FY22 Multi-stressor Program – Chan
Project Activities and Outputs Summary

Outcome: Multistressor-ready Dungeness crab fishery in the northern California Current Ecosystem (nCCE) that is sustained by a collaborative partnership among ocean users, managers, and researchers.

Outputs:

(1) Comprehensive synthesis products to empirically define multi-stressor exposure risks that are reflective of management and fishery priorities;

(2) Interpreted model findings that identify the future conditions of the Dungeness crab fishery and time horizons for disruptive changes as informed by biological vulnerability; and

(3) Integrate information on current and future stress exposure and species sensitivity in a management strategy evaluation, in consultation with end-users, to assess the effectiveness of management levers to bolster the multi-stressor readiness in the Dungeness crab fishery.

Objective 1: Construct a comprehensive synthesis of multi-stressor exposure in the nCCE.

Team: Observation Synthesis (PMEL - Feely, Alin, Carter; NANOOS – Newton; OSU – Barth, Kavanaugh; NCCOS – Trainer); NANOOS will bring its extensive ocean observing network; Trainer will liaise with the Olympic Region HAB and Tribal Marine Stewards Network

Activities:

Spatial Scale: intertidal to slope for Southern BC, WA, OR, and northern CA to 500 m depth.

Temporal Scale: upwelling season, sub seasonal to interannual, year to year changes.

- Characterize in situ multi-stressor exposure (OAH, MHWs, and HABs) and exposure duration using *existing* datasets.
    - Characterize carbon and oxygen dynamics from OCNMS monitoring data and calculate anthropogenic CO2 burden. (PMEL – Feely, Alin, Carter)
    - Synthesize glider and ship-based observations of ocean physics and DO (OSU – Barth)
    - Characterize dynamics of HABs in nCCE using data from flow cytobots, phytotoxins assays, and microscopy to support analyses of current and future HAB risk (OSU – Kavanaugh, NCCOS – Trainer)
- Collect new data using existing programs.
    - Tribal Marine Stewards Network (TMSN) will process HAB samples collected in Northern California as part of their ongoing monitoring efforts
    - Olympic Natural Resources Center (ONRC) will process HAB samples collected on the Olympic Coast as part of their ongoing monitoring efforts

Outputs:

- Maps of changing temperature, salinity, pH, O2, HAB risk, aragonite and calcite saturation, and anthropogenic contributions to carbonate chemistry changes.
- Estimates of the temporal and spatial scales of OAHT and HAB variability (coupling and de-coupling) including the extent and duration of exposure below critical thresholds of interest to identify spatial hot spots for multi-stressor exposure (and observational gaps), and to inform realistic biological studies (Objective 3)
- HAB – determine HAB risk, test for enhancement of DA production under OA and evaluate the strength of predictive functional response of HAB prevalence to ocean warming.
- Support model validation through the development of observational data products.
- NANOOS will make the data and visualization products available through their website.

Objective 2: Characterize the future dynamics and spatial footprint of multi-stressors.

Team: Downscaled Climate Modeling (UConn – Siedelecki; UW – MacCready; OSU – Kavanaugh) and Traditional Ecological Knowledge (OSU- Chisholm)

Activities:

Spatial Scale: OR, WA, Vancouver Island, and Salish Sea

Temporal Scale: downscale regional climate out from the present to 2100 using CMIP6

- Simulate marine conditions (including nutrients, phytoplankton, zooplankton, two size classes of detritus, carbonate chemistry, and oxygen) from 1992-2100 using CMIP6 and LiveOcean for SSP5-8.5 and SSP2-4.5 using the time varying delta method (Uconn – Siedelecki; with UW – MacCready as an unfunded collaborator)
- Using previously recorded and documