A roadmap to assessing the feasibility of applying insurance in fisheries

Environmental Markets Lab (emLab)

1. Introduction

Wild capture fisheries are inherently risky. Environmental stochasticity creates uncertainty around the outcomes of management processes and individual fisher behaviors. Climate change is exacerbating these uncertainties by shifting the distribution of potential environmental shocks. Fisheries need to adapt to become climate-ready to protect against climate change. Climate-ready fisheries entail responsive management strategies, improved information systems, and sufficient infrastructure to withstand future climates ; however, management agencies are often limited in their capacity to invest in this urgently needed transition (Lomonico et al., 2021). The resulting financing gap can be eased with financial tools funded through private or blended capital approaches (Fitzgerald et al., 2020).

Insurance may be an ideal financial tool to assist the transition to climate-ready fisheries management (CRFM) given its widespread use in agriculture (Bell et al., 2020). Fisheries and agriculture share many characteristics including exposure to environmental risks, diverse products, and a broad scale of harvest from small-scale to industrial. Crop insurance is used to adapt to greater climatic risk and has widespread adoption with nearly 80% of all acreage in the United States covered under insurance (Falco et al., 2014; Smith and Goodwin, 2013). Insurance actively protects against climatic damages to agriculture -- up to 20% of indemnity payments to farmers in the United States are attributed to climate change (Diffenbaugh et al., 2021). There are concerns that increased climate variability will raise premiums making insurance more expensive, but updated forecast models to improve actuarial tables and more responsive management seek to minimize those costs (Tack et al., 2018; Tack and Ubilava, 2015; US GAO, 2014). Additionally, access to crop insurance can incentivize additional risk-management practices. For example, in the United States, to qualify for federal crop insurance, a farmer must demonstrate “farming best practices” such as disease and pest management, cover crop use, and sufficient fertilizer application. Similarly, Danish farmers improved soil-management practices when required to opt into an insurance contract (Jorgensen et al., 2020).

Why is crop insurance a standard practice adaptation tool for climate change in agriculture but nearly absent in fisheries? One likely answer lies in the challenges associated with identifying actuarial loss and connecting threat to a specific environmental variable in most fisheries (Mumford et al., 2009). In 2001, the Risk Management Agency of the US sought to design an insurance product for Sockeye Salmon in Bristol Bay, Alaska to help stabilize the fishery dependent economy in the face of poor fishery performance. Ultimately, the fishery was deemed not suitable for insurance due to exorbitant costs, inability to determine a fishery “best practice”, and a moral hazard disincentivizing fishers to exit the fishery eliminated the actuarial soundness of an insurance program (Herrmann et al., 2004). The authors concluded the salmon fishery’s imperiled state required better management -- not financial amelioration -- to fix it. To our knowledge, the Bristol Bay Sockeye Salmon determination of 20 years ago was the last concerted effort to extend the U.S. Department of Agriculture's crop insurance program to the fishing sector. Since then, one additional study sought to provide a theoretical justification of fishery productivity insurance using generic herring biological data (Mumford et al., 2009), but its findings were not applied to a real world fishery. At present, the Caribbean Ocean and Aquaculture Sustainability faciliTy (COAST) initiative is the only example of a functioning risk insurance mechanism for the fishing industry. Available to fishers in Grenada and St. Lucia, COAST is a parametric insurance product that uses storm intensity and storm geographic extent to “trigger” payouts to all covered parties within the affected zone. The development of this new insurance product, the advancement of data collection technologies in fisheries, and greater climate threats leading to increased risk across the fishing sector demand a reassessment of the viability of insurance for addressing challenges to sustainable fisheries management.

It is worth noting that application of crop insurance is limited in developing countries, due in part to many of the same challenges standing in the way of fisheries insurance (e.g. data limitations, moral hazards, correlated risks). Index-based Insurance (IBI) was specifically developed to combat these limitations. Index insurance typically uses weather to act as a proxy to determine payouts. A trigger could be rainfall or a temperature threshold that is known to be detrimental to crop yields. The index and realized trigger value are often independently assessed by unbiased third parties to reduce costs to the insurers and remove moral hazards. Though index insurance smooths farmer income, protects assets, and improves farm productivity through releasing constrained capital inputs (Janzen and Carter, 2019; Sibiko and Qaim, 2020), uptake can be as low as 10%-35% of available farmers (Binswanger-Mkhize, 2012; Carter et al., 2017). Under certain conditions -- high correlation with index and loss, high financial risk, familiarity with insurance that lends itself to demand for insurance products -- weather index insurance is a suitable risk management tool to assist climate change adaptation (Collier et al., 2009). A deeper understanding of the efficacy and limitations of IBI provides a unique opportunity to test its ability to transition fisheries towards climate readiness.

