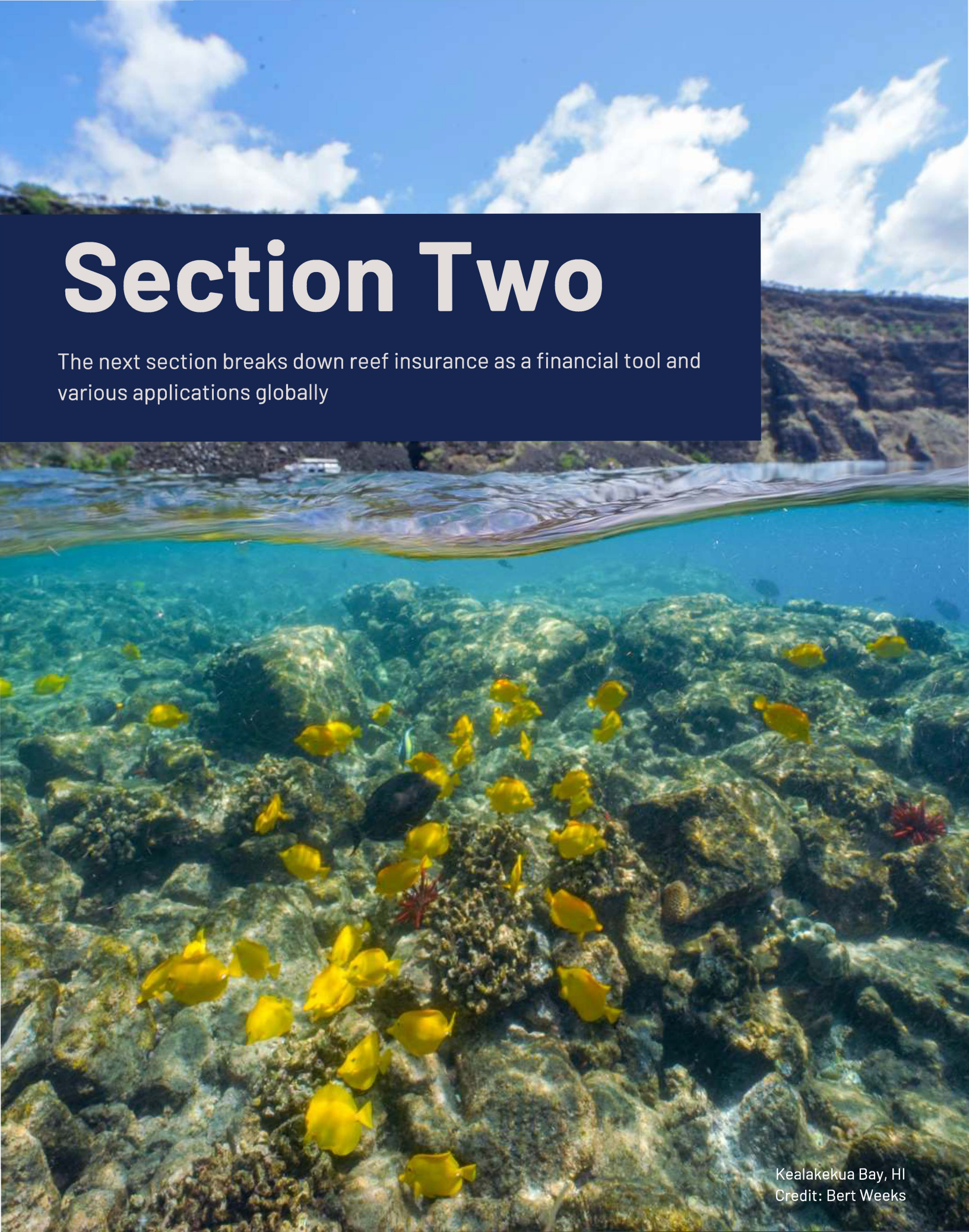
Some of these innovative financing tools are already being pursued in Hawai'i . A few examples of these initiatives include: the Ocean Stewardship Fund, the establishment of a coral reef mitigation bank, the pursuit of diverse granting opportunities from federal agencies, and reef insurance represented in the chart below.

Utilizing these potential financing solutions in concert with each other and traditional financing mechanisms would provide the greatest benefit for coral reef management for the State of Hawai'i to meet future management needs. Reef insurance has gained considerable traction recently with The Nature Conservancy (TNC). TNC implemented a policy in October 2022 to protect coral reefs from hurricanes throughout the Main Hawaiian Islands (MHI). While this is an exciting development, and promising for the management of Hawaiian coral reefs, there is a need to determine how to best utilize this new funding opportunity. To do this, reef insurance will be investigated in depth throughout this report and analyzed specifically for Hawai'i.

Funding initiative	Ocean Stewardship Fund	Coral Reef Mitigation Bank	FEMA hazard mitigation grants	Reef Insurance
Status in Hawaii	Implementation in the near future	Pursuing Implementation	Pursuing Implementation	Implemented
Diverse Fund	Recreational ocean users, collected by vessel based commercial ocean operators	Commercial businesses, Hawai'i department of Transportation, US Army Corps of Engineers	FEMA	Public+private partnerships with insurance agencies
Description	The Ocean Stewardship fund is a special fund that will go into effect in 2023 and charge recreational ocean users $1.00 (collected by recreational ocean user companies, such as dive shops, boating tours, fishing charters, etc.) per participation in specific ocean recreation activities. This initiative could generate $30.3 million over 15 years (Gross & Hicks, 2020).	A coral reef mitigation bank would function in a similar way to wetland and land-based mitigation banks. This finance mechanism is utilized to create a standardized crediting system for planned and unplanned damage events. Organizations that create damage can purchase credits to fund specific restoration projects that are priority to the State.	Diversification of federal funding streams could be a substantial capacity builder in coral reef management, specifically through FEMA's hazard mitigation funding.	Reef insurance is a financing tool that will offset emergency restoration costs after an insurable damage event. This funding stream is of particular interest to the State of Hawai'i as this could provide a 10:1 benefit in benefits vs. investments and is applicable to state government agencies, private businesses, and not-for-profits.

Section Two

The next section breaks down reef insurance as a financial tool and various applications globally



Kealakekua Bay, HI
Credit: Bert Weeks

Reef Insurance

Reef insurance is a form of insurance for nature, an innovative finance mechanism that funds repair of natural assets after a specific damage event occurs (Fajardo et al., 2019). This concept is being investigated for many different damage events like hurricanes, fires, or coral bleaching for many different ecosystems like coral reefs, forests and wetlands that provide specific and insurable ecosystem services. These insurable ecosystem services include storage to shoreline protection, to water quality improvements. TNC recently released the report: How to Insure a Natural Asset. To learn more about insurance for a natural asset, please review this guide.

Parametric Insurance

Current examples of reef insurance policies utilize parametric insurance. Parametric insurance policies are unique in design, as they utilize pre-determined thresholds after specific damage events, within specific spatial constraints. In the event that a specific threshold is met that is associated with a damage event, the insurance company will pay out the named insured (owner of the insurance policy). This payout is automatic based on a predetermined trigger (e.g. windspeed) and does not require an assessment of the damage. It may be tiered, so that the amount of payout received correlates with proximity to the insured area and the severity of the damage and/or the needed resources to repair or restore the ecosystem components (Bergh et al., 2020).

Another form of insurance called indemnity insurance is less appropriate to insure natural assets. Some well-known examples of indemnity insurance include home insurance, car insurance, and health insurance. Indemnity insurance typically requires an appraisal of loss which can take weeks to months, face disputes, and require additional capacity to evaluate damage. This payout delay contrasts with the primary goal of insurance for nature, which is to provide a rapid outflow of funds to mitigate loss related to specific damage events. Therefore, parametric insurance is the preferred insurance scheme and will be used as the model for reef insurance throughout this report (Bergh et al., 2020).

Four elements of parametric insurance

A trigger event: A trigger event is the reason for damage. In the case of coral reefs this could be a hurricane, bleaching event, disease outbreak, or algal bloom.

A parameter: The parameter is the metric that will notify the insurance company a payout needs to occur. This can be thought of as a threshold or tipping point. Further discussion on parameters is discussed below in the case studies.

A specific geographic area: sometimes referred to as a "polygon" to determine the location covered in the insurance policy. This geographic area is also tiered, with a tighter proximity to the geographic area receiving a larger payout.

A predetermined tiered payout structure: based on the intersection of the parameter and the geographic area.

Reef insurance has five primary benefits

1

Provide immediate emergency restoration resources through a rapid payout to reef emergency reef restoration.

2

Build long term coral reef management capacity through collaboration amongst reef management partners like state and federal agencies, community groups, and regional organizations to react to damage events.

3

Proactively implement management plans for specific areas, damage events, and identification/alignment of management priorities.

4

Access innovative funding opportunities underutilized in coral reef management initiatives, such as insurance companies, private beneficiaries, and philanthropic donors

5

Promote continual maintenance of structurally significant coral reefs that undergo periodic damage.

Commerson's Frogfish in coral. Credit: Ryan Okano

Quintana Roo is the flagship case for reef insurance globally. In 2020, one year after establishing the first reef insurance policy in the world, Hurricane Delta intercepted the Quintana Roo insurance policy's geographic region at 100 knots, triggering an $850,000 payout to repair and stabilize nearshore coral reefs.

Case Study

Quintana Roo, Mexico

This insurance policy came about because of coastal infrastructure devastation from hurricanes continually hitting the Yucatán Peninsula. The local government and tourism representatives noticed that stretches of beach along the Peninsula with healthy coral reefs nearby, received less damage, compared to beaches associated with degraded reefs. This realization produced a concerted effort to ensure resiliency along 160km of coral reefs lining the economically significant coastline of Quintana Roo.

