4 Project Description

4.a Proposed Research

Introduction

In 2015, the West Coast California Current marine ecosystem experienced a marine heatwave (nicknamed "the blob") that caused major shifts in the phytoplankton and zooplankton communities at the base of the food web (Bond et al. 2015). The blob is believed to have triggered a coast-wide bloom of the diatom *Pseudo-nitzschia australis* that contaminated shellfish with high concentrations of the toxin domoic acid (DA), forcing closures or delays of shellfish fisheries up and down the West Coast (Du et al. 2016, Zhu et al. 2017). DA outbreaks often continue to impact benthic organisms long after the toxin-producing species have dissipated (Horner et al. 1993). The opening of the 2015-16 Dungeness crab season was delayed on the West Coast due to high DA concentrations in crab that persisted long after the bloom had ended. The delays were unprecedented in duration, lasting nearly five months in some regions of California.

The Dungeness crab fishery is the most valuable fishery on the US West Coast with gross revenues for California, Oregon, and Washington averaging over $200 million annually in recent years. It is also one of the largest fisheries in the region in terms of participants, with well over 1,000 permitted fishers. It is the primary source of income for many fishing households (Holland et al. 2019). The unusually long delay of the 2015-2016 Dungeness crab season in California led to a request for disaster assistance from the Governor of California based on an estimated $48.3 million in direct economic losses. When the fishery did open, catches (revenue) in California were only 52% (58%) of the average for the prior five years. A key point is that recent losses in the California fishery were not due to direct mortality of crab associated with the *P. australis* bloom; they arose from the delayed season start that was needed to ensure that contaminated crab was not sold and consumed by the public.

Toxic blooms of *P. australis* have been shown to be more likely and larger under warmer ocean conditions. The frequency, size, and intensity of harmful algal blooms along the West Coast is expected to increase in the future as ocean waters warm (McCabe et al. 2016, McMcKibben et al. 2017, Zhu et al. 2017, Trainer et al. 2020). There is concern that future delays could have more severe consequences due in part to new regulations that require closing the fishery in the spring to avoid whale interactions, which have become much more frequent in recent years (NOAA Fisheries 2019). For example, the California fishery is now required to close in mid-April, which is when the fishery finally opened in 2016.

Since 2016 there have been smaller and less persistent DA outbreaks leading to shorter closures and delays in Dungeness crab fisheries, including in-season closures in Oregon in 2017, 2018, and 2019. In response, Oregon implemented an area management scheme enabling area closures for part of the fishery. In addition, Oregon has introduced a new regulatory tool: evisceration orders requiring crab from areas with DA concentrations in crab viscera above 30 ppm to be landed and sold, provided that the crab is eviscerated before cooking and the meat concentrations are below 20 ppm. Oregon evisceration orders have so far been used only after in-season closures, rather than as an approach to avoid delaying the season. California and Washington have not allowed landing of crab under evisceration orders to date, but face an increasing need to develop mitigation options to address future HAB events.

4.a.i Topic to be Addressed

We propose to analyze the potential effects of alternative mitigation strategies for HAB impacts on the West Coast Dungeness crab fishery. Our primary focus is on regulatory approaches that are flexible and can increase opportunities for the industry amid HAB events while ensuring food safety for consumers. Allowing for the harvest and sale of eviscerated crab is one such mitigation policy. Since DA in crab tends to be concentrated in the viscera, primarily in the hepatopancreas, eviscerating crab before they are cooked and consumed can make contaminated crab safe to eat. In 2018 and 2019, Oregon initially closed some areas of the coast when elevated levels of DA were found in Dungeness crab during the season, but reopened areas under regulations requiring crab from these and surrounding areas to be eviscerated (personal communication from Transition Advisory Council (TAC) member Troy Buell (Oregon Department of Fish and Wildlife)).

Evisceration is not the only mitigation alternative. Domoic acid concentrations in crab viscera will decline over time if they are held in tanks and not fed, and even more quickly if they are fed uncontaminated food. In a controlled experiment Lund et al. (1997) found that DA concentration dropped 38% in 7 days for crabs that were fed uncontaminated razor clams, by 73% in 14 days, and by 89% in 21 days. Reductions for starved crabs were only 4% in seven days, but were 28% in 14 days, and 57% after 21 days. This suggests holding contaminated crabs in tanks and feeding them might be an effective strategy for mitigation. However this would require a potentially large investment in storage capacity and, importantly, a monitoring, testing, and chain of custody infrastructure to ensure contaminated crab are not sold to the public.

Both of these mitigation strategies may be more effective if combined with finer scale spatial management, particularly if HAB monitoring and forecasting tools, for example the California-Harmful Algae Risk Mapping Model (C-HARM) and Pacific Northwest HAB Bulletin, allow more timely and spatially-refined identification of areas of high and low toxin risk and smaller targeted closures. If concentrations of DA in crab are patchy, it may be possible to continue harvest and sale of whole crab from areas without high concentrations and limit the need to eviscerate or hold crab to areas with high concentrations. This could considerably reduce the resources and labor needed to employ these mitigation strategies; however, it also requires a system of monitoring, regulation, and tracking of harvested crab to ensure crab from areas with high DA concentrations are eviscerated before cooking or are held in tanks.

To determine whether state agencies and the industry should make the investments required to implement these mitigation options, a cost-benefit analysis (CBA) is necessary. Such an analysis must consider the costs of the mitigation itself (regulatory costs and actual costs of mitigation processes) as well as impacts it may have on value (e.g., if eviscerating crab reduces the market value of the crab). Additionally, mitigation strategies should be evaluated against plausible scenarios for future HAB events–including potential duration, spatial pattern, and scale of contamination–in order to bound potential gains this mitigation option would provide. Finally, in order to quantify the economic value of information (VOI) provided by HAB monitoring or forecasting capability, it is essential that modeling integrates mitigation strategies and existing fishery management policies with the economic structure of the industry.

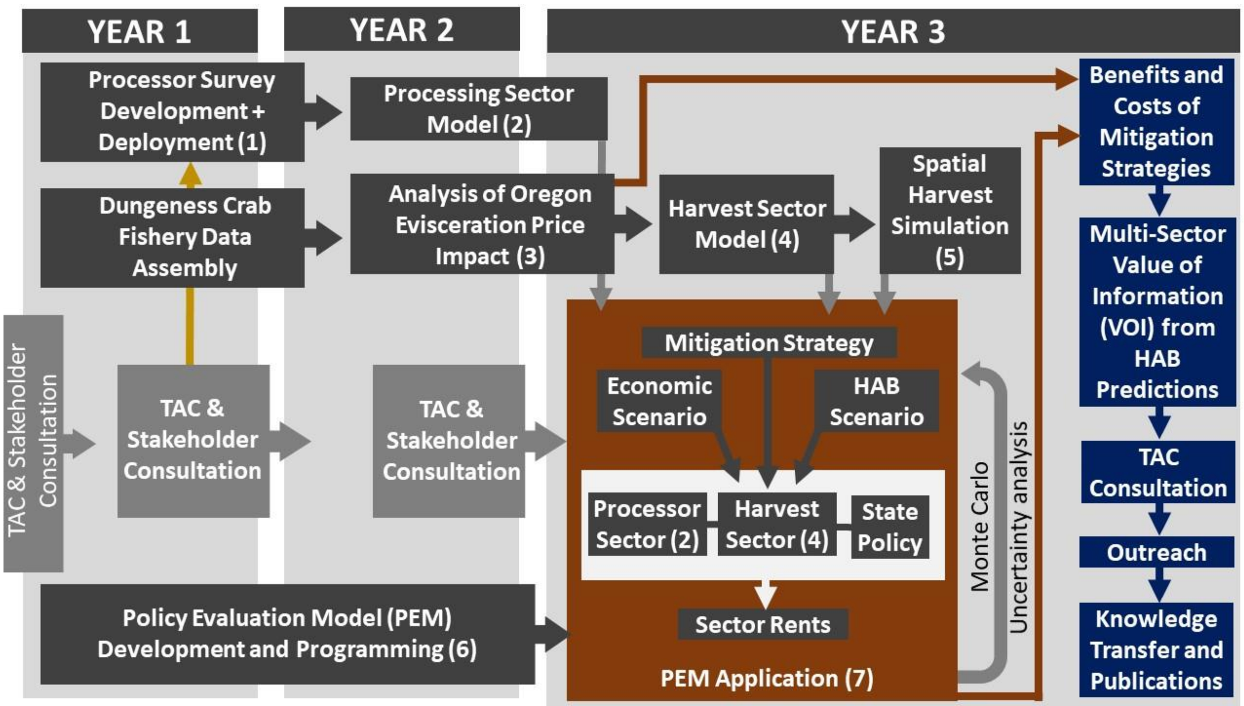

Figure 1: Diagram of workflow, deliverables, and outreach plans

4.a.ii Proposed Scientific Objectives and Research Activities

This proposed project has the following research and outreach objectives. These objectives and associated research activities are summarized in the diagram shown in Figure 1 above:

Objective 1: Develop a quantitative model that describes how input costs and Dungeness crab supply determine crab product form choice and profits generated by processors.

Objective 2: Develop an empirical model for how potential spatial fishing regulation and season timing associated with HAB mitigation strategies will impact fishing location choices, port choices, fishing profits, and the distribution of revenues across small and large vessels in the West Coast Dungeness fleet (the "harvest sector").

Objective 3: Construct a Policy Evaluation Model (PEM) that integrates the harvest sector and processor models, and use the PEM to evaluate the benefits and costs of mitigation strategies. Specifically, we will evaluate the following:

- West Coast-wide adoption of spatial management similar to the strategy implemented by Oregon following the 2016-17 season.
- Permitting crab to be landed with DA concentrations exceeding 20 ppm in the meat (30 ppm in viscera) with requirements to eviscerate crab before cooking (so that cooked meat tests below 20 ppm);
- Allowing landing of crab with DA concentrations exceeding 20 ppm in the meat with requirements to hold crab in tanks until DA had depurated to safe levels before sale.

Objective 4: Run scenario analysis with the PEM to understand how the value of information (VOI) provided by advanced knowledge or rapid within-season monitoring of HAB events and predictions of duration of events is determined by: i) mitigation and other fishery management policies; ii) industry economic structure; and iii) length, size, and duration of HAB-associated delay under status-quo management.

Objective 5: Work with TAC members to promote the use of research outputs in agency and industry decision making regarding mitigation strategies

Data Collection and Empirical Analysis

Economic impacts of Evisceration on Processor Profits and Fishing Revenue

We will measure the economic impacts of an evisceration policy. The potential benefits of allowing the Dungeness crab industry to eviscerate their crab during a HAB include decreasing variability in season start dates and increasing total harvest (e.g. the 15-16 HAB closures in California pushed the season back into a period of crab molting, leading to a decrease in total catch). However, eviscerating crab will prevent the industry from selling crab in high-value markets for live crab and other product forms. Therefore, it is important for the crab industry to understand the tradeoffs (benefits and costs) associated with an evisceration policy. We will examine the economic impacts of evisceration using two empirical modeling approaches.

First, we will develop a model of the product form decision for Dungeness crab processors, (*hereafter* the processing sector model) (**Deliverable 2**). The processing sector model will be estimated using primary data via an original processor survey (**Deliverable 1**). The processor survey will collect a plant's weekly product form choice and key predictor variables, i.e. key factors driving profits associated with various product forms. These key predictor variables will be identified in part with the help of our TAC and potentially include inputs to producing each product form (e.g. labor, equipment, materials), wholesale prices for each product form, and plant-level and firm-level inventories. We will organize focus groups, comprised of processing plant operators, who will take the survey and discuss their interpretation of each question and provide an explanation of their answers. Based on the feedback from the focus groups, we will finalize the survey instrument and distribute the survey in the summer of 2021. Our plan for close involvement of the TAC in designing and implementing the processor survey is emphasized with an orange vertical arrow shown in Fig. 1 (top left). We emphasize, however, that we plan to consult closely with the TAC on all planned deliverables.

In the 2016-17 fishing season, there were over 300 businesses that received Dungeness crab landings. Fig. 2 below shows the number of crab buyers in each landing port group area on the West Coast during the 2016-17 fishing season. However, a small number of buyers comprise the majority of landings, with 15, 10, and 18 firms purchasing over 80% of crab landed in California, Oregon, and Washington (respectively). We anticipate that our sample will be comprised of buyers landing over 80% of crab in each state during recent crab seasons.