At the same time, traditional insurance products (i.e., indemnity insurance) to protect fishery yield or revenue may also have a role in addressing threats to fishery sustainability. Indemnity insurance in fisheries insures fishers productivity assets, namely harvest, revenue, and profit. Fishers would take coverage levels (e.g. some percent of historical catch), and receive payouts in the event shocks lower their harvest. Recent changes to fisheries management -- including better data collection and the opportunity to explore market opportunities via the Magnuson-Stevens Fishery Conservation and Management Act reauthorization in 2006 -- may make traditional insurance more viable than IBI in certain fisheries. For example, in settings with rights based fishery management -- which has expanded to encompass 20% of annual global marine capture (Costello and Ovando, 2019) -- individual data reporting eliminates common pool issues that affect determining an individual's actuarial loss, increasing the feasibility of applying indemnity insurance. Additionally, new technologies like on-board video monitoring and vessel tracking through Global Fishing Watch could provide measures to reduce moral hazards.

This proposal will provide a roadmap to assist determining where, how, and why insurance may be a feasible option to achieve climate-ready fisheries.

2. Research questions and approach

The key research questions this work aims to address are:

1. What does the full landscape of fisheries insurability look like?
    i. For different consumers/product types: individual, mutual, agency
    ii. For different sectors: commercial, recreational, indigenous (noting that the focus is on the commercial sector here, but the methodology could be applied to additional sectors)
2. What determines the viability of a fishery insurance product?
3. What do we need to know to develop an insurance product for a given fishery?
4. How do different fishery objectives (e.g. improved climate ready fishery management) affect the viability and design of insurance?
5. How do we assess insurance viability for an individual fishery?

To answer these questions, we propose using a framework we have developed for thinking about how to apply insurance to fisheries: the Fisheries Insurance Spectrum. Section 2.1 provides an overview of the Spectrum and the key considerations ("ingredients") for assessing insurance viability for a given fishery (question 1). These ingredients and their role in determining the type of insurance and product viability are presented in sections 2.2 - 2.6. In each section, we outline what we need to know (question 2), we cover how fishery objectives might affect the viability and design of insurance (question 3), and we propose specific approaches to assess insurance viability for fisheries (question 4). In addition to data and modeling approaches, a true assessment of fisheries insurance viability will require engagement with both the fishery and insurance sectors, and we therefore highlight opportunities to further inform findings via interviews and a stakeholder workshop.

We note that the outlined approach is intended to inform viability assessments at the level of a single fishery, rather than a collection of fisheries (i.e. this assessment methodology is not meant to inform the design of insurance portfolios to risk smooth across regions of interest; however, in Section 4 we highlight an opportunity to do a high level portfolio assessment). Moreover, we do not explicitly assess the role of moral hazard or how insurance design could leverage moral hazard in fisheries, although key considerations around moral hazard are discussed. Instead, the methodology presented focuses on fisheries production as the asset of interest, and details an assessment scheme to determine the type and design of insurance most suited for a given fishery and objective.

2.1 The Fisheries Insurance Spectrum

Fisheries are diverse. The problems and solutions for one may not be sufficient in another. Insurance is appealing because it offers a scalable, flexible solution to combat the myriad of idiosyncrasies in fisheries. Though there will be difficulties in applying traditional indemnity insurance in fisheries, the scope of feasible options should not be constrained to IBI insurance products alone. Instead, insurance products and their role in achieving fisheries objectives can be thought of along a spectrum, with indemnity insurance applicable under one set of conditions and IBI preferable in different fisheries contexts. This creates a roadmap where objectives can be aligned with insurance options to structure what information needs to be collected to implement a successful insurance product.

The range of triggers that could reasonably be insured against forms the nodes along the Fisheries Insurance Spectrum (Figure 1). These triggers represent different factors relevant to fishery outcomes, with the level of "control" insurees have over each factor determining its position along the Spectrum (more control on the left; less control on the right). Control is defined as the ability to influence a trigger or outcome, and is intimately linked to moral hazards. In insurance, moral hazard occurs when an insuree takes on greater risk to trigger a payout. Thus, if an insuree can control the payout, the greater the moral hazard. Normally moral hazards are considered destructive to insurance due to unsustainable increases in cost to the insurer. However, they may be a good thing in fisheries since inducing a moral hazard implies lowering fishing effort, which could lead to greater conservation benefits. A potential trade-off then arises to provide enough of an incentive to lower effort, but not at the expense of destabilizing the entire premise of insurance. The Insurance Spectrum visualizes this trade-off.

Different insurance products have different data requirements. Without robust data on individual catch, indemnity insurance will not be able to establish actuarial loss. Index insurance has lower data requirements, but at a minimum, IBI needs data on an index, often publicly available (e.g. NOAA weather data), and some measure of fisherywide catch to quantify correlations. More data improves IBI's capabilities by minimizing basis risk, but its requirements are less than that of indemnity insurance.