To do this, TNC created the Trust for Coastal Zone Management, Social Development, and Security in partnership with state and municipal governments and tourism industry representatives. The first year the trust fund utilized private donations, but in subsequent years the funding for the premiums became self-sustaining through taxes and tourism related fees. This particular insurance policy is triggered when wind speeds exceed 100 knots and focuses on rapid reef restoration actions to mitigate further mortality and damage to the corals after the hurricane. Eleven days post-Hurricane Delta resulted in specific actions:

11 days post Hurricane Delta resulted in specific actions:

Removed debris such as articles pulled from shore , sand, loose stones, or broken corals

Stabilized 2,152 large coral colonies that were displaced and overturned

Reattached 13,570 coral fragments

Engaged 80 community SCUBA divers and snorkelers

In addition to direct benefits correlated with emergency restoration actions, this reef insurance policy also creates an avenue of collaboration among reef management practitioners and community support for people experiencing disruptions in their employment due to the hurricane. The insurance policy brought government, non-profit, and for-profit organizations together to develop action plans, and prioritize restoration sites. This collaboration will likely lead to greater cohesiveness among these separate entities moving forward and establish a community-based approach for coral reef management practitioners in the region. The insurance policy also promotes an avenue for tourism industry practitioners to participate in emergency restoration actions through the established "reef brigades" program. In Quintana Roo, the reef brigades included 80 volunteers from the tourism sector and local communities to respond to the storm damage (World's First Coral Reef Insurance Policy Triggered by Hurricane Delta, 2020)(A post-storm response and reef insurance primer, 2021)(Reguero et al., 2019).

Case Study

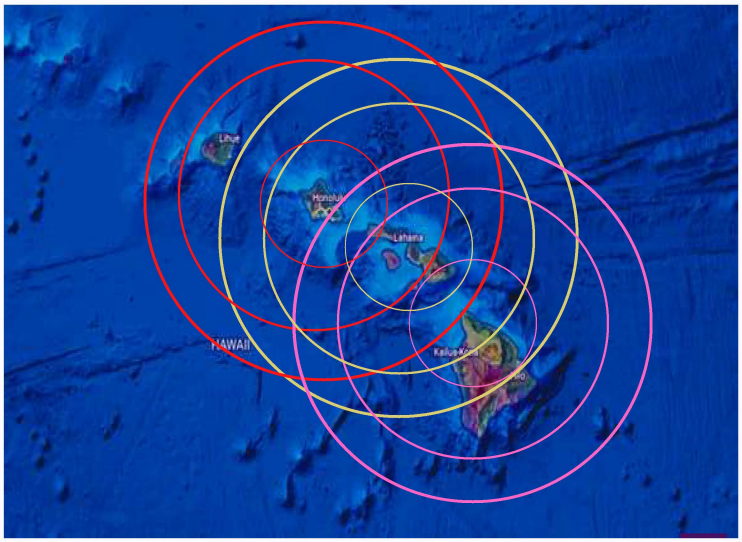
Hawai'i, USA

TNC is in its final stages of negotiating a reef insurance policy for nearshore reefs located throughout the Main Hawaiian Islands (MHI). This policy covers tropical storm and hurricane damage for the upcoming 2023 hurricane season. Premiums for the first two years of the policy are funded by private donors.

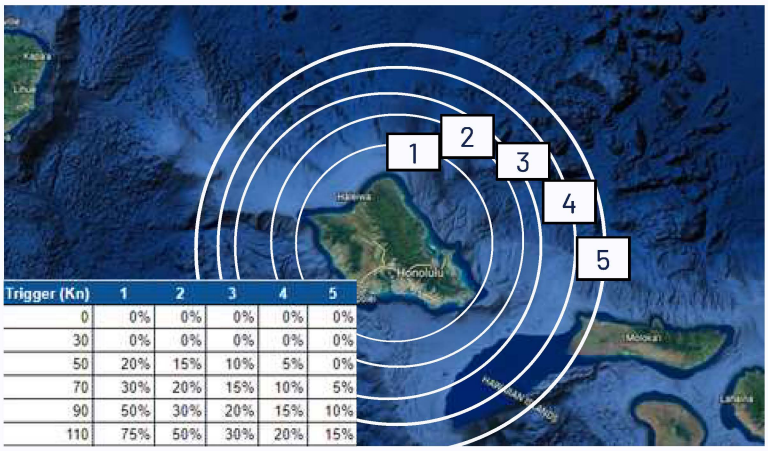
The policy is broken into three target areas, one targeting O'ahu, one targeting Maui, and one targeting Hawai'i Island. TNC anticipates that each individual target area will have a maximum payout of $1,000,000, but if multiple target areas are triggered, then the maximum payout could be $2,000,000. These three target regions have overlapping parameters across the entire MHI, demonstrated in the graphic with multiple target areas.

This specific policy's minimum trigger parameter is a named tropical storm with one-minute sustained wind speeds at 64 knots. The graphic to the right shows the relationship between sustained wind speed and the percentage of the total payout. As concentric circles move further away from the target area, the percent of payout decreases.

It is important to note that TNC worked with insurance agency representatives specifically to include tropical storms in the insurance policy. This was justifiable because tropical storms that reach Hawai'i are often long-lasting and accompanied by heavy seas, so even storms with sub-hurricane intensity have a local impact on nearshore environments.



Graphic representing a hypothetical of three target areas overlapping. The red lines cover O'ahu, the yellow lines cover Maui Nui and the pink lines cover West Hawai'i. Parameters not to scale. (Credit: Google Earth, retrieved 2022)



Trigger (Kn)	1	2	3	4	5
0	0%	0%	0%	0%	0%
30	0%	0%	0%	0%	0%
50	20%	15%	10%	5%	0%
70	30%	20%	15%	10%	5%
90	50%	30%	20%	15%	10%
110	75%	50%	30%	20%	15%

Graphic representing a hypothetical O'ahu target area and spatial payout thresholds. Threshold payouts in percentages in chart. Parameters not to scale. (Credit: Google Earth, retrieved 2022)

Other examples of investigations into reef insurance

Meso-American Reef	Asia -Pacific	Guam
Following the success in Quintana Roo, the Mesoamerican Reef Fund (MAR) announced their own parametric reef insurance program in four key areas of reef in Mexico, Belize, Guatemala and Honduras. This insurance policy will focus on hurricane related damage and focus on capacity building for rapid response to damage events (Victurine et al., 2022).	The Asian Development Bank (ADB) and other organizations are exploring the application of a similar insurance model in Indonesia, Philippines, Solomon Islands, and Fiji. This exploration is in support of the Asia-Pacific Climate Finance Fund, which is part of a larger regional project focused on nature-based solutions (Victurine et al., 2022).	In Guam, the Tumon Bay Insurance Task Force is actively investigating the use of parametric insurance to fund post-storm repairs of the Tumon Bay reef system, including the potential of establishing a Coral Reef Trust, similar to Quintana Roo Mexico's approach of public-private insurance policy management (Task force discusses insurance for Tumon Bay reef 2021).

Tumon Bay, Guam.
Credit: NOAA

Section Three

The next section breaks down insurable and non-insurable actions for reef insurance for the State of Hawai'i .

Kealakekua Bay, HI
Credit: Bert Weeks

Insurable Restoration Actions

Legally, insurance agencies cannot dictate the use of the funds after there is a payout. Although many insurance agencies would prefer to see a management plan and demonstrated ability of the policy owner to complete the task. This informal review from the insurance agency will likely occur when the bid for the policy is under review.

Reef insurance can be an applicable tool for both emergency and long-term restoration responses but has a particular benefit in quick deployment of funds, which makes reef insurance restoration action plans more likely geared towards emergency restoration. This is in line with management philosophies as well. Immediate restoration should be prioritized to maintain ecosystem services and overall reef health instead of letting the ecosystem degrade and then intervening with long-term restoration plans. This philosophy is especially applicable to coral restoration projects due to Hawaiian coral's slow growth rates. The benefits of long-term restoration projects for shoreline protection won't be felt for 50-100 years (post-coral outplant). This is assuming 100% survival rate and a growth rate of 1m2 per 100 years (Stovall et al., 2022). Therefore, emergency restoration to maintain ecosystem services and overall coral reef health should be prioritized with funds from reef insurance if the primary goal is maintaining shoreline protective services of nearshore reefs.

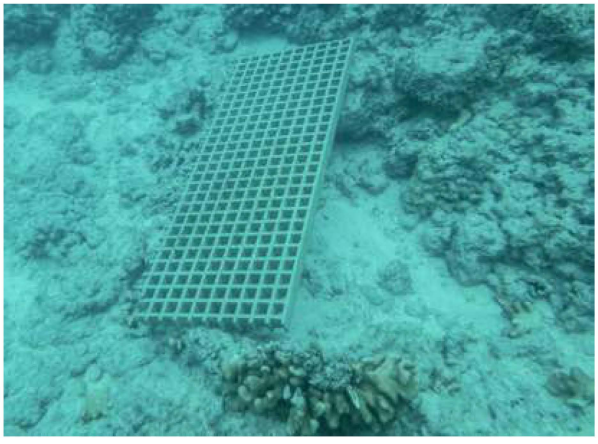
Corals outplanted from the State of Hawai'i land-based nursery onto a reef. (Credit: Hawai'i DLNR)

Emergency vs. Long Term Restoration Responses

Emergency and long-term restoration responses both hold merit and should be used in tandem for a holistic restoration approach after a damage event. However, coral reef practitioners often must prioritize specific actions based on restrictive funds and capacity.

The primary goal of Emergency restoration response is to minimize further damage. This usually entails stabilizing loose large boulder corals, removing debris, and removing sedimentation, to increase survivorship of non-damaged corals on the reef. Stabilization of large boulder corals is particularly important because they will get caught in the surf and cause further damage to the reef. After the environment is stabilized from immediate threats, the secondary goal is re-attachment of loose corals to nearby hard substrate and transportation of loose corals to nearby nurseries. Emergency management actions have demonstrated success in Hawai'i.

A recent example is the Honolulu Harbor Channel damage event. To mitigate coral damage from channel maintenance, DAR oversaw a cooperative group removed/transplanted corals from the damage site. 12-month monitoring results of this effort show 80% survivorship of corals that were returned to an upright position and reattached to the reef.



Assessing the damage of the Honolulu Harbors Channel Damage (credit: DLNR)

The primary goal of long term reef restoration is an overall restoration of ecosystem function of the coral reef. This takes a more holistic approach and targets in-water and land-based threats. Some long-term reef restoration actions include long-term monitoring, developing in-situ and ex-situ nursery infrastructure, education and outreach to community members, erosion control to reduce sedimentation, addressing concerns related to cesspools and fisheries management, and construction of artificial reef/hybrid reef structures to promote coral growth and increase fisheries habitat.