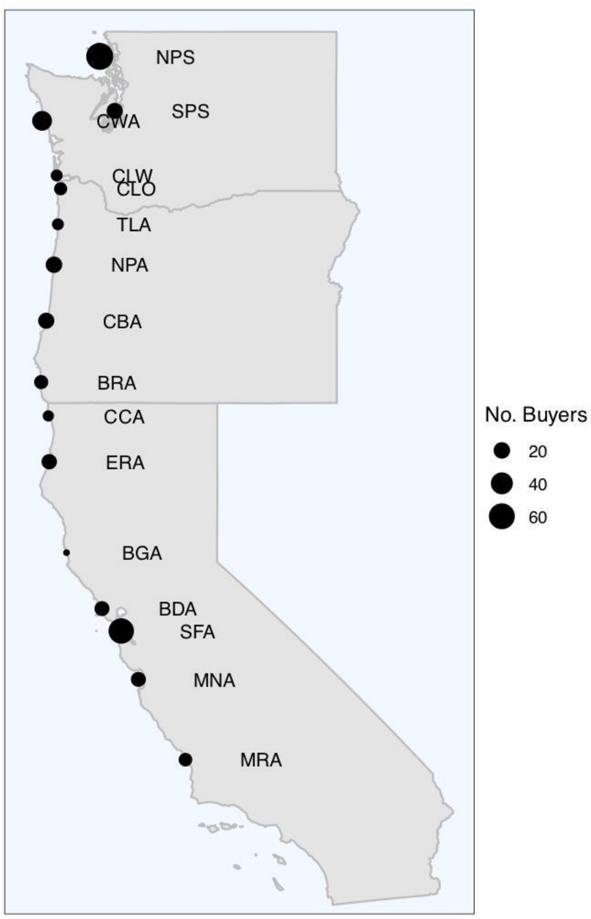

Figure 2: Dungeness crab buyers in the 2016-17 fishing season

Multiple efforts will be taken to maximize our response rates and quality of the data. First, we will leverage existing relationships with seafood firms to gain buy-in from large firms, which own multiple processing plants. Second, PIs will work to schedule the hand-delivery of the survey instrument before the start of the crab season. An in-person meeting with the survey participants will serve to explain the survey instrument and answer any questions the participant may have. Third, we will build flexibility into the data collection process to accept data in alternative forms. For example, participants may only be able to submit relevant raw data, requiring confidential data entry by research team members to complete the survey response. Fourth, participants will be provided a modest cash incentive for their participation.

Lastly, to add additional personnel support for the survey, PI Jardine will develop a capstone project and recruit 3-6 master's students, from the University of Washington's School of Marine and Environmental Affairs, to assist with implementing the survey and processing and analyzing survey data. Capstone projects meet degree requirements for a Master's in Marine

Affairs, in lieu of a traditional thesis, and offer students to work on important real-world problems while gaining professional skills and growing their professional networks. A prior SMEA capstone project on the socioeconomics of harmful algal blooms has resulted in two publications (Ritzman et al. 2018, Moore et al. 2019). These students will supplement PI and PI-supervised graduate student effort dedicated to the survey, spanning all three West Coast states.

Collected survey data will be used to estimate a random utility model (RUM) of product form choice at the plant level. The basic premise of the model is that plant managers choose to process crab into the product form that maximizes their profits. The model can be estimated using a multinomial logistic regression with proportions by product form as the dependent variable and determinants of profits associated with each product form as the independent variables. Model estimates can be used to simulate the impact to processor profits associated with restricting the product form choice (i.e., due to evisceration orders).

Second, we will use the 2017-18 and 2018-19 Oregon fishing seasons as a "natural experiment" to better understand the impact of evisceration on prices received at the dock by fishers (ex-vessel prices). During these years certain areas of the fishery were temporarily closed after the season had begun when testing found crabs with excessive DA concentrations. Areas were allowed to reopen under evisceration orders which required crab landed from these areas to be eviscerated before cooking. This required new reporting systems and chain of custody requirements to ensure crab from these areas was properly handled. Using data on areas with and without the evisceration order in place, before and after the evisceration order, we will be able to measure the impact of evisceration on ex-vessel prices using a differences-in-differences identification strategy (e.g., Jardine et al. 2014), similar to the before-after-control-impact (BACI) design frequently applied in the natural sciences (**Deliverable 3**).

Impacts of spatial management and evisceration orders on fishery outcomes

To measure the impacts of spatial management and evisceration orders on fishing location choices, fishing profits, and the distribution of revenues across small and large vessels, we will estimate a standard model of fishing location choice for Oregon and Washington, hereafter the "harvest sector model" (**Deliverable 4**). Data inputs to the harvest sector model will come from several sources including: fish tickets, which contain information on landings, revenue, port of landing, and a general approximation of fishing location; vessel registration data, which include information on vessel characteristics such as length and engine power; and logbook data that reveals fishing locations for crab vessels; and vessel monitoring system (VMS) data. We will use a statistical modeling framework, known as random utility model (RUM), which assumes harvesters make location choices to maximize their expected profits. We will also assume that participation in a fishery is a multi-level decision process with fishing region or not participating at the first stage and area choice within a large region as the second decision point (Holland and Sutinen 2000). This decision-making framework lends itself to be estimated using a standard nested multinomial logit econometric model. Expected profits will be modeled with predictor variables that account for revenues in past periods (e.g., through a time-weighted