On the left side of the Spectrum are triggers most suitable for a traditional indemnity-based insurance. For example, using harvest as a trigger would be akin to indemnity crop insurance policies offered in US agriculture. If environmental conditions lead to a bad year of harvest, payouts will be disbursed to compensate for the loss. Indemnity insurance is more tailored towards individual outputs (e.g., harvest, profit, and revenue), but group policies can also be designed. Here, fishers control harvest and a strong potential moral hazard exists. Additionally, for indemnity insurance to be feasible, data requirements are high to provide sound actuarial basis.

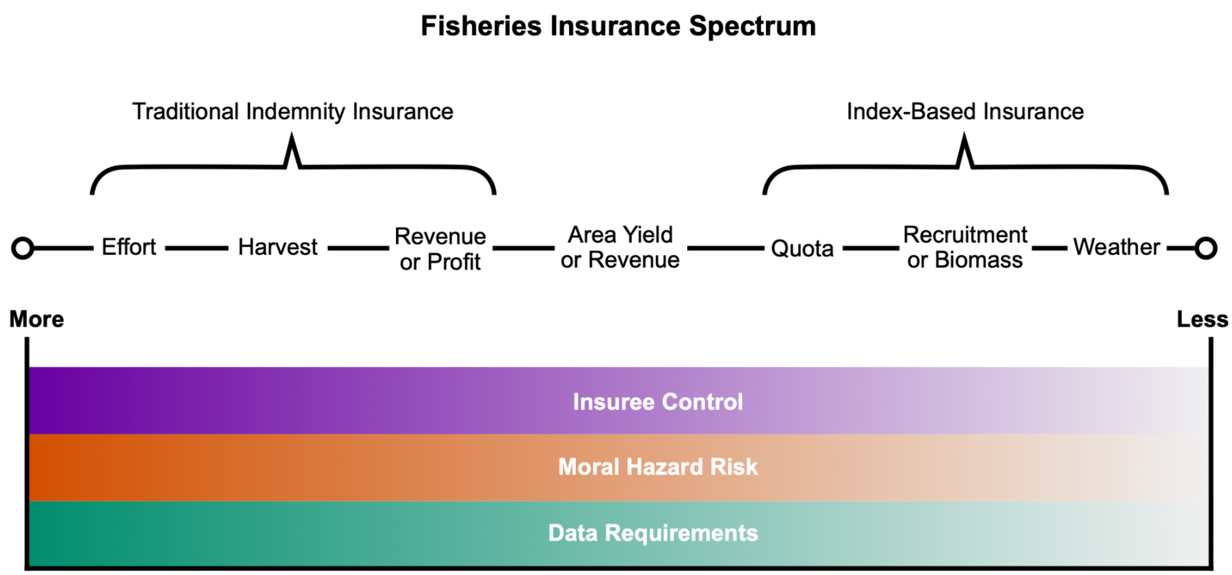

Figure 1. The Fisheries Insurance Spectrum. General categories for the 7 most likely candidates for a trigger in an insurance form a spectrum of insurance. Triggers that would be considered more like a traditional indemnity plan fall on the left with higher levels of fisher control (purple), moral hazards (orange), and data requirements (teal). Index-based insurance triggers reside to the right.

As we move to the right along the Spectrum, fishers have less control in determining payouts, moral hazard is thereby reduced, and information requirements are lessened. Potential triggers for index-based schemes -- including weather or climate-based measures -- are located at the right end of the Spectrum. Here fishers have no to little influence on triggering payouts. However, there is also no guarantee that insuring weather events protects fishers income or other desired outcomes, because individual weather variables do not fully explain the complex ecological dynamics of a fishery. Instances where an index does not payout despite weather decreasing fisher productivity is called basis risk. Triggers must be chosen to minimize basis risk, so that the trigger accurately correlates to fisher loss. Triggers are also fisherywide, thus payouts will be given to every insured fisher and the need for individualized data in IBI is diminished.

There are five key ingredients that guide where and how feasible an insurance product is across different fishery contexts and objectives:

1. Demand
2. Fishery Management
3. Stock Biology
4. Triggers
5. Payouts and Premiums

Management, biology, and triggers greatly influence the data availability of a fishery. Demand and payouts influence the structure of an insurance product and its feasibility. Each of these ingredients can therefore be framed as an additional axes of consideration, covering key elements of product design including who is insured (i.e. self insurance, mutual insurance, or agency/individual held products as well as customer demographics, covered in the *Demand* section), what is involved in the verification process (covered in *Payouts and Premiums*), and how differing objectives will support the design of different insurance products (covered in all sections).

The remainder of this proposal presents each of these ingredients and data availability considerations as a framework that can be used to determine the feasibility of applying insurance in fisheries. For a given viability assessment, an objective will need to be stated (e.g. insurance as a tool to achieve CRFM objectives), and a list of fisheries of interest must be defined. The viability methodology then details key considerations and assessment approaches for each ingredient, while highlighting specific considerations for CFRM objectives. Each section concludes with a brief overview of possible methods for acquiring information needed in viability determination. Methods are separated into stakeholder engagement and data and modeling techniques.