Insurable Damage Events

Insurance companies determine what damage events are insurable through risk modeling. These semi-quantitative models are created by analyzing verified long-term data to determine the probability of an event occurring. According to these risk models, events like fires, floods, and hurricanes are feasible insurable events.

Yellow Tang on a reef in Hawai'i (Credit: Paula Ayotte, NOAA)

Likely Uninsurable Threats

Likely uninsurable threats include coral bleaching, algae blooms, coral disease, ship groundings, and aquatic invasive species (Bergh et al., 2020). Coral disease, aquatic invasive species, coral beaching, algae blooms have less robust long-term recurrence data, which impedes the risk modeling process. [BJW1] These events could be insured in theory, but more research is needed[BJW2] (Fajardo et al., 2019). Efforts are underway to develop risk assessments for these threats. DAR created a risk model for invasive species, called The Aquatic Species Invasiveness Screening Kit (AS-ISK) tool (J. Boord, personal communications 2022). Additionally, scientists at the Hawai'i Institute of Marine Biology created a coral disease tool to predict coral disease outbreaks in the short term. These risk modeling tools continue to evolve as data becomes available.

Ship groundings on the other hand, already have an insurance mechanism for funding emergency restoration projects, via litigation. This program is well documented and accounts for millions of dollars for emergency restoration over the last 10 years (Bergh et al., 2020).

Section Three

The chart below pairs insurability with a damage event, the recommended parameter for the damage event, and the recommended short- and long-term restoration actions based on the damage event. These categories are further broken down in sections after the chart.

Threat	Threat level to Hawaiian reefs	Insurable with parametric reef insurance ?	Parameter metric	Recommended Emergency Restoration Activity
Hurricanes	Medium	Yes	Wind Speed	• Debris removal • Coral reattachment • Free-moving reef-building coral stabilization • Transportation of coral fragments to a nursery setting for future out planting to the damaged site
Coral Bleaching	High	Maybe. Would require more risk analyses.	Length of time (in weeks) the ocean has exceeded a specific temperature	• Monitor bleaching corals • Long-term: Fund coral restoration activities at sites that experienced severe mortality from bleaching • Marine cloud brightening to cool and shade corals • Investigating genetic predispositions for heat tolerance in corals.
Flooding	High	Maybe. Would require more risk analyses.	National Water Center from the National Weather Service's strategically placed weather gauges	• Remove sediment via small vacuum • Assess severity of sediment plumes and monitor for mortality • Reduce sources of erosion through land-based restoration activities

Hurricanes

Hurricane damage is the primary damage event featured in reef insurance policies to date. In Hawai'i , hurricane damage to property and state infrastructure is less common than other regions around the world , and hurricane data on the impacts of hurricanes on reefs is sparser. However, there are examples of large hurricanes impacting coastal communities. For example, the 1982 Hurricane Iwa and 1992 Hurricane Iniki both impacted the MHI and associated nearshore waters. Additionally, hurricanes are predicted to increase in duration and intensity under warming climate conditions (Webster et al., 2005).

The measured parameter is wind speed, which is measured by a third party, like the Tropical Prediction Center of the National Weather Service of the United States. This parameter is measured in knots and would correlate to knots above a certain threshold, for a specific amount of time.

Flooding/Sedimentation

Sedimentation can be damaging to reefs, causing localized sediment plumes in the ocean that suffocate corals/ This is common during storm events (Wedding et al 2018) and in areas experiencing chronic erosion. There is interest from insurance companies regarding the potential insurability of this damage event, even though a correlation between precipitation volume, sediment load on reef, and coral damage is yet to be established (Bergh et al., 2020). A potential challenge could be establishing accurate risk models, as the frequency of extreme precipitation events has changed between 1960 and 2009 in Hawai'i, but the trends vary depending on the location within the State. For example, storm events and flooding have become more frequent on Hawai'i Island, but less common on O'ahu and Maui (NOAA, 2022).

This threat can be more effectively remediated through land-based management practices. If there are considerable land-based erosion controls already in place, this would lessen the amount of sedimentation occurring on the reef compared to an area with high levels of chronic erosion.

Bleaching

The threat of coral bleaching throughout Hawai'i has grown in severity since the 1990's and continues to pose concern for coral reef management initiatives. As an example, in West Hawai'i the 2015 bleaching event resulted in 50% mortality of corals while the 2019 bleaching event resulted in 90% mortality in some colonies. As global temperature continues to rise due to climate change, bleaching events are expected to continue and worsen globally (Dixon et al., 2022).

TNC created a metric for parametric insurance using "Degree Heating Weeks (DHWs)". Degree heating weeks are 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. Significant coral bleaching is likely when DHWs reach 4°C-weeks (7.2°F-weeks), when DHWs are 8°C-weeks (14.4°F-weeks) or higher, widespread bleaching and mortality is likely to occur (Bergh et al., 2020).

Section Four

The next section breaks down the legal, operational, and social feasibility of reef insurance for the State of Hawai'i .

Kealakekua Bay, HI
Credit: Bert Weeks

Legal Feasibility

An analysis of the legal factors related to reef insurance included conversations with leadership in the Hawai'i DLNR, the Hawai'i Insurance Division at the Department of Commerce & Consumer Affairs, Insurance Policy expertise at Willis Towers Watson (WTW), and consultations with non-profits, such as Conservation International (CI) and TNC. Throughout these conversations, several findings surfaced related to procurement of funds for reef insurance premiums, allocation of payout to local reef practitioners, permitting challenges, and costs and benefits of named insured (entity who receives the benefit of the insurance policy and is listed on the policy) eligibility.

Reef insurance ownership

Reef insurance could be purchased by any public or private entity with a proven benefit from the existence of coral reefs (financially or otherwise in the form of ecosystem services) (Bergh et al., 2020). This means, community organizations and cultural practitioners, tourism industry representatives like hotels and nearshore recreation operations, individuals, not-for-profit organizations, in addition to government agencies can purchase reef insurance. All of these groups have proven direct benefit through coral reef ecosystem services, like coastal protection, fisheries habitat, cultural significance, and economic development.

Paying for a policy

Currently, no legal frameworks exist to direct who can pay for an insurance policy. Due to the structure of insurance policies, typically the owner/named insured party of the insurance policy will make payments. This could be through a trust, like Quintana Roo's model previously mentioned, or this could be through a single monetary source, like TNC's Hawai'i policy previously mentioned.

Use of payout

Currently, there are no legal frameworks guiding the use of a payout for a reef insurance policy. Typically, before awarding an insurance policy of this monetary scale, insurance agencies would like to see demonstrated ability to appropriately respond to the insured damage event. These factors can be demonstrated through a management plan and reviewed by the insurance agency before they bid on the policy. These management plans should ensure that ample consideration is given to ecologic, economic, cultural, and social factors in design of a response plan. These plans can also ensure funds are used for restoration, and not recycled into other program funds. There is no guarantee that the named insured will follow through with said management plan, and there is no direct oversight or legal penalty associated with misuse of funds post pay-out.

Payout Recipient

In the policy, the entity receiving the funds will be outlined, but there are no guidelines to determine who is eligible and ineligible to receive the payment. For parametric insurance policies, the payout does not have to go back to the named insured, the loss payee (the party entitled to payment) can be a number of individuals. Who is eligible as a loss payee is likely regulated to some degree by the insurance company issuing the policy. They will investigate what type of entity receives the funds and confirm the applicant's credibility. The loss payee must also have the capacity to distribute funds (if funds must be distributed outside of the loss payee's capacity).

Parties Eligible for purchasing Reef Insurance

Due to these specific considerations mentioned above, three avenues of reef insurance policy ownership are feasible with varying degrees of limitations. These limitations are broken into sections below.

Alternative 1: State Owned Reef Insurance

The primary benefit in listing the State as the named insured has potential to align emergency restoration efforts with current long-term management plans, which would create greater capacity for holistic coral reef management throughout the State. This would also allow the State to establish stronger interagency partnerships, as DAR, Office of Conservation and Coastal Lands (OCCL), and the Coastal Zone Management Program (CZM) are all potential examples of coordinating bodies within the State that have expertise related to shoreline protection, reef health, and nearshore waters management. Counties are another potential reef insurance owner, as they are authorized to regulate coastal development, shoreline setbacks, minimize hazard risks, and other shoreline protection actions (HRS § 205A). Better understanding the capacity of state agencies to coordinate and manage and insurance policy is needed to fully comprehend this alternative's feasibility.

Potential challenges associated with state owned reef insurance is the need to secure funds for the premium, internal capacity to manage administrative aspects of a policy, and challenges related to rapid distribution of funds. The funding for paying premiums would likely come out of general funds for the State, potentially impeding other priority projects from receiving proper funding. Within DAR specifically, potential sources of funding could come from fines for violations of coral protection laws, from federal grants, from trust funds, or from the newly established ocean stewardship fund, which will collect revenue from ocean recreation participants. The State would need to think critically about the use of funds going towards reef insurance premiums, and the realistic buy-in from constituents to utilize funds in this way.

In addition, it would be challenging to rapidly distribute funds to outside entities. As government agencies, certain checkpoints are in place to ensure proper use of public funds to outside vendors/ collaborators. These checkpoints are often time intensive and limit the rapid payout of monies. This is a fundamental challenge of a state-owned reef insurance policy, as it would disrupt the rapid outflow of funds necessary to conduct emergency restoration work. If this alternative is of interest to the State, it would need to be remediated through policy changes. There are exceptions, for example emergency disaster funds after natural disasters can bypass these checkpoints. Another potential work around could be to keep the funds internal. The State could place insurance funds into a trust fund account and use the funds to pay DLNR staff to conduct the emergency restoration work.