rolling average of revenues in a fishery-region-area) and predictors approximating expected costs such as distance from home port and ocean conditions.
Using the estimated RUM model, we can explore the impact of evisceration orders on fishing location choices, fishing profits, fishing exit strategies, and distributional outcomes (**Deliverable 5**). These simulations will be conducted by implementing changes in expected revenues consistent with effects of evisceration orders on ex-vessel prices. The nested multinomial logit model can also be used in policy simulations that explore the impact of fine-scale HAB closures on fishing location choices, fishing profits, and distributional outcomes in the Dungeness crab fishery. Similar simulations have been conducted to examine the impacts of fisheries closures from MPAs (Smith and Wilen 2003) and wind farms, which effectively create MPAs (Kirkpatrick et al. 2017).

Due to the limited available data for the fishery in California (primarily, the lack of logbook data), initial development of the harvest sector model will focus on fleet behavior in Oregon and Washington. Available data (e.g., fish tickets) will be collected for California, and will permit some insights into port choice and landings patterns. Below we discuss our strategy for including California in our model of harvest sector behavior as a component of the policy evaluation model.

Policy Evaluation Model

The data collection, analysis, and modeling discussed above will inform the development of an integrated stochastic simulation model (hereinafter the Policy Evaluation Model, or PEM) (**Deliverable 6**). The PEM will be used to evaluate the potential economic outcomes of implementing mitigation policies given future HAB events that lead to DA contamination of Dungeness crab. This will be an integrated model of management, explicitly linking processing and harvest sectors to simulate choices and outcomes in each sector and calculate performance metrics for alternative mitigation strategies (Figure 1, at lower right). This model will be used to carry out a cost-benefit analysis of alternative policies as well as provide other policy performance metrics. Performance metrics include the net revenues (“rents”) generated for each sector (harvest and processing sectors, by state), and also other indicators of performance such as the variation and distribution of net revenues realized under different mitigation strategies and the management costs associated with implementing these policies. Information on management costs will be obtained from state agencies in consultation with relevant TAC members. Similarly, estimates of handling and capital costs associated with holding crab to allow depuration will be obtained from industry stakeholders and public sources.

The PEM will integrate sub-models of the processing and harvest sectors in each state. The processing sector model simulates the product form choice of processors and consequently the supply and wholesale value of products produced as well as the costs of production and storage. The processor sector model will be based on predicted behavior of representative large and small processors in each state.

Harvest sector sub-model will simulate the supply of crab landings over time and space in response to regulations, mitigation options, and prices. The model will quantify harvester net revenues (ex-vessel revenues less variable costs) as well as the quantity of crab caught and landed by area, and also track requirements for crab handling (e.g., if it must be held or eviscerated). The harvest sector model will rely on empirical vessel-level models estimated for Deliverable 4. Best available data will be used to parameterize the sub-model component representing the California fishery. In particular, parameter estimates determining fleet spatial behavior in Oregon and Washing (derived from the empirical harvest sector model described above) will be used to augment the California sub-model such that behavior is consistent with observed data (e.g., California landings patterns revealed by fish tickets).

The PEM will be similar in structure to the management strategy evaluation framework developed by Wang and Anderson (2018) to model responses to escapement policies in Bristol Bay sockeye fishery. As in that study, we will tune our product choice model based on annual production data, our processor survey, and expert advice from our industry TAC members. The simulation model will also incorporate variability in terms of biological and economic processes (crab recruitment and distribution and HABs). Stock assessments for the Dungeness crab fishery are unavailable, so rather than maintaining an explicit spatial-dynamic crab population model we will follow recent empirical harvest sector studies by simulating the distribution and magnitude of crab yield consistent with the empirical distribution from past landings (Davis et al. 2017). By running thousands of stochastic simulations with different scenarios and random variation in parameters and processes, we will generate a distribution of possible outcomes that capture how Dungeness fishery prospects may vary across different (and possibly coinciding) biological and economic scenarios (a so-called Monte Carlo analysis).

Once the components described above are in place, the PEM will be applied to assess the properties of different mitigation strategies outlined under Objective 3 (**Deliverable 7**). The PEM will also be the basis for quantifying the potential value of information (VOI) provided by HAB forecasting or monitoring tools (Objective 4). The question posed in this analysis will be: under what circumstances will better knowledge of HAB events generate the greatest value (or largest loss reduction) through either responsive policy or adaptive industry behavior?