2.2 Demand

Fundamentally, there needs to be demand for insurance to work. Demand originates from the policyholder of the contract. Most insurance contracts would work at the individual level, in this case fishers, but we could expand the concept of policyholder to be a collective of fishers or even fisheries managers. Risk aversion is an important determinant for demand, because more risk averse people are likely to buy into an insurance product (Clarke 2016). Insurance provides more consistent outcomes in an uncertain world, which risk averse individuals prefer. Income smoothing is the greatest benefit to individual fishers when they are the policyholders, whereas conservation, management objectives, or risk transfer to support financing of fisheries disaster relief obligations (e.g. COAST) may be a manager's goal when buying insurance. Policies that seek to align fisher and manager incentives may require behavior changes (e.g. the adoption of specific climate ready technologies) for those choosing to opt in. Alternatively, the manager could use insurance to hedge against politically unfavorable actions such as reducing quota.

The objective the implementation of an insurance program is seeking to address directly informs demand. Insurance can achieve CRFM objectives by reducing barriers to adaptation (Bell et al., 2020). Insurance can meet CRFM goals through three measures. First, insurance reduces risks and provides income stability. Second, it can be used as an incentive tool to adapt other climate ready technologies or management goals. Third, it facilitates collaboration between fishers and managers potentially freeing political capital to make the necessary adaptive management actions such as quota adjustments without fisher backlash. It will be necessary to assess the importance of these goals specifically for potential insurees to ensure that demand aligns with insurance program objectives.

Desirability of insurance is also influenced by characteristics outside of risk mitigation such as the ability to diversify income and capital constraints. For example, the existence of alternative risk management strategies, like income diversification, may change insurance demand (Niewuwoudt and Bullock, 1985; Knapp et al., 2021). If fishers are already diversifying their fishing portfolio, they may be less inclined to purchase insurance and simply choose to fish an alternative species. Consistency of payouts also affects demands. Farmers more often choose higher coverage levels that induce smaller, but more frequent payouts (Carter et al., 2016). Finally, wealth levels further predict willingness to pay for insurance. Low income farmers are often credit constrained and do not have the means to afford premium payments, which decreases demand. In the US, larger, more valuable farms with more capital are the dominant source of demand for crop insurance (Goodwin, 1993). Therefore, a first step in assessing the viability of insurance for a fishery is to understand who will buy into the program and how much demand there is for a potential insurance product.

2.2.1 Demand proposed assessment approach

- Stakeholder engagement
    - Engage with fishery managers through structured interviews to determine whether they believe insurance will help them meet their objectives.
    - Open discussion with fishers about their interest in and concerns about a possible insurance product.
- Modeling and data
    - Willingness to pay (WTP) studies for insurance by fishers through Household Surveys would directly assess demand for insurance (Hill et al., 2013). Additionally, model outputs from WTP studies inform who buys in and help flag risky designs (adverse selection).
    - Identify fisheries with high variance in catch, profit, or stock through statistical analysis.

2.3 Fishery Management

Management greatly influences the feasibility of insurance and the objectives of a given insurance product. Fisheries management promotes ecological and economic sustainability, and serves as a holistic risk-mitigation tool. Insurance can complement and even improve management of fisheries resources through risk smoothing, but insurance could be redundant if management already smooths risk sufficiently. However, insurance could help transition to climate ready, adaptive management. This section will highlight how insurance feasibility depends on existing management. Specifically, assessing the feasibility of fisheries insurance requires that we (a) identify existing management structures, (b) take stock of how management influences data availability, and (c) determine how insurance could integrate with management.

2.3.1 Fisheries management structures

Fisheries management tools can be classified as input or output controls. The most regulated fisheries often have elements of both entwined together. Climate ready fisheries will need robust input and output controls to effectively protect against future climate damages. Input controls limit the methods fishers use to catch fish. Gear restrictions, seasonal closures, boat capacity, and permits are all examples of input controls. Insurance is primarily focused on protecting outputs, but understanding the inputs helps ensure best fisheries practice. An insurer would want guarantees that the policy holders are not engaged in destructive or suboptimal extraction techniques. Additionally, insurance could incentivize input transitions in fisheries where mandated input controls have been unpopular or impractical. For example, transitions to less environmentally damaging gear are often met with stiff opposition from fishers as they prioritize their financial productivity (Innes and Pascoe, 2010; Catchpole et al., 2005). Offering a well designed and desirable insurance product to protect against future shocks, provided fishers update their gear, could improve the popularity of the gear change.