Alternative 2: State Owned Reef Insurance

Privately owned reef insurance is the current model of reef insurance in the state. A private entity owns the policy, manages funding the premiums, would distribute the payout to reef practitioners if applicable, and manages all permits for restoration actions. Privately owned reef insurance is accessible for businesses, non-profits, individuals, community organizations, and cultural practitioners. In many ways, private reef insurance has greater capacity in fund management compared to the State, due to issues with procurement of funds and rapid distribution of funds post-payout. Private entities have a much greater capacity to accept money from private donations and beneficiaries, which builds operational feasibility in a way that government entities cannot. This is in line with recommendations from Wildlife Conservation Society and the Conservation Finance Alliance in their analysis of reef insurance. They use the example of hotels to explain how coastal businesses could receive a large benefit from purchasing a reef insurance policy, In their example they state that hotels would benefit from a reef insurance policy that directly protects the hotel against inundation and severe storm damage, which will lower their risk of storm surge damage and therefore lower their premiums on other insurance policies, like flood insurance (Iyer et al., 2018). The primary challenge with private reef insurance is capacity for reef restoration, this includes navigating cumbersome permitting at state and federal levels and large-scale capacity for organizing reef restoration practitioners.

Alternative 3: State+Private Trust

Generally, only one entity can buy an insurance policy, listing multiple named insured parties can delay the rapid outflow of funds post damage event, especially if a government entity is listed as a named insured because the payout would be subject to rapid payout challenges outlined in the alternative 1 section. This is because collaborative funding between a state and private entities would need to enter government managed funds.

If there must be more than one named insured entity, it may be necessary to establish an institutional arrangement to represent them, collect their contributions, purchase the insurance, and manage the funds. For example, the Quintana Roo Government established the Trust for Coastal Zone Management, Social Development, and Security in 2018 to secure long-term funding from private and public sectors (Bergh et al., 2020). Although a trust between state+private entities could prove challenging, establishing a memorandum of understanding (MOU) could be a feasible alternative in Hawai'i. The State of Hawai'i DLNR has already set a precedent for public+private MOU's, an example is the 30x30 Holomua initiative, which is a DAR program, implemented throughout the State, but supported by funds from the Hawai'i Community Foundation (Memorandum of understanding for implementation of Hawai'i's Marine 30 by 30 initiative, 2020).

Operational Feasibility

An analysis of operational factors related to reef insurance included conversations with leadership in the Hawai'i DLNR, The State of Hawai'i Office of Planning and Sustainable Development, The State of Hawai'i DLNR OCCL, and consultations with non-profits, such as CI and TNC. Through these conversations operational feasibility concerns are primarily related to capacity, specifically capacity of restoration response and capacity of fund and policy management.

Response Capacity

It is important to determine who would be able to respond to damage events. If the named insured party requires allocation of funds to outside parties, who will receive these funds? This could go to internal operations, compensation for volunteers, or a third-party contractor. If response actions will be performed by the loss payee, named insured, then they should consider all supplies that need to be purchased (example of rapid response supplies is listed in the appendix of TNC's rapid response protocol: Early Warning and Rapid Response Protocol), prepare individuals that will respond to the damage events, and acquire necessary permits. Many of these concerns should be outlined in a management plan that is likely needed when a named insured entity is establishing a policy with an insurance broker.

Fund and policy management

The named insured will need to determine how they will manage premium payments, and what is the long-term sustainability of premium payments. A multi-year reef insurance would increase the odds of a payout occurring. Also, how will the named insured manage the payout if it occurs. Will these funds need to enter long-term funding, and then be allocated for rapid distribution, will they immediately distribute to other parties? These questions related to funding capacity require careful thought and pre-planning and should be included in a management plan associated with the policy to ensure the highest level of success.

Snorkeler in Kona, Hawai'i (Credit: Bert Weeks)

Permitting

Permitting processes exist to ensure that governing bodies are appropriately managing changes to natural resources. In the case of coral restoration there are multiple governing bodies that require permits, based on the scope and scale of the restoration project. Permitting allows the State to oversee site selection and restoration actions through the permitting approval process.

State Permits

A note: state agencies are self-permitting, and do not undergo the rigorous permitting process as outside practitioners, but still follow similar protocols and documentation requirements.

- DLNR: DLNR permits are required for any interaction with coral, typically in the form of a special activity permit. These special activity permits can take at a minimum 6 months for approval because they must be reviewed by the Board of Land and Natural Resources.

- OCCL : Typically, OCCL based permits cover any activity that consists of placing objects or instruments, like those needed for nurseries, on submerged land (e.g., sand, bare substrate, live rock, reef flat, etc.) for greater than 30 days. Conservation District Use Permits are also under OCCL purview. These permits take an average of 6 months - 1 year to approve, depending on specifics.

Diver collects data (credit: NOAA)

Federal Permits

Projects utilizing federal permits require consultations with the National Oceanic and Atmospheric Administration (NOAA), the United States Fish and Wildlife Service (USFWS), the United States Army Corps of Engineers (USACE), and the Environmental Protection Agency (EPA) as appropriate actions that affect coastal uses and resources.

- NOAA and USFWS: NOAA and USFWS permits are required for restoration actions related to essential fish habitats. Coral reefs provide essential fish habitat and therefore the manipulation of these ecosystems requires federal approval.

- USACE permits are required for placement of larger in-water structures like in-situ nursery infrastructure. USACE permits are also necessary for any actions that are potentially a hazard to navigation. Specifically, through the Rivers and Harbors Act, Section 10.

- EPA: EPA permits are required if activity infringes on the Clean Water Act 404/401 by altering navigable waters. Currently, this capacity is managed in the Hawai'i State Department of Health through water quality certifications.

Social Feasibility

An analysis on social feasibility of reef insurance in the State included conversations with leadership in the Hawai'i DLNR, The State of Hawai'i Office of Planning and Sustainable Development, The State of Hawai'i DLNR OCCL, and consultations with non-profits, such as CI and TNC.

Social feasibility requires extensive outreach and long-term stakeholder engagement. This scoping should include community organizations, cultural practitioners, residents of Hawai'i , beneficiaries within the tourism industry, and coral reef management practitioners in the private and public sectors. Particular emphasis should focus on just and equitable engagement, ensuring community buy-in throughout diverse audiences. This level and detail of scoping was not possible in the creation of this feasibility report, largely because these conversations must be place-based to be effective and comprehensive. Without the identification of restoration sites, it is unlikely that a holistic overview of reef insurance social feasibility will be realized.

The Nature Conservancy (TNC) conducted social feasibility scoping as a product of their 2020 report Insurance for Natural Infrastructure: Assessing the feasibility of insuring coral reefs in Florida and Hawai'i. The result of this scoping shows that "local insurance companies, government representatives, reef managers, community foundations, hotels and/or tourism associations expressed interest in insurance for natural infrastructure." This was assessed through a forum attended by 50 individuals and targeted outreach to 30 public and private key stakeholders (Bergh et al., 2020).

Moving forward, the DLNR recommends scoping reef insurance social feasibility with a larger number of stakeholders, particularly community organizations, Kūpuna and cultural practitioners, and residents of Hawai'i to determine community buy-in and formulate future reef insurance policies including specific considerations brought forth by these groups.

Another important subset of stakeholders should capture the feasibility of private beneficiaries, tourism industry representatives, and community trusts and foundations to determine interest in third party funding for insurance policies. The final subset of stakeholders to engage in reef insurance social feasibility are coral reef practitioners. This includes entities involved in coral reef management such as local and federal government agencies, public organizations such as non-profits, and private organizations such as contractors.

Coral on reef in Hawai'i, (Credit DLNR).

Section Five

The next section breaks down economic analyses and site selection recommendations for reef insurance feasibility

Kealakekua Bay, HI
Credit: Bert Weeks

Under specific circumstances outlined in the legal, operational, and social feasibility sections above reef insurance is a viable option for coral reef restoration financing in the State. Although this is a feasible financing mechanism, its real-world application in the State can be better understood through economic analysis and prioritization of restoration sites. These two processes will likely go hand in hand and factor into the considerations of each other. This next section will outline these two considerations in more detail.

Economic analysis considerations

According to the TNC report Guide on how to insure a natural asset, three economic analyses are needed to determine the economic feasibility of coral reef insurance.

1. The cost of restoration actions: An estimation of the cost of repairing the damages to the asset caused by a storm to reduce or prevent the loss of environmental services.
2. The cost of losses with no intervention: An estimation of the economic losses associated with the damages to the asset, such as diminished revenues or the increase in risk from a degraded reef after a storm.
3. The benefits of a payout: An economic estimation of the benefits from ecosystem services, such as the cultural and recreational value of coral reefs for residents, business revenues from fisheries and tourism, or the value of coastal protection provided by reefs (Fajardo et al., 2019)

This next section will outline potential ways to approximate these costs at the global and regional scale. These economic analyses are crucial to determining the feasibility of a reef insurance policy but are difficult to fully comprehend if there is not a restoration site selected, a specific restoration goal in mind, and an analysis of response capacity. These considerations will factor heavily into the feasibility and could not be accurately analyzed in this report due to the wide range of applications of reef insurance and data present in the State.

Restoration costs

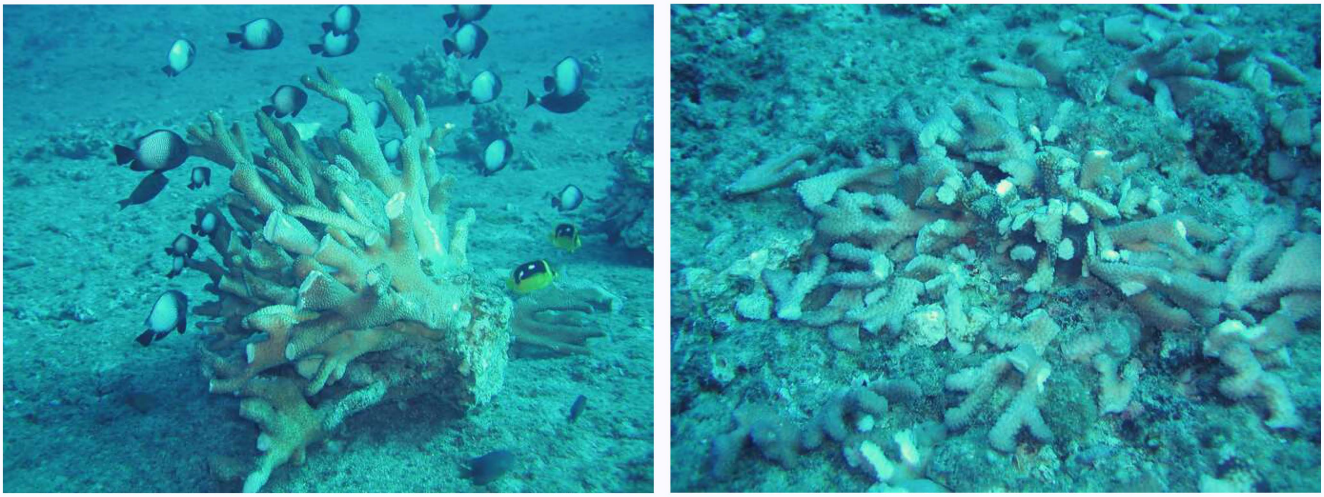
The first factor in determining economic feasibility of reef insurance is quantifying restoration costs. This step is likely the most important because insurance payouts should be determined by the cost of restoring the reef (or other intervention action) - not by valuation of coastline benefit. This metric is highly dependent on the predetermined restoration activity and could be tiered and based on the extent of damage.