Constructing realistic scenarios that accurately represent the state of knowledge about the likely frequency, duration, strength, spatial distribution of future DA contamination events is critical for quantifying the value of mitigation strategies. In particular, an understanding of how DA moves through the food web and persists in it following a *P. Australis* bloom is essential. Working with HAB experts (unfunded collaborators Kathi Lefebvre and Stephanie Moore, both with NOAA), we will draw on past HAB events and results from existing HAB monitoring and forecasting programs (e.g. California-Harmful Algae Risk Mapping Model (C-HARM) and Pacific Northwest HAB Bulletin) to construct plausible future HAB events (described by duration, extent, and distribution of delays under status quo policy). We will explore how the most cost-effective choice of mitigation strategy is influenced by several factors, including: expectations of the duration of the toxicity event; and the intensity of the toxicity which may limit sales of more valuable whole crab. Another consideration is that there may be a substantial capital investment involved in undertaking these mitigation strategies (e.g., large holding tanks), meaning that they entail a multi-year commitment.

4.a.iii Value of Proposed Research to Program Goals

This project directly addresses the HAB Socioeconomic Objective to "...assess the social and economic costs of HAB events as well as the costs and benefits of prevention, control, and mitigation efforts". As requested in the Notice of Federal Funding (FFO), this project will help "resource management and public health agencies, affected sectors and communities, and biophysical scientists to develop and implement coordinated, effective responses to HAB events at local and regional scales". Our attention to both the harvest and processor sectors reflects current recommendations for socioeconomic research on HABs, for example a call made in the HARR-HD report to "...to fully characterize the implications of each potential management approach [...] includ[ing] the economic effects on different sectors of the economy" (Bauer et al. 2006, p. 13).

Table 1: Summary of PI Function

Deliverable (#) or Function	PI				
	Holland	Jardine	Kling (Lead)	Sanchirico	Sylvia
(1) Processor Survey	Support	Co-Lead	Co-Lead	Co-Lead	Co-Lead
(2) Processing Sector Model	Co-Lead	Co-Lead	Co-Lead	Support	Support
(3) Evisceration Impact Study	Support	Lead	Support	Support	Support
(4) Harvest Sector Model	Co-Lead	Co-Lead	Support	Co-Lead	Support
(5) Spatial Harvest Simulation	Co-Lead	Co-Lead	Support	Co-Lead	Support
(6) PEM Development	Co-Lead	Support	Co-Lead	Co-Lead	Support
(7) PEM Application and VOI Analysis	Co-Lead	Support	Co-Lead	Co-Lead	Co-Lead
TAC Meetings	Co-Lead	Support	Co-Lead	Support	Support
Outreach	Support	Co-Lead	Co-Lead	Support	Co-Lead
Supervise graduate student?		✓	✓	✓	

4.a.iv Function of PIs

PI functions are summarized in Table 1 above. The PI team will leverage individual strengths and institutional capacities while allowing PIs to contribute to multiple deliverables. It is anticipated that each PI will at a minimum support production of every deliverable by providing research assistance and feedback. For example, graduate students from either OSU or UC Davis (supervised by Kling and Sanchirico, respectively) will assist PI Jardine on Dungeness crab fishery data assimilation and production of Deliverables 4 and 5. Jardine, Kling, and Sanchirico will lead processor survey (Deliverable 1) deployment in their respective states. Lead PI Kling will be responsible for communicating with the Federal Program Manager.

Our unfunded NOAA collaborators Kathi Lefebvre and Stephanie Moore will provide expertise on monitoring and prediction systems, toxin uptake, depuration, movement through marine food webs, and specification of plausible HAB scenarios for integration into the PEM. Our proposal includes letters of collaboration from Lefebvre and Moore. Lastly, an OSU-based project manager (anticipated to be Laurie Houston) will assist with coordination of the TAC, organization of PI and TAC meetings, processor survey administration, and outreach.

4.b Application to Management

This project is directly focused on management measures and production responses that could be implemented by state agencies and industry in the event of future HAB events that lead to costly closures of the Dungeness crab fishery. We will undertake a rigorous but practical CBA of policies that have been piloted in Oregon, as well as additional mitigation measures. While these policies may succeed in partially and safely opening crab fishing, it is as yet unclear whether they will necessarily increase the value generated by the fishery relative to the traditional approach of simply delaying opening. Mitigation will be costly to implement; it will typically require new monitoring and reporting systems, additional processing and storage costs, and potential loss of flexibility of product forms. On the other hand, these costs may be smaller than those posed by more frequent emergency measures like long season delays and the associated costs and uncertainty borne by the industry. Our proposed research can help clarify whether it is worthwhile to implement policies and industry investments that enable these mitigation strategies to be used. In addition, our analysis will help decision makers determine *whether* and *when* to invoke mitigation strategies at their disposal (e.g., allow openings of some areas under evisceration or holding orders) when future DA outbreaks occur.