The most common output control is total allowable catch (TAC), which limits the amount of fish that can be extracted in a given time frame. Catch limits range from tradeable allocations to free entry where anyone can fish until the TAC has been reached. Insurers need to understand how these systems work in order to provide the best product. For example, in TACs where past catch determines next year's allocation, fishers may choose to continue to fish regardless of insurance as they are compelled to maintain their fishing levels. Thus, the goal of insurance may not be for conservation outcomes, but to mitigate price or profit shocks. These considerations do not limit insurance; instead, assessing insurance viability requires a thorough understanding of management structures to design creative products able to achieve desired objectives.

Management structure can be assessed through the regulations and management plans published by the enforcement agencies.

2.3.2 Fisheries management data availability

Management systems also fundamentally inform data availability. Quota systems require strong monitoring protocols and data reporting. Monitoring practices that management controls include fisheries observers, logbooks entries, and landings reports (e.g. fish tickets). New efforts combine log-books with independent data from vessel monitoring systems (VMS) to verify days of catch with on-the-water effort. Insurers would also find these systems beneficial -- and for some products, necessary -- as they would allow for claim verification and the development of actuarial models. Most fisheries, however, have less stringent management requirements, and consequently less data availability.

One approach to determining data availability in a fishery is to leverage publicly available fishery management reports. Information on the regulations, data available, and stock assessments are often public facing on fishery management agency websites.

2.3.3 Integrating fisheries management with insurance

Insurance has the potential to work independently of management, but collaborating with managers to align objectives and facilitate implementation boosts the chances of a successful insurance product. There are two avenues for collaboration. First, managers could be the customer of an insurance product. A management agency purchases an insurance contract to provide funds in the event a trigger (e.g. biomass) drops below a critical value. The manager could then distribute those funds to fishers to smooth income while supporting sustainable fishery management objectives. The COAST index-insurance model in the Caribbean functions in this manner: governments receive payouts for extreme weather, which are then channeled to a set list of fishers (Sainsbury, et al., 2019). Managers would likely use qualifying criteria to ensure that fishers receiving payouts are complying with certain requirements (e.g. installing a data monitoring system to comply with a catch reporting requirement). When the management agency is the insuree, there should be further consideration around how the insurance premium is paid (and by whom). If solely funded by the manager, insurance could replace expensive -- and slow -- disaster relief allocations. Landings taxes, for example, could be administered to pass premium prices on to fishers.

Second, managers could act as partners with an insurance company, as is the case for the MAR reef insurance programme (underwritten by AXA Climate). Together, managers and an insurance agency can design a policy for fishers to buy into to correct identified shortcomings. For example, consider a management agency with an objective to improve environmental monitoring (e.g. in service of a CRFM objective). Managers possess an excellent understanding of the biological system. If monitoring arrays for a weather index were installed and operated using insurance company funds, the manager could update its stock assessments more accurately using the insurer provided technology. At the same time, insurers gain improved monitoring of stock status for their payout determination, and fishers buy into an insurance scheme that smooths their income. Open dialogue and collaboration is vital for private-public partnerships to work.

The collaboration process between management and insurance companies facilitates insurance as a transition tool towards CRFM. With managers as the insuree, insurance can achieve the CRFM objective of facilitating responsive disaster relief. Likewise, with manager-insurance partnerships, there is a higher likelihood for successfully incentivizing a transition towards CRFM. In particular, managers would need to identify potential incentive programs or strategies that are not achievable without sufficient financial motivation; an insurance company could then provide the funds to incentivize manager led behavior change. Even if managers are not the recipients of the funds, structuring and adapting management plans to incorporate private fisher insurance products into the management strategy will allow managers to shift towards more adaptive, and therefore climate-ready, management.

2.3.4 Fishery management proposed assessment approach

- Stakeholder engagement
  - Partnerships with managers greatly increase the feasibility of insurance in fisheries. If managers are the recipient of payouts, then it is imperative to engage with managers. Through interviews or workshops, managers can clearly articulate objectives they believe insurance could be used to achieve.
  - Insurance providers need to understand how fishery management works to assist developing products. Their expertise could inform how insurance could work within a given management framework.
- Modeling and data
  - Review fishery management plans to understand regulations and gaps for incentive programs.

- Review and/or request logbook and other monitoring data to understand data availability (if not reported in available stock assessments or management plans).

2.4 Stock Biology

Biological stochasticity drives uncertainty and subsequent risk in fisheries. Environmental conditions directly affect stock biology, but the underlying quantity of fish (biomass) determines fishers' outcomes. Thus insurance can be used to mitigate fluctuations in stock biomass. Each fishery is biologically unique, but there are some overarching characteristics important to insurance that must be considered when determining insurance viability. Some fish species exhibit highly volatile growth patterns. For example, squid and salmon demonstrate boom-bust cycles, with high abundances one year, followed by stock collapse the next (Krkosek et al., 2011; Moustahfid et al., 2021). The frequency of the cycles can change over time and climate change is expected to exacerbate these volatile stock dynamics. Conveniently, insurance may be more desirable in a system subject to high volatility.

