HABs, Crabs, and Whales Working Group: a collaboration between TNC CA, NOAA Fisheries, & SFG

**Background and Objectives**

Climate-driven ocean changes are posing critical threats to California fisheries, which provide food, jobs, and recreation for hundreds of thousands of people across California. Recent impacts include economic losses from delayed fishing seasons and closures, human health impacts from consuming toxic animals, novel fishery interactions with threatened and endangered species, significantly altered fishing grounds creating permitting and other social challenges, and increased bycatch of non-target species and protected marine mammals. Addressing these threats and ensuring fisheries can meet the dual objectives of providing for nature and people requires testing of new management models that account for climate-driven impacts.

TNC, NOAA Fisheries, and UCSB are undertaking a collaborative research program to develop a framework for designing and implementing ‘climate-ready’ management solutions in priority fisheries along the west coast, starting with the Dungeness crab fishery. The Dungeness crab fishery has significant economic value, but its stock status has not been formally assessed. Furthermore, there are large uncertainties surrounding the Dungeness fishery’s sensitivity and exposure to impacts associated with climate change, as well as its impacts on protected marine mammals due to entanglements. The shared goal of the effort is to improve our understanding of the emerging threats to and from the Dungeness crab fishery, with a focus on domoic acid contamination and whale entanglements, and identify actionable opportunities to confer greater economic and ecological resilience to the fishery.

*TNC CA and SFG*

TNC and SFG are working together to develop a management strategy evaluation (MSE) that seeks, through simulation, to identify and better understand the different types of management strategies that will maximize ecological and economic outcomes for the CA Dungeness crab fishery, while minimizing public health and whale entanglement risks. **We are specifically interested in understanding how different management strategies perform, given potentially interacting threats facing the fishery now and in the future.** To this end, our primary question is: how can we design management strategies for the CA Dungeness crab fishery that consider multiple threats and account for our uncertainty about future climate change impacts? We will consider voluntary and non-voluntary management strategies that explicitly account for the spatial and temporal dynamics of the fishery and its climate-related threats.

We propose using a two-pronged MSE approach. Our approach will employ both a retrospective MSE that simulates performance of potential management strategies over recent historical domoic acid and whale entanglement risk (2014-present), and a forecast MSE that simulates fishery performance given risk that could be experienced under climate change. Each MSE is comprised of three components: (1) a population dynamics model (i.e. an age- and sex-structured population model that operates on weekly timesteps at the level of individual fishing blocks); (2) a risk model (i.e. risk of both domoic acid contamination and whale entanglement); and (3) a management model that will consider current management procedures and alternative management options (e.g., increasing the spatial and temporal resolution of viscera sampling, evisceration orders, etc.). In both the retrospective and forecast analyses, the objective is to characterize uncertainty and identify management strategies that maximize catch and profits while minimizing catch variability, public health risk, whale entanglement risk, costs of management, and management complexity.

The results from this work can not only inform future fishery management decisions, but also serve as a model for how to address complex climate effects in other California fisheries and adapt to a changing ocean.

*NOAA Fisheries*

Jameal to add a new updated timeline

The NOAA Risk Assessment Integration for Mitigating Bycatch of Whales (‘RAIMBOW’) team has developed a road map for research intended to inform both fisheries and protected species management along the full US West Coast. This road map consists of the following components: (1) whale distribution modeling (initial focus: humpback and blue whales), (2) analysis of spatiotemporal dynamics of trap- and pot-based fisheries (Dungeness crab, spot prawn, sablefish, California spiny lobster), (3) risk assessment for humpback whales due to Dungeness crab fishery under alternative management scenarios, (4) tradeoff analysis considering risk to humpback and blue whales as well as risk to Dungeness crab fishery under alternative management scenarios, (5) development of a fleet dynamics model for the Dungeness crab fishery based on behavioral, economic, and environmental variables, and (6) a management strategy evaluation considering shifts in whale and Dungeness crab fishery distributions in relation to alternative climate and management scenarios. The RAIMBOW team has also worked closely with Jarrod Santora to develop an understanding of how environmental conditions alter distributions of forage species, and how those changes affect risk of whale entanglement.

The tradeoff assessment (4) is a hindcast retrospective analysis that answers what would have happened had certain alternative management decisions been made. It relies on fish ticket data, fishing vessel VMS data, logbook data (OR and WA only), the most up-to-date versions of Elizabeth Becker’s and Karin Forney’s species distribution model for humpback whales, and Briana Abrahm’s and Elliott Hazen’s species distribution model for blue whales. This is a coastwide project (CA, OR, and WA), but it will be largely driven by fishery and whale dynamics in California. The RAIMBOW team plans to conduct a coastwide (CA, OR, WA) Dungeness crab fishery MSE with Owen Liu (postdoc), but that work has not yet begun. This coastwide MSE could explore the ecological and economic impacts of scaling the optimal California management plan to Oregon and Washington, as well as effects of shocks to the Dungeness crab fishery on the broader social-ecological system (including participation in other fisheries [e.g, groundfish] and ecological impacts of shifting participation as well as climatic influences). It could also focus more specifically on climate influences and management interventions in OR, WA, and/or all 3 West Coast states.

**Coordinating Efforts**

Differences between the TNC/SFG and NOAA workstreams can be coordinated such that both are complementary and synergistic.

The primary goal of the TNC/SFG effort is to understand the interactions between the various threats facing the CA Dungeness crab fishery, the impact that climate change and future uncertainty will have on the fishery, and how to use this information to improve management. To this end, we will use a short-term retrospective simulation to acquire key insights about the performance of various management strategies given recently experienced conditions. The simulation will use weekly and monthly binned data to model population dynamics given catch and effort, threats (humpback whale entanglement risk, domoic acid contamination risk), and various management interventions in order to optimize ecological and economic outcomes. We will use these insights to guide a forecast simulation that will predict the future performance of the fishery under alternative management strategies and given future uncertainty about climate conditions and associated threats.

The NOAA NWFSC effort is a targeted approach to understand entanglement risk to protected species on the West Coast and evaluate how alternative management interventions have affected and will affect fisheries and fishing communities. Model data will be at a higher spatial and temporal resolution for both fishery dynamics and whale migration (for both humpback and blue whales), meaning the risk assessment will be able to address fine-scale retrospective questions about maintaining a sustainable fishery while minimizing whale entanglements under alternative management scenarios. NOAA will also try to design a model that can provide closer to real-time information about risk, and as such will investigate how data resolution affects the efficacy of short-term forecasts and management advice. The NOAA effort can also add new coastwide insights by developing an understanding of how management in CA might impact Dungeness fisheries in OR and WA under coordinated and uncoordinated implementation strategies, as well as assessing how coastwide coordination of management interventions may influence whales, fisheries, and fishing communities.

Ultimately, aligning the messages from these two bodies of work will be highly valuable for informing both fishery and risk management decisions. One clear avenue for doing so will include comparison of model results, and consideration of using model ensembles to inform fisheries managers.

**TNC-SFG-NOAA Collaborative Working Group**

To strengthen our collaborative relationships and ensure complementary bodies of work between TNC, SFG, and NOAA, we will hold an in-person meeting in TBD in the Fall of 2019. The goal will be to present analysis updates, identify and strengthen nodes of synergy, align workstreams under an integrated and common message, and identify opportunities to enhance impact such that the whole is greater than the sum of the parts. Potential topics of discussion will include data sharing, model integration (e.g., VMS-based vs. block-based analyses), future presentations in the Ocean Modeling Forum, products and future directions, etc.