4.b.i Coordination with Management Agencies

In coordination with the Oregon Department of Fish and Wildlife (ODFW), research funds will be committed to support trained data entry technicians to increase the coverage of Dungeness crab logbook data in critical years. Currently in some years only a share (e.g., 30%) of logbook data is randomly sampled and entered into a useable electronic form from the returned raw logbooks. ODFW is currently committing available data entry resources to increase the coverage of the data only in the most recent years, and so older logbooks that are crucial for our purposes are unlikely to otherwise be entered (personal communication from Troy Buell (ODFW)). More complete data within crucial windows is important for obtaining more accurate results from our planned econometric analysis of Oregon-based fleet behavior.

We have also included on our TAC individuals from the state agencies in California, Oregon, and Washington responsible for implementing management responses to DA in the Dungeness crab fisheries (Table 2 below). This includes staff from state fish and wildlife agencies responsible for managing the Dungeness crab fisheries, and staff from the health departments (Agriculture in the case of Oregon) responsible for ensuring biotoxins from seafood do not enter the food supply.

4.b.ii Significance of Project to Management Priorities and Needs

California recently faced an unprecedented 5 month delay in the Dungeness crab fishery that results in an estimated loss of $43 million in income as the result of a large-scale *P. australis* bloom. The economic impacts were likely due to a combination of lost harvest and lower prices. Mao and Jardine (2020) estimate that the 2015-16 HAB event reduced ex-vessel prices by 22%-23%. Economic impacts of the delay likely spread beyond the crab fishery since fishers had to choose between crabbing and other fisheries they would normally have participated in during late spring and summer. The prospect of increasingly frequent, large, and prolonged HABs in future–and the need to limit crab seasons to avoid whale entanglements–creates an urgent need to have mitigation strategies ready to implement in the event of future HAB events. This project will provide state agencies and industry with the information necessary to determine what mitigation strategies are likely to be effective and provide the greatest benefits. That information will be disseminated to and through our TAC, who are in key positions to influence what strategies are implemented (see below).

Additionally, there is substantial interest in quantifying the value of new HAB information tools, such as forecasts and rapid within-season monitoring programs. From an economic standpoint, the VOI provided by these programs connected to the Dungeness fishery depends on the economic structure of the industry and management choices (including mitigation). The PEM we are proposing will provide the first multi-sector empirical platform (to the best of our knowledge) for understanding the circumstances when HAB information and mitigation strategy can work synergistically to preserve economic value in the fishery during severe HAB events.

We note here that this proposed project is related to another proposed project entitled "Value of the Pacific Northwest HAB Forecast" (Di Jin, Lead PI). If both proposals are funded, we plan to coordinate and collaborate with Jin's team in developing scenarios that incorporate the Pacific Northwest HAB forecasts to determine how the value of mitigation strategies (e.g., loss reductions) is impacted by the quality of HAB monitoring and forecasts.

4.b.iii Outreach Activities

We intend to publish papers based on our deliverables in peer-reviewed economics and marine science journals, and also write articles for outlets accessible to the general public (e.g., OSU's *Terra* magazine). However, the near-term practical impact of the proposed work depends on state agencies or industry stakeholders using our analysis in their decision making regarding

HAB mitigation. As described below, our TAC includes individuals in key positions in state fishery and health agencies responsible for managing responses to HABs, as well as stakeholders from the processing and harvest sectors (Table 2). We expect that our TAC will play an important role in disseminating information from our research to their colleagues and the stakeholders with whom they interact.

We also plan to hold a large workshop in Seattle, WA toward the end of the project that will involve the TAC, additional stakeholders, and opportunities for in-person and remote participation by interested members of the public (including other researchers and students). This workshop will provide a forum to assess the acceptance and understanding of the results and develop more effective ways to communicate them through web-based and written media such as fact sheets and infographics. We have also included travel funds for outreach and consultation with stakeholders not currently on the TAC. For example, we intend to present our research goals and preliminary findings to the Oregon Dungeness Crab Commission. Lastly, Lead PI Kling will work with OSU communications staff to establish a website for the general public that will describe the project and provide regular updates on research progress and findings.