Stock biology has spatio-temporal considerations that guide the structure of an insurance product in terms of risk narrowing, trigger design, and buy-in and payout scheduling. The fact that fish are not distributed homogeneously in space creates natural variability that can be leveraged by insurers to narrow risk. Further, the design of triggers may be linked directly to stock biology. For example, sedentary species, like oysters, could use hyper-local water quality indices as triggers rather than a holistic measure of water quality across the entire region. Finally, stock biology affects the seasonality of fisheries due to considerations around spawning, migrating, and/or aggregating behaviors. When designing an insurance product, knowing when to issue periods for fishers to buy in or distribute payouts will therefore be driven by the biology of a fishery, and must be carefully assessed to determine insurance viability.

Stock biology not only influences the structure of an appropriate insurance product for a given fishery, but it also affects how an insurance program will give rise to different fishery outcomes. Insurance products may be designed to specifically target biological outcomes (e.g. via biomass triggers) by inducing behavior change or providing incentives to fish less. Modeling the interplay between insurance and stock dynamics requires some understanding of stock biology, suggesting that biological data requirements are necessary to assess insurance program impacts on biological outcomes. Simulation approaches can also be used to further determine which type of change -- e.g. behavioral or incentive based -- an insurance product should target to meet biological objectives. For example, if motivating a behavior change to improve gear, the choice of gear and its biological impact matter. Selecting which gear should be done under a lens of improving resiliency in a CRFM framework.

Most sources of biological data for fisheries come from stock assessments. New tools for data-limited fisheries can provide some information on key biological parameters. Designing triggers from environmental variables may require a clear understanding of the impact the environment has on stock biology and ultimately biomass (see Section 2.5).

2.4.1 Stock biology proposed assessment approach

- Stakeholder engagement
    - Interview experts in specific fishery biology to identify possible spatio-temporal triggers and discuss how insurance could be used to adjust fisher behavior during key biological events such as spawning.
    - Interview managers to understand agency level reform considerations to identify which risk reducing management strategies are possible and which are not.
- Modeling and data
    - Fishery biological data is often contained with the stock assessments found under management data portals.
    - There are other independent sources of biological parameters, often collected from stock assessments, in resources like the RAM Legacy Database and FishBase.
    - The biological data can be used to assess insurance viability in two manners:
        - Spatial-temporal trigger designs need the underlying biological data (see Section 2.5).
        - The biological data can also be used to parameterize a model to simulate future impacts of insurance on the fishery. If integrating a gear change or other conditional incentive requirement, a simulation model can forecast changes to compare insurance interventions with the status quo (e.g. a management strategy evaluation modeling approach).

2.5 Triggers

Armed with a thorough understanding of the management and biology of a given fishery, we can then determine the correct trigger for the fisheries insurance product. The Fisheries Insurance Spectrum reveals two overarching categories of insurance: indemnity and index-based. Each insurance category can more effectively achieve different objectives, and each has different information requirements. Indemnity insurance also needs more refined data. Insurance policies for individual fishers or management agencies will need to undergo thorough evaluation of past performance. If a fishery has robust harvest, profit, and/or price data and monitoring infrastructure, indemnity insurance triggers for any of these indices tailored to individual fishers are possible. Active monitoring procedures tie into claim verification. Without up to date information and data from fishers, insurers will struggle to make justified payouts. Indemnity triggers directly protect fishers' losses (i.e. achieve profit smoothing objectives) at an individual level. With indemnity insurance protecting individual harvest, fishers may be less inclined to exert higher fishing efforts, reducing pressure on a managers quota.

Index insurance has many potential triggers. Determining applicable triggers depends on understanding which environmental variables explain a sufficient proportion of the variation in a fishery outcome of interest (e.g. harvest, profit, biomass). Though there is no official standard, when an agricultural index explains at least 40% of the variation of yield it is considered an acceptable index trigger (Yu et al., 2019; Jensen et al., 2016); a similar rule of thumb could be applied to the fishing sector. Though not comprehensive, potential environmental triggers to use include: sea Surface temperature, primary productivity, dissolved oxygen, precipitation, and wind speed. Each of these triggers have extensive independent observations from unbiased entities and have some influence on biomass (and therefore other fishery outcomes of interest). The independent observations simplify the claim verification process for IBI. If the trigger is reached, so long as an insuree holds a contract, payouts will be made.