Diver assessing coral in Hawai'i. (Credit DLNR)

Section Five

This chart below outlines emergency restoration responses based on impact to the coral reef. Costs will be different for different levels of damage. Chart adapted from: Guide on how to Insure a natural reef

Threat level	Impact on coral reef	Recommended restoration action
Minor	Minor destruction of colonies. Reef rugosity and complexity not impacted.	Assess damages, re-attach broken coral pieces, remove debris.
Moderate	Destruction of colonies. Reef rugosity and complexity not impacted, but reef mildly impacted.	Assess damages, re-attach broken coral pieces, remove debris. Typically will need to occur in a larger area.
Severe	Destruction of colonies in many areas. Reef complexity and rugosity impacted.	Assess damages, re-attach broken coral pieces, remove debris. Replant corals from nursery setting if applicable. Prioritization of actions will be necessary.
Catastrophic	Extensive and widespread destruction of coral colonies. High impact on reef and complexity and rugosity.	Assess damages, re-attach broken coral pieces, remove debris. Replant corals from nursery setting if applicable. Prioritization of actions will be necessary and investigations into structural restoration.



Broken and dislodged coral after a damage event. (Credit: Ryan Okano)

Restoration costs globally

Looking at examples from around the globe, coral reef management practitioners have determined a wide range of costs associated with restoration projects. Recent literature suggests a cost of about $10,000 - about $1,500,000 per hectare. The $10,000 cost includes harvesting coral colonies from a donor site and then transplanting them to a restoration site, while the $1,500,000 cost includes transplantation of nursery grown corals (Bayraktarov et al., 2019). These costs are more so associated with long-term restoration costs and therefore not as applicable for emergency restoration cost estimates. A more applicable example is recent restoration work conducted after Hurricanes in Puerto Rico. Restoration work after Hurricane Fiona has a daily operation cost of $7,500 a day and reattaches about 200 corals a day. This cost includes vessel fees, hourly rates for captains, deckhands, divers, scientists, program managers, lodging, per diem, etc. After hurricane Maria, FEMA conducted an emergency restoration which cost around $1 million and reattached about 17,000 corals over a 8,500m2 to 17,000m2 region (for a cost of: $59/m2-$118/m2) (S. Ruseborn, personal communication, 2022). These global comparisons are not standardized within the coral reef restoration industry and are highly dependent on many external factors. Therefore, this information should be used with caution as scaling-up repair actions and associated costs from small sites to regional or reef scale efforts.

Hawai'i cost of restoration

In Hawai'i, reef restoration costs are very project specific and not scalable in the same way that other regions globally show cost of restoration. One reason for this scalability challenge is the growth rate of Hawaiian corals compared to branching coral species in other locations. Branching coral species in the Caribbean or Great Barrier reef grow an average of 12-18 cm a year, while Hawaiian coral species average 2 cm growth rates annually (Stovall et al., 2022). Most notably, this slow growth rate accounts for longer time in nurseries before outplanting and use of often costly innovative techniques such as micro fragmentation. This challenge is more relevant to long-term restoration actions, and therefore not as informative to reef insurance and emergency restoration costs.

Recent analysis from TNC, UC Santa Cruz, Roadbridge, and Earth Economics found that for a hypothetical long-term restoration project in Maui, coral restoration for shoreline protection would cost a fixed one-time cost of $200/m2 ($2 million/ha) for biological repair efforts conducted by academic or agency organizations. This cost includes collection, rearing, and outplanting a coral fragment, including staff time, nursery cleaning and repairs, and materials. These estimates do not reflect actual restoration operational costs in Maui (Stovall et al., 2022). Again, these costs represent long-term restoration actions like nursery operations, which are not necessarily applicable to coral reef emergency restoration actions that would likely be the focus of a reef insurance response.

A more applicable example is the Honolulu Harbor Entrance Channel Anchor Damage case. Healy-tibbitts, the party assuming liability in the case, spent ~2.5 million on emergency response actions, paid to a third party contractor. These actions included stabilizing and reattaching 5.096 coral colonies and additional aggregations of live rock over an area of about 2ha ($1.25 million/ha). This is the most applicable cost of restoration for comparison in emergency reef restoration costs in the State to date.

The value of valuation

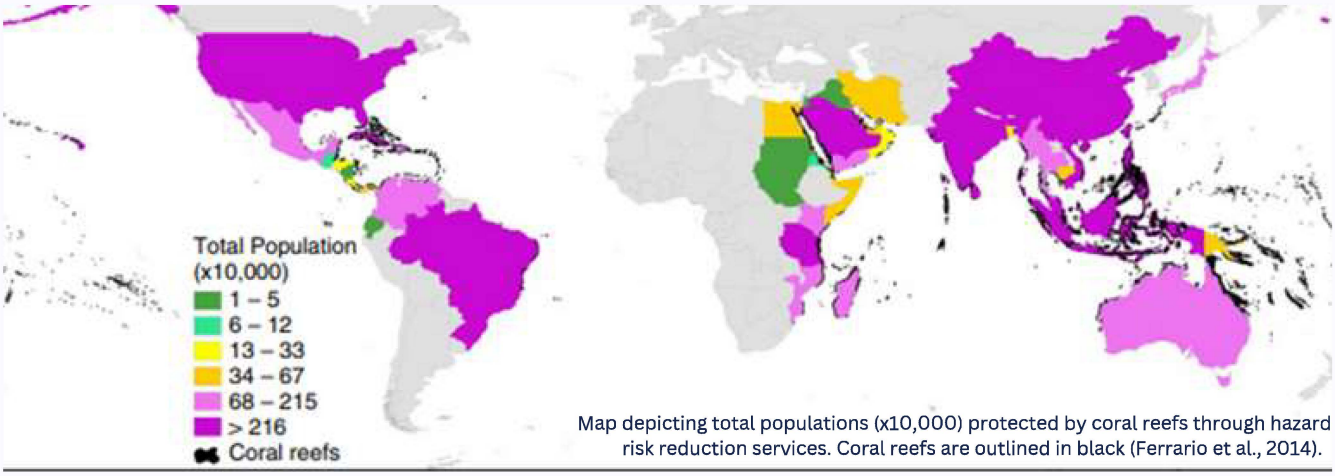
Comparing the cost of restoration actions and the economic benefits from payout actions are the second and third pieces of the puzzle. This will allow restoration managers to review the costs associated with ecosystem loss, and the economic benefit of repair. These economic benefits can go beyond shoreline protection and include cultural and recreation value of coral reefs, business revenue from fisheries and tourism, and other indirect economic benefits of reefs.

Coral reef ecosystem service valuation is well documented, and there are many case studies valuing the coastal benefits of healthy reefs globally, but place-based specifics in Hawai'i should be implemented into this line of thought. In addition, indirect benefits captured through community organizations, residents and practitioners of culture and tradition should be allowed to contribute to this justification of documented valuation to incorporate non-cost based values.

Valuation costs globally

Valuation of coral reef's hazard mitigation services is a growing field globally. These studies are often site specific and are difficult to compare from one region to another, because reef composition, reef health, and shoreline stability can vary greatly between regions. Overall, some broad studies have attempted to categorize the global risk reduction services. A study by Ferrario at al. showed the total number of people that may receive risk reduction benefits by country. This study targeted wave height and wave energy reduction for individuals living within 10m of the ocean. This research showed that 3 million people in the United States receive hazard risk reduction services from coral reefs annually (Ferrario et al., 2014).

In addition, a study conducted by the USGS analyzing coral reef hazard reduction services in Florida and Puerto Rico show the annual value of flood risk reduction is more than 3,100 people and $272.9 million (2010 U.S. dollars) in economic activity (Storlazzi et al., 2019).



Map depicting total populations (x10,000) protected by coral reefs through hazard risk reduction services. Coral reefs are outlined in black (Ferrario et al., 2014).

Valuation of shoreline protection services in Hawai'i

Considerable effort has gone into understanding similar valuations for Hawai'i . A comprehensive example of this valuation effort is listed in this report for Maui: unlocking FEMA's Hazard Mitigation Funding: Appendix. In addition, work by Storlazzi et al. evaluates coral reef ecosystems and breaks down the total value of all buildings protected by coral reefs from flooding based on 100-year storm return intervals (Storlazzi et al., 2019).

- Island of Hawai'i : $52,324,393
- Island of Maui: $225,630,115
- Island ofLāna'i: $105,981
- Island of Moloka'i : $128,534
- Island of O'ahu: $340,006,994
- Island of Kauai: $1,867,536

This type of valuation information is necessary to appropriately determine site specific details and give us clues to measure the economic effectiveness of a reef insurance policy.

Other real-world projects performed at small scales can give us a better understanding of the value of coral reefs in Hawai'i. One set of data accessible for cost estimation are payouts from ship grounding litigations. Settlement values for ship groundings in Hawai'i range from $7.00 - $3,744.00 /m2. Looking at reefs of medium ecosystem value, they typically receive between $1,290m2 and $2,079m2, respectively. Although, this is not a perfect way to estimate the potential costs of damage and therefore value of the coral reef, it could be used to get a better understanding of current State valuation metrics.

Economic analyses recommended course of action

After determining which metrics to use in 1) determining the cost of restoration actions against 2) the cost of losses with no intervention, against 3) the benefits of a payout, the insurance policy owner can compare these to the annual premiums and the anticipated payout. Then, the policy owner can utilize suggestions from The Nature Conservancy to determine economic appropriateness of a reef insurance policy (Fajardo et al., 2019).