Table 2: Anticipated Transition Advisory Committee (TAC) membership

Name	Job Title	Affiliation
Dan Ayres	Coastal Shellfish Manager	Washington Department of Fish and Wildlife
Jerry Borchert	Marine Biotoxin Lead	Washington Department of Fish and Wildlife
Troy Buell	State Fishery Manager	Oregon Department of Fish and Wildlife
Christy Juhasz	Environmental Scientist	California Department of Fish and Wildlife
Dan Obradovich	General Manager, Processing Sales/Key Accounts	Pacific Seafood Group
Mike Okoniewski	Senior Advisor, Processing Operations & Fisheries Policy & Management	Pacific Seafood Group
Noah Oppenheim	Executive Director	Pacific Coast Federation of Fishermen's Associations
John Sackton	President	Seafood Datasearch
Beckye Stanton	Staff Toxicologist	California Environmental Protection Agency
Isaak Stapleton	Director of Food Safety & Animal Health	Oregon Department of Agriculture

4.b.iv TAC Structure and Activities

To ensure that the policies and industry responses evaluated are realistic, and to facilitate uptake of results by stakeholders, we seek active participation from state agencies and industry during development, implementation, and dissemination of the research. We have formed a

Transition Advisory Committee that includes stakeholders from state agencies in California, Oregon, and Washington responsible for implementing management responses to DA in the Dungeness crab fisheries (Table 2 above). It is clear that our proposed research will be of higher quality given access to data and expertise from both regulator and industry stakeholders. We also expect that research outputs will be more likely to support decision making if stakeholders are consulted and provide input into certain aspects of research design (e.g., processor survey development, or scenarios and assumptions evaluated with the PEM). Accordingly, we have reached out to stakeholders (including representatives from a firm responsible for a high volume of crab processing), and received TAC membership confirmation letters that typically affirm openness to our research goals. While we do not offer these letters as designated Letters of Support (due to space constraints), following FFO instructions we include with the proposal package TAC letters from (or written on behalf of) each member listed in Table 2.

The TAC will be regularly informed of progress on the research and will also be convened at least once per year during the project in Seattle, WA. This will include an initial meeting early in the project to develop the specifics of the mitigation policies that will be explored and the methods and data used to evaluate them. The second meeting will provide an opportunity to review preliminary analysis and review the models and data that have been developed. As described above, the final meeting will be a workshop in which results of the research will be presented and ground-truthed, and strategies for dissemination of research and possible implementation of policies will be co-developed with TAC members.

4.c Data Management Plan

Our data management plan will adhere to best practices identified in the Government OPEN Data Act principles as well as Oregon State University policy. Lead PI Kling will have responsibility for overseeing, coordinating, and implementing the data management plan. PIs co-leading work on specific deliverables (see Table 1 above) will have responsibility for implementing the data management plan for products associated with the deliverable. Kling and OSU will be the data owners and will be responsible for long-term archiving of all data and code produced during the project, all of which will be stored on secure cloud-based storage services provided by OSU. Confidentiality of stakeholders Personally Identifiable Information (PII) and Business Identifiable Information (BII) will be guaranteed according to NOAA’s provisions and OSU’s standards for social science research.

<u>Data Management during the Project</u>

Co-PIs will utilize a controlled access Google Drive folder maintained by OSU to store and share collated data and model output. Fishery data obtained from state agencies will be handled in accordance with agency-specific security policies. Data access will be subject to strict protocols and any necessary non-disclosure agreements will be signed and filed. Handling of processor survey response data will adhere to OSU Human Research Protection Program (HRPP) guidance for data security and confidentiality.

Metadata will meet NOAA's metadata preparation guidelines.

Source code (e.g. Matlab, R, or Python) used to produce the Policy Evaluation Model (PEM) will be posted to GitHub, along with documentation and guidance on code usage including complete parameter definitions and valid input ranges.

Long-Term Data Management after the Project

Near the end of the project, PI Kling will organize and store all data and will retain a copy of the final datasets, code, metadata, and original survey instrument responses in a controlled access Google Drive folder maintained by OSU over the expected lifecycle of the data. Final PEM model code will be archived on GitHub. Funds have been budgeted to seek publication of project results in peer-reviewed, open access journals.

Note on Letters of Support

We are including two letters of support with our proposal: one from the Oregon Department of Fish and Wildlife, and another from the West Coast Seafood Processors Association.