Any index trigger needs to be independently assessed, available for all parties to see, and minimize basis risk. Because no index perfectly explains the variation in biomass or catch, there is a risk that an environment change significantly impacts fishery production, but the predetermined index threshold is not reached and therefore payouts are not distributed (e.g. an SST index is developed, SST is 0.5 degrees < the trigger, stock productivity declines, CPUE declines, fisher profits are negatively affected, but fishers are not compensated because the trigger was not met). These negative occurrences destroy faith in the insurance; however, the opposite outcome is also possible in which an insuree receives a payout because a trigger was met even though the indexed variable did not significantly affect catch

Instead of attempting to predict the weather's influence on biomass, there are some fisheries with robust enough data that biomass or recruitment numbers could be used as index triggers themselves. The calculation is independent of fishing effort, though past effort does influence current biomass. Under such a scheme, if fish counts (i.e. as determined via fishery independent data collection efforts) fall below predetermined thresholds, fishers would receive payouts.Alternatively, quota allocation could serve as a trigger for an IBI product. From a fishers perspective, they could buy into a plan that estimates quota allocation in the next year for the fishery as a whole. If the managers then require quota reductions due to poor recruitment or weather conditions, the fisher would receive a payout.

Finally, indices can be constructed by combining key environmental determinants. The ENSO index is an excellent example of this application. It combines temperature, pressure, and wind speed measurements and compares those conditions to relative strength levels of past events. ENSO has profound physical and biological effects with consequences to ecosystems and fisheries (Lehodey et al. 2020), and thus could serve as a potential index. Other event indices may also be constructed. For example, the declaration of a closure due to a harmful algae bloom (HAB) from a fishery manager could be a feasible trigger. Though HABs may not directly impact stock biomass, they can result in closure (e.g. due to subsequent domoic acid contamination of fished species), which is a devastating loss of harvest (Moore et al., 2020).

2.5.1 Triggers proposed assessment approach

- Stakeholder engagement
    - Insurance companies may have methods for assessing actuarial soundness in a trigger. Engaging with them could pinpoint what levels of correlation between indices and yield are sufficient or inform contract design in the trigger.
- Modeling and data
    - Perhaps the most crucial step in assessing the viability of any insurance product in fisheries is the trigger design. The previous management and stock biology sections detail how to collect fishery specific data that could inform indemnity models. Actuarial models will then inform the trigger points for individual fishers.

Aggregating the output from individual models can then forecast the broader impacts of an indemnity insurance on the fishery.

    - For a climate-based index product, understanding the strength and certainty of the relationship between environmental variables (i.e., the index) and overall stock productivity can be assessed using mechanistic population dynamics models (e.g. Free et al. 2019 for ocean temperature effects on stock productivity); correlations between climate indices and stock productivity are not sufficient because relationships are often nonlinear and may be mediated via multiple biological processes. An actuarial model can then be built using methods like quantile regression to pinpoint suitable trigger values, provided established relationships are strong enough (Conradt et al., 2015).

2.6 Payouts and Premiums

Payouts and premiums complete the insurance product once a trigger has been selected following thorough evaluations of data availability, management structure, and the biology of a fishery. Insurance companies charge premiums that cover their administrative cost as well as the expected value of payouts in a given year. Once a trigger distribution for a given coverage level has been established, insurers need to offer a payout that is appealing enough to the insuree (e.g. fishers or managers) to buy into, but not too expensive that it raises the premiums (i.e. beyond the policy holder’s willingness to pay). Payouts may be fixed at a set amount, or they may be responsive, e.g. proportional to catch for the year to make up the difference from a fishers observed and expected catch. Distribution channels for payouts must also be considered and assessed depending on the structure of the policy (i.e. agency held, cooperatively held, individually held). For indemnity payouts, insurers would need to verify catch before payouts could be distributed.

Insurers also need to account for correlated risk to ensure they have sufficient funds to pay out. Weather triggers inherently represent a fishery-wide risk, but IBI is designed to account for correlated aggregate losses across policy holders (Morsink et al., 2016). Insurers can minimize their risk by investing in a portfolio of fisheries. An insurer reduces the risk of simultaneous payouts for one weather event and allows for a consistent stream of premium payments to sufficiently fund payouts to insurees.

2.6.1 Payouts and premiums proposed assessment approach

- Stakeholder engagement:
    - Insurance companies: interviews/discussions to determine what premiums and payouts they would be willing to offer given distributions of proposed triggers.
    - Stakeholder workshop: recipients of funds (either fishers or managers) and insurance companies must agree on payment methods in an open forum.
- Modeling and data
    - Adjust actuarial models developed from the trigger section to accommodate different premiums and payout schedules.