1. If the restoration actions can be paid outright, then entering into an insurance policy is not recommended. The named insured should either lack the financial capacity to pay for the restoration or wish to offset the risk to a third party.
2. If the cost of repairing the asset is higher than the avoided losses, then an insurance policy is not recommended.
3. Does the named insured have the financial capacity to pay the premiums?

A rough estimation of the cost of the premium varies from 8% to 16% of the needed payout. In other words, if a payout of $1 million is needed after an event, the annual cost of the insurance premiums would range from $80,000 to $160,000, roughly. Additionally, the named insured party has the responsibility to determine the final amount needed for their desired location and restoration actions.

Site selection considerations

Current models of reef insurance in the State show that the entirety of the main Hawaiian islands can be covered by a single insurance policy. This is not the only option in how an insurance policy must be structured, the named insured and the insurance agency can delineate a smaller area and choose the location of where the payout will be greatest. Although a single policy can cover the entire MHI, response to damage events will likely have to prioritize sections of reef for emergency restoration due to limitations in financial and operational capacity, regardless of the payout amount. For this reason, it is important to examine the most up to date information on site selection metrics, recommendations, and State identified focal areas.

Prior site selection metrics

In Hawai'i , historical site selection for reef restoration occurred in response to specific damages, like ship groundings, harbor dredging's, and other acute threats. Restoration events expanded to sites with broader threats, such as invasive algae, extreme erosion, and coral bleaching events. Now, the State is working in tandem with federal and non-profit partners to develop reef restoration action plans with three focuses: coral bleaching, fisheries habitat, and shoreline protection. This plan is expansive in nature and will proactively identify sites to mitigate damage and promote coral reef resilience in the MHI. In addition, non-profit organizations are working with communities to address local coral reef restoration needs in the water and on land. The State of Hawai'i should anticipate reef restoration endeavors to continue to strengthen in scope and scale in the future.

The process of site selection is challenging without prioritization of some factors over another, because multiple factors are likely to cancel each other out. For example, in some areas, if a reef is evaluated to have high ecological resilience, it is generally further from dense human populations and coastal development. There are of course reefs where both factors are applicable, but in general prioritization of desired factors will need to occur to achieve a desired outcome.

Fish on reef. (credit: Bert Weeks)

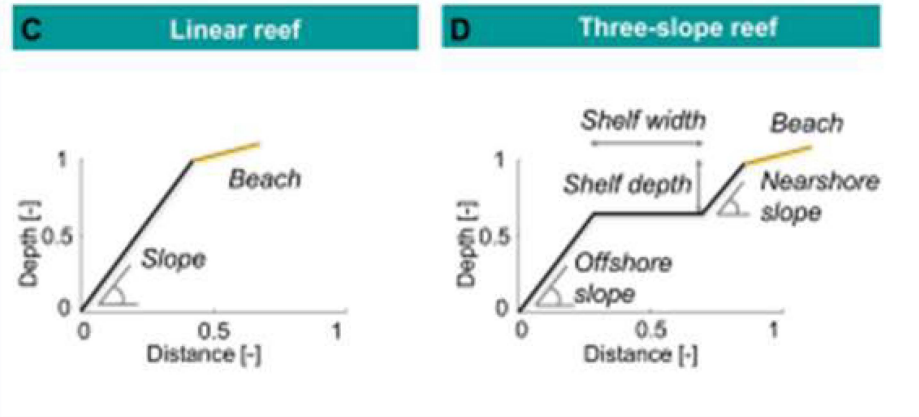
Site selection important considerations

1. An important consideration would be to pair sites designated with long-term reef restoration and resilience plans with reef insurance, so the work done in these long-term restoration projects also receives benefits of short-term emergency restoration actions.
2. Current governance frameworks are not in place to regulate site selection for restoration, this means that the entity that owns the reef insurance policy can choose the site for emergency restoration based on their own focuses and specific criteria. If left unchecked, this could exacerbate inequity in certain areas, with well-funded reefs targeting wealthy tourist inundated coastlines receiving repeated restoration and monetary benefits, and side-stepping coastlines in less affluent areas.
3. A key facet of site selection for Hawai'i restoration activities is community engagement , as mentioned in previous sections. This includes incorporation of cultural and community knowledge, and socio-cultural principles. Restoration projects and management efforts incorporating multiple ways of knowing are favored in Hawaiian and should be standard practice.

Priority restoration targets for shoreline protection

To better understand how exactly coral reefs provide shoreline protection services, scientists analyze coral's impact on wave attenuation (the key service from coral reefs associated with coastal protection). Wave attenuation depends on reef dimensions, elevation (of reef crest), location relative to shore, roughness and porosity, and waves & water level conditions. Citation!! These factors should be considered as reef practitioners prioritize reef restoration in the context of coastal protection.

According to the literature, reef restoration for hazard mitigation would be particularly cost effective when focused along the reef crest, this is where scientists see the greatest reduction in wave energy (86% of the reduced wave energy benefits occur at the reef crest) (Ferrario et al., 2014). In particular, reefs with linear and three slope designs (see images of reef slope design from: Roelvink et al. (Roelvink et al., 2021)) have the greatest benefit for shoreline protective services. These considerations are more geared towards long-term restoration actions, but can be applied to emergency restoration actions if on-site prioritization is needed due to limited time, funds, etc.



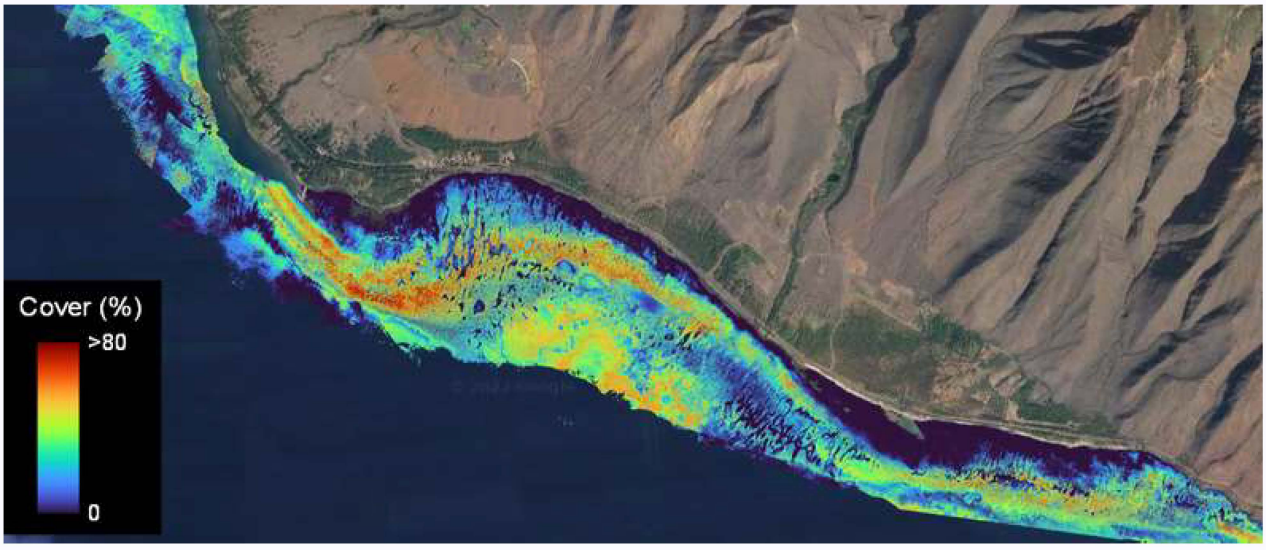
Graphs depicting reefs with coastal protective services, (Credit: Roelvink et al., 2021)

Site selection recommended course of action

Site selection for restoration actions and for target areas of a potential reef insurance policy could follow a myriad of practices and techniques. The following general guidelines should be considered to determine appropriate sites:

- **Determine goals/priorities in emergency restoration. Is this restoration project focused on shoreline protection of public infrastructure, private businesses, cultural and traditional sites? Once this is determined, then associated site selection criteria will fall into place.**
- **Determine which reefs within your specific goal provide the greatest coastal protective services. These reefs with more coastal protective benefits should be prioritized for emergency restoration actions, since the goal of emergency restoration is to maintain reef resilience in high performing areas.**
- **Determine the appropriate budget. Determining the financial capacity of restoration should include considerations based on the size of the intended restoration site and local response capacity.**
- **Engage community input and socio-cultural principles. To determine the most appropriate actions for coastal resilience based on community priorities, early community engagement and use of socio-cultural principles is necessary.**

For a more detailed analysis of reef profiles and site selection considerations, please review the unlocking FEMA's hazard mitigation funding for coral reef restoration: a feasibility study in Maui, Hawai'i : appendix.



Map depicting coral cover on the South Shore of Maui, Olowalu region. Red colors show more coral cover, and blue colors show less coral cover. Data and maps created by the Global Airborne Observatory from Arizona State University

Section Six

Future Recommendations

Kealakekua Bay, HI
Credit: Bert Weeks

Comparable emergency restoration funds for shoreline protection

Overall, reef insurance policies provide substantial funding for emergency coral reef restoration, this rapid outflow of funds is unique among conservation finance initiatives and few opportunities in coral reef management compare.

One of the few comparable financing mechanisms is FEMA's hazard mitigation grants. The goal of these grants is to reduce disaster loss and eliminate long-term risk to people and property (Stovall et al., 2022). Based on the current understanding of coral reefs reducing storm related hazards, there is growing interest from federal and state agencies to pursue FEMA money for coral restoration actions as a cost-effective mitigation action.

There are two applicable hazard mitigation grants for coral reef restoration actions through FEMA. The first grant is the Building Resilient Infrastructure & Communities (BRIC) program, which is through the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act). These are pre-disaster grants that elevate community priorities to improve mitigation assistance and reduce reliance on reactive actions and spending. The second grant is the Hazard Mitigation Grant Program (HMGP), which is a post-disaster grant to rebuild damaged areas and mitigate future damages in non-affected areas. To note, the HMGP grant is only applicable after a presidentially declared disaster (Hazard Mitigation Assistance Grants, 2022). Both the BRIC and HMGP grants can provide a 75:25 match (occasionally a 10:1 match), with $300 million - $400 million available funds annually for competition throughout the United States and associated territories.

For an in depth understanding of FEMA related funding and its applicability in Hawai'i , please review: Unlocking FEMA's hazard mitigation funding for coral reef restoration: a feasibility study in Maui, Hawai'i .

Based on the evidence, FEMA grant funding is the most comparable funding alternative to reef insurance in capacity for emergency response. If paid out, a reef insurance policy's benefit - cost ratio has a 10:1 benefit (with payout : annual policy premiums). Similarly, FEMA grants provide a 10:1 benefit - cost ratio (with grant amount : match amount). The primary difference between these two funding opportunities is accessibility and risk of receiving a benefit. The level of difficulty in acquiring reef insurance is low, as many entities are eligible and there are already established pathways in place, but the payout is not guaranteed, as paying premiums could result in no payouts. In contrast, the level of difficulty in acquiring a FEMA grant is high, as the application process is rigorous and competitive, but would result in guaranteed matching based on funds invested from the grant applicant. Both models have associated risks and benefits that will largely be dependent on the damage event and the party interested in remediating damage post damage event.

Case Study

Puerto Rico

Puerto Rico received a grant following devastating damage from Hurricanes Irma and Maria. In these storm events, more than 11% of Puerto Rico's coral reefs were damaged. In response, FEMA issued a mission assignment to NOAA to conduct coral reef damage assessments and perform emergency restoration activities.

NOAA and partners assessed damages and conducted emergency reattachment of corals, resulting in approximately 16,000 reattached corals over 63 sites in Puerto Rico and the U.S. Virgin Islands. This use of federal funds was a first of its kind and set a new precedent in emergency restoration of coral reefs (Peer-to-Peer Case Study: Post-Disaster Coral Reef Assessment and Restoration Set Important Precedent for Coastal Communities). After this precedent was set, the government of Puerto Rico pursued a FEMA Public Assistant to Grant to fund operation of a in-situ coral nursery in Culebra Island to restore critical coral reefs for future hazard mitigation services. This grant application is under review. Additionally, a Hazard Mitigation Grant Program is in phase -1, design of scoping evaluating feasibility, and reviewing financial and other considerations for a hybrid coral reef project on the San Juan Barrier Reef (M. Amador, personal communication, 2022).

Although no grants from FEMA have been awarded to restore coral reef ecosystems for coastal protection to date, there is interest from state and federal agencies across the Nation to support this potential funding opportunity. Currently, the Hawai'i Emergency Management Agency (HI-EMA) is updating the State Hazard Mitigation Plan. In this plan, HI-EMA will include coral reef restoration as an applicable nature-based alternative, which will allow communities via governing agencies to submit grants for coral reef restoration in Hawai'i (State of Hawai'i 2018 Hazard Mitigation Plan, 2018).

An important thing to note, these grants do have rigorous economic, social, and technical requirements that must be accounted for as applications are prepared. Another consideration is the need for cost-sharing. Mitigation grant programs require a cost-share where at least 10% - 25% of any awarded funds are to be paid by the project applicant. This cost can include volunteer or in-kind contributions and will need to be budgeted for well before applying for a grant.

Divers assessing corals for emergency restoration in Puerto Rico (credit: NOAA)

Future Recommendations

As reef insurance policies transition to a feasible reef restoration tool in Hawai'i, the State should proactively determine regulatory needs for reef insurance policies. Based on conclusions from this feasibility analysis, some focuses have come to light for consideration by governing bodies. To note: these topics should serve as tools to guide discussions among governing agencies and legislative staff, they should not be taken as "action items" that need to occur for reef insurance policy success in the State of Hawai'i .

The State of Hawai'i already has checkpoints in place to ensure proper use and manipulation of corals for a myriad of purposes, which allows for considerable government oversight in emergency restoration activities. This oversight allows DAR to provide input on: who is conducting restoration, where restoration is occurring, and what are the specific approved actions based on site specific conditions. In addition to regulation of activities, permitting lays a foundation of collaboration among coral reef restoration practitioners and the State. To continue to support this foundational collaborative relationship, DAR would like to encourage proactive communication with state agencies as a reef insurance policy is developed, as the restoration management plan is developed, and as a potential payout occurs.

Permitting

DAR is responsible for any permitting needs relating to aquatic resources, and therefore this is the most integrated form of oversight in reef insurance policies. Through permitting structures, DAR can assist in determining appropriate response actions, approving specific response protocol, and potential locations.

As a special consideration for reef insurance related actions, the DLNR has discussed awarding emergency restoration permits to named insured parties, if named insured parties have prior approval and communication with the DLNR before implementation of the policy. This will shorten the review timeline for permits from months to a couple of weeks. The named insured will need to provide as much information as possible related to potential location of restoration actions, intended restoration actions, intended individuals/organizations who will respond once a damage event occurs, and other information that should be readily available in the management plan associated with the insurance policy. In addition, the DLNR is willing to amend existing restoration permits with reef practitioners if they are already permitted for restoration or experimentation in-situ. This amendment could allow a reef practitioner to operate in an area not in their original permit, with the specific intent that they will be responding to a reef insurance related emergency action.

Site selection

The process of determining an appropriate site to insure and perform reef restoration could be challenging for potential owners of reef insurance policies, especially if policy holders are outside of the state government. DAR can offer resources, recommendations, and insights on potential locations of interest and determination of appropriate restoration actions based on specific goals of the policy.

Collaborations with existing management plans

Aligning reef insurance policies with current management goals would be beneficial for a holistic approach to coral reef management in the State. As previously mentioned, aligning reef insurance policies for emergency restoration use with long-term restoration projects is beneficial, because the reef insurance policy actively addresses short term events that could impede long-term success of the restoration project. There are many active management plans for investigation of potential alignment, such as:

- The Hawai'i Coral Reef Strategy 2030
- The Road to 30x30 Holomua
- The Hawai'i Ocean Resources Management Plan
- DLNR Coastal Erosion Management Plan
- Hawai'i Sea Level Rise Vulnerability and Adaptation Plan
- Coral reef restoration action plan with three focus areas: coral bleaching, shoreline protection, and fish habitat
- Hawai'i Emergency Management Agency State Hazard Mitigation Plan

In addition to alignment with state priorities, DAR is interested in supporting community, not-for-profit, and private interests related to coral reef management. This support is outlined in the Hawai'i Coral Reef Strategy 2030 and states that DAR has a particular interest in supporting restoration collaboratively managed between public and private entities (Hawaii Coral Reef Strategy 2030, 2020).

Oversight outside of current governance frameworks

Before a payout occurs and emergency restoration actions are implemented, the State has little control or say in who is applicable for a policy, how the policy is funded, or how the funder distributes the payout. Also, the State has little control in how the policy is structured. The insurance company determines what is an insurable damage event, the payout metric, and the spatial constraints of the policy. All of these determinations are managed between the named insured and the insurance company, which is likely sufficient and does not require robust government oversight.

State government and coastal protection

Reaching outside of reef insurance and into the greater scope of coastal protection for the State of Hawai'i , it is worth mentioning management agencies directly involved in coastal protection at the state level. This conversation on reef insurance comes at a critical time in Hawai'i 's development of proactive shoreline protection management goals. This is an opportunity to define how the State would like to prioritize certain nature-based alternatives over others, how the State would like to prioritize funding mechanisms for coral reef restoration, and what are the primary agencies involved in shoreline protection actions.

State agencies are involved in shoreline protection

In Hawai'i , the primary governing bodies in coastal protection are the Office of Planning and Sustainable Development Coastal Zone Management (CZM) program and the Department of Land and Natural Resources (DLNR) Office of Conservation of Coastal Lands (OCCL). Both of these entities were contacted in the creation of this feasibility report and contributed to the understanding of coastal protection priorities in the State. The Division of Aquatic Resources (DAR) and the Division of Forestry and Wildlife (DOFAW) within the DLNR also contribute to coastal protection efforts through management of resources in nearshore waters and land management that contributes to nearshore ecosystem health. In addition, counties with localized expertise should be included in shoreline protection decision making to contribute local priorities into place-based management actions. HI-EMA should also be included to tap into hazard mitigation expertise for the State and determination of hazard mitigation priorities. Hawai'i Department of Health should also be consulted if considerations related to water quality for coral reef health are incorporated.

In the creation of this report, the legislature determined DAR should investigate reef insurance feasibility in the State, likely due to DAR's direct link to protection and management of coral reefs and permitting infrastructure. DAR is an appropriate governing agency to oversee the implementation of potential reef insurance policies, but there may be other agencies with unique assets and perspectives in coastal protection that should be utilized as shoreline protection considerations arise. The State should consider how reef insurance and coral reef coastal protective services play into the greater landscape of coastal protection in the State, especially when considering government owned reef insurance policies.

It is worth mentioning that these other governing agencies, like CZM, counties in Hawai'i , HI-EMA, OCCL, DOT etc. may be interested in parametric insurance as a finance tool for coastal protection. These governing agencies may wish to investigate other parametric insurance mechanisms to fund restoration of other ecosystems, such as beaches, wetlands, or forests in the name of shoreline protection or to protect assets under threat from episodic damage events.

Appendices

Kealakekua Bay, HI
Credit: Bert Weeks

Example Term Sheet

This term sheet is modeled from real term sheets for coral reef insurance in Hawaii and Quintana Roo, Mexico. These term sheets will have unique values based on pre-agreed metrics from insurance agents and the named insured. These term sheets are typically prepared by a broker and can be thought of as an outline of the potential contract/policy.

Original Insured	The Original Insured is the party with insurable interest. If this is the same as the protection buyer (below) this section can be omitted.
Protection Buyer	This section will include the name and contact information for the buyer of the policy, the named insured.
Protection Seller	This section will include name and contact information for the insurance agency providing the insurance coverage. Typically, this will go through a competitive process where the protection buyer will receive multiple bids from different sellers and select the most attractive offer.
Surplus Lines Broker	Surplus lines broker refers to an insurance broker that is licensed to write a policy in the specific state the policy will be in effect. This is only necessary if the protection seller is outside of the protection buyer's state.
Structure	This section refers to the structure of the insurance policy. In the case of reef insurance, the structure is likely parametric and consists of "cat-in-nested-circles" (CiNC) coverage. This section would also describe in detail the parameters, the spatial buffers, and the how many "levels" of payout there are.
Insured Contingency	This section details what the insurance policy payout will be used for. For reef insurance this section would likely detail emergency restoration actions.
Policy Period	Describing a policy pay period is likely necessary for reef insurance, such as: April 1st to 30 April 2024 inclusive.
Date Convention	This section will describe the specific start and end time of the policy. This is usually a 24-hour period starting at 00.00.00 and ending at 23.59.59. In addition, a specified time zone will be necessary.
Premium Payment Dates	This section will clarify the frequency of payments and the expected start time of payments, for example: 30 days after the policy is enacted.

Example Term Sheet

Currency	The currency should reflect the protection buyer's operational currency.
Defined Geographical Area (DGA)	This section will describe in detail the specific coordinates of the spatial constraints of the policy. If there are multiple sites covered under one policy, then the specific geographic areas of each site will be covered separately. If the policy has concentric circles expanding out of the specific site of the policy, the radius for these concentric circles will also be detailed in this section. This section could also include graphics to supplement written geographic explanations.
Event	The event section will detail the damage event, as an example this could be "tropical cyclones reported by the Tropical Cyclone Reporting Agency".
Event Date	This section describes when an damage event first becomes an event that would trigger the parameter (below).
Event Parameter	The event parameter explains the metric for damage necessary to receive a payout. As an example this could be: a maximum of 1-minute sustained wind speeds in knots (kn).
Event Parameter Calculation	The event parameter calculation will be determined by a calculation agent, this calculation will use data from the reporting agency. This section will list in further detail the necessary steps of the calculation agent to determine the parameter calculation in the event of a damage event.
Covered Event	This section of the term sheet will explicitly state that a covered event is an event within the policy dates that meets the parameters at or above the primary trigger threshold.
Location	The location refers to the precise locations of the policy and the associated concentric circles, if applicable. This section will detail how the precise location and parametric thresholds and met based on event location. If there is supplemental files or graphics or maps to better understand the geographic position of the policy, that will likely be referenced in this section.

Example Term Sheet

Reporting Agencies	The reporting agencies refer to the third party entity that the insurance agency will use to determine if the policy is triggered.
Primary Trigger Threshold	This section explicitly states the lowest threshold to trigger the policy, which would be the least expected damage and the least amount of payout. For example, 50knots for 1-minute sustained winds.
Pay-out Percentage	This section describes how the payout percentage will be determined. Likely, the payout percentage will be the highest of any percentages that are calculated and equivalent to the maximum trigger within the specific defined geographic area.
Calculation Date	This section describes when an damage event first becomes an event that would trigger the parameter (below).
Site Event Limit	The site event limit refers to the maximum amount of payout that could be received for each site. If there are multiple sites, then each site will be listed separately.
Program Term Limit	The program term limit refers to the total maximum payout that could be received during a policy period.
Claim Payment Amount	This section will describe the specific steps needed to determine the claim payout amount, considering the site event limit for the applicable site, the aggregate for each covered event, and the payout percentage.
Payment Date	The payment date will specify when the policy payout will occur. For example, the policy will be fully paid within 10 days of the Calculation Date.
Net Premium (for 100%)	The Net Premium is finalized after the policy goes out for bid. This section will detail how much the anticipated premium costs will be.
Commission	This section is related to the insurance agency that assisted in preparation of the term sheet to put the policy out to bid. This section will state the percent commission for preparing the term sheet and associated insurance policy preparations.

Example Term Sheet

Calculation Agent	This section is related to the insurance agency that assisted in preparation of the term sheet to put the policy out to bid. This section will list the name of the calculation agent.
Calculation Agent Fee	This section is related to the insurance agency that assisted in preparation of the term sheet to put the policy out to bid. This section states the calculation agent's fee

Site prioritization tools

Site prioritization can be a challenging aspect of any restoration project and requires meaningful engagement with communities and analysis of multiple factors contributing to reef resilience, vulnerability, and benefits of ecosystem services. Luckily, there are many tools identified to assist in determining the prioritization of specific sites.

The following tools are broken into goals and damage assessments. Goals refer to the identification of a specific priority for the insurance policy and the intended outcome of it's use. Damage assessments refer to the potential threats to coral reefs. These tools can be used to understand what reefs most at risk to specific threats, and what threats are most prevalent throughout Hawaii. Goals and damage assessment tools can be used in combination to determine appropriate sites for an insurance policy's focal area and restoration actions. This list is not comprehensive, but should serve as an opportunity to better understand coastal threats and reef health at finer spatial scales.

Goal: Reef Restoration

Reef restoration mapping tool (beta testing): https://vrp2116.users.earthengine.app/view/reef-restoration-mapping-tool
This tool is it's beta-testing stage and is in development by TNC. According to the platform home page "This tool provides access to map products derived from hyperspectral aerial imagery that, when combined, can be used to identify optimal locations for outplanting coral

Goal: Economic loss

Below are tools that attempt to quantify the risk of coastal destabilization, sea level rise, and other negative climate change related risks. These values are quantified in the form of economic loss, through buildings under threat, populations at risk, and critical infrastructure.

- PACIOOS Sea level rise vulnerability index: http://www.pacioos.hawaii.edu/shoreline/slr-hawaii/
- Value of US Coral reef for flood risk reduction: https://www.nature.com/articles/s41893-021-00706-6

Goal: Reef Health

Below are tools to better understand fine grain reef health through various forms of surveys. These datasets provide varied collection methods and have varied coverage throughout the MHI. These tools can be used to understand where reefs are located, which will inform the ideal location for a policy and associated restoration actions.

- Climate vulnerability (symbioseas): https://www.symbioseas.org/projects
- Asner Lab Coral Atlas: https://hawaiicoral.org/map/
- CRAMP: http://cramp.wcc.hawaii.edu/LT_Montoring_files/lt_status_of_the_reefs.htm
- Marine Managed Area Benthic Cover: https://www.coris.noaa.gov/activities/habitat_assessment/hawaii.pdf

Site Prioritization Tools

Goal: Flood RIsk

Flood risk remediation is one of the primary benefits that coral reefs provide to coastal communities. These tools analyze flood risk under varying flooding predictions to determining vulnerable infrastructure and industries.

- NOAA coastal flood exposure map: https://coast.noaa.gov/digitalcoast/tools/flood-exposure.html
- NOAA sea level rise viewer: https://coast.noaa.gov/digitalcoast/tools/slr.html
- Climate Ready O'ahu: https://www.climatereadyoahu.org/
- DLNR Flood Hazard Assessment Tool: http://gis.hawaiinfip.org/fhat/

Goal: Critical Infrastructure

Critical infrastructure is particularly important for government agencies to consider when creating a flood risk and erosion risk analysis. These tools can be used to see where the highest vulnerabilities are related to roads, critical buildings, etc.

- PACIOOS sea level rise vulnerability index: http://www.pacioos.hawaii.edu/shoreline/slr-hawaii/
- DOT resiliency tools: https://hidot.hawaii.gov/wp-content/uploads/2021/07/HDOT-Climate-Resilience-Action-Plan-Exposure-Assessments-April-2021.pdf

Goal: Culture and traditional infrastructure

Hawaii's culture and tradition is tied heavily to place. Historical Hawaiian cultural features such as loko i'a (fish ponds), coastal Heiau (cultural buildings) and significant coastal sites are under threat from coastal destabilization. These tools can be used to better understand where these cultural sites are located.

- Fish pond: https://uhawaii-kapiolani.primo.exlibrisgroup.com/discovery/fulldisplay?context=L&vid=01UHAWAII_KAPIOLANI:KCC&docid=alma9910198577305681
- OHA arcGIS maps: https://kipukadatabase.com/kipuka/#view6

Damage assessment: Natural disasters

Natural disasters like hurricanes and tsunamis affect Hawaiian reefs. These tools detail historic hurricane data which could be used to predict frequency and severity of natural disaster events in the future.

- NOAA weather service: https://www.weather.gov/
- UH climatological data: https://guides.library.manoa.hawaii.edu/climatological_data
- NOAA's historic hurricane data : https://coast.noaa.gov/hurricanes/#map=4/32/-80

Damage assessment: coral bleaching

Coral bleaching maps and assessments are necessary to understand where mortality events on reefs have occurred. This tool predicts the likelihood of coral bleaching, which could contribute to an understanding of the threat of coral bleaching.

- Coral reef watch: https://coralreefwatch.noaa.gov/

Damage assessment: coral disease

Boat Grounding more often occur in close proximity to harbors and marinas, because this is where boat traffic is often concentrated. The locations of harbors and marinas could be used to approximate likely locations of a boat grounding event.

- ◯Harbors: http://www.worldportsource.com/ports/USA_HI.php
- Marinas: https://marinas.com/browse/marina/US/HI

Economic analyses tools

Economic evaluation tools do exist to determine if a nature-based solution is feasible, or if a restoration cost is feasible. A couple of these tools are listed here.

FEMA: Benefit-cost analysis tool

This tool was designed for use to determine if a proposed project is fundable by FEMA, a project must have a benefit-cost ratio greater than or equal to one, in order to qualify for FEMA's hazard mitigation programs.

- https://www.fema.gov/grants/guidance-tools/benefit-cost-analysis/full-bca#download

USACE: Economic analyses tool:

This tool breaks down "what is achieved" (benefits) and compares it to "what is invested" (costs). This analysis also utilizes a benefit-cost ratio and includes an analysis of net benefits.

- https://www.iwr.usace.army.mil/Portals/70/docs/IWUB/board_meetings/meeting77/UB77_06_Hammond_Inland_Navigation_Economics_Cost_Benefit.pdf

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TNC, along with insurance industry partners like Willis Towers Watson (WTW) are pioneering natural infrastructure insurance globally and through these efforts have created extensive guidance and research on coral reef insurance. This feasibility report relied heavily on this guidance and research throughout its creation. For a more detailed understanding of many of the topics covered in this report, please refer to the reports below:

- Early Warning and Rapid Response Protocol
- A Post Storm Response and Reef Insurance Primer
- Insurance for Natural Infrastructure: Assessing the feasibility of insuring coral reef in Florida and Hawai'i
- Unlocking FEMA's Hazard Mitigation Funding for Coral Reef Restoration
- Guide on how to insure a natural asset
- Guidance Document for Reef Management and Restoration to Improve Coastal Protection

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