    - Repeat the FIS application for additional fisheries then simulate fund holding for an insurer to guarantee a sufficient flow of payments in and out of a fund

3. Anticipated Outcomes

The Fisheries Insurance Spectrum serves as a useful roadmap to aid the construction of insurance in fisheries. Clearly articulating what the goals of an insurance application strives for facilitates its implementation and an assessment of insurance viability for individual fisheries. Anticipated outcomes of this work are the following:

- A standardized methodology for assessing the viability and informing the design of insurance for a given fishery and objective to elucidate:
    - The type of insurance product that is best given the fishery & objective
    - The most viable triggers for index products
    - The most viable premium and payout structures
    - The most insurable fisheries (in a region of interest)
    - The insurance application that best aligns fisher/manager/insurer incentives

4. Feasibility Snapshot Analysis

As an initial step, we outline a rough cut analysis that could leverage the Fisheries Insurance Spectrum to provide a relatively rapid assessment of insurance viability for a predefined set of fisheries (e.g. trap fisheries in California). We start with the a priori assumption that insurance is a reasonable tool to assist the transition to climate-ready fisheries in California, and that CRFM is the objective of interest. We further assume away key considerations that must be gleaned from stakeholder engagement processes and focus on considerations related to data availability, management structures, and trigger design. We stop short of quantifying payouts and premiums due to their reliance on stakeholder input; however, as a final step, we propose examining covariance amongst groupings of fisheries to identify opportunities for insurers to reduce risk through portfolio approaches.

The research questions this rapid analysis aims to address are: (1) where do individual fisheries lie along the Fisheries Insurance Spectrum? (2) which fisheries demand further consideration as targets for insurance products in support of CFRM objectives? and (3) which fisheries could be collectively insured as a portfolio to further reduce risk?

Step 1. Assess the ingredients

1. *Demand*: For this assessment, we would assume demand is given (i.e. there is no need to explicitly assess demand), but that both fishers and management agencies are potential insurees. We would further refine our understanding of demand by identifying fisheries with high variance in catch, profit, or stock through statistical analyses. Each fishery would be rated as high, medium, or low variance.

2. *Fishery Management*: To simplify our assessment of management considerations, we will assume that data availability and management effectiveness are correlated. We will then rate each trap fishery as having a high, medium, or low management index based on monitoring and reporting requirements (i.e., temporal and spatial resolution of catch and effort reporting; availability of fishery independent information; etc.)

3. *Stock Biology*: For each target species, we will collate relevant biological data to determine confidence around data availability required for trigger design (see below). Fisheries will again be categorically assess, with low given to fisheries missing key biological parameters, medium for fisheries with available biological parameters through global data repositories (e.g. FishBase, RAM Legacy), and high for fisheries with available and stock specific biological parameters.

4. *Triggers*: The goal of this first assessment is not to identify precise trigger points, but rather to obtain a relative understanding of the strength and certainty of the relationship between each of the indices along the Fisheries Insurance Spectrum and overall stock productivity. For indices towards the left, these relationships will depend on biological data (e.g. is it an r or K selected stock?) and management regulations (is there a TAC?). For indices on the right hand side of the spectrum, we will leverage the mechanistic population dynamics model developed by Free et al. (2019) to assess the relationship between ocean temperature effects on stock productivity. Each fishery will receive two separate trigger scores: (1) high, medium, low for the level of control the insuree (fisher or manager) has over indemnity relevant triggers; (2) high, medium, low for the strength and certainty of the relationship between environmental triggers (in this case SST effects) and stock productivity. Fisheries in which potential insurees have high control over indemnity triggers and a strong relationship between stock productivity and ocean temperature will be candidates for parametric insurance products; fisheries with low control over indemnity triggers and weak relationships between stock productivity and environmental indices will be candidates for indemnity products. We note that temperature effects are not the only environmental impact of interest, and highlight that new mechanistic population dynamics models will need to be developed to assess a suite of potential environmental trigger options.

5. *Payouts and Premiums:* From the assessed strength of the relationship between indices, we would determine if there is distinct covariation to allow an insurer to build a portfolio. This could further refine the list of fisheries to groupings of fisheries and provide an understanding of how insurer risk can be reduced through potential portfolio approaches.

Step 2. Identify CRFM insurance opportunities

Layering these categorical assessments together will provide a first cut view of (a) where on the Fisheries Insurance Spectrum each fishery lies, and (b) if basic data requirements are met such that requisite actuarial tables, payout and premium schedules, etc. could be created to support the development of a viable insurance product to support the transition to CRFM in California.

This snapshot assessment will provide a list of fisheries (and fishery portfolios) requiring a further in depth viability analysis. Critical next steps (beyond the scope of this first proposed analysis) include:

- Stakeholder engagement to refine viability assessment parameterization and provide realistic bounds on insurance product specifications (e.g. risk tolerance, premiums, payouts, etc.).
- The development of new mechanistic population models to expand consideration of environmental triggers beyond warming.

5. Timeline and Deliverables

Deliverable:

- Report on the feasibility of insuring fisheries including details on the key design factors. The report would include: a standardized methodology for assessing the viability and informing the design of insurance for a given fishery and objective and a rough cut analysis (described above) identifying which fisheries from a given set are best suited for the application of an insurance mechanism.

Timeline (12 month project):

- Complete viability assessment methodology *(3 months)*
- Conduct the feasibility analysis (for a predefined set of fisheries) *(7 months)*
- Report drafting and revisions *(2 months)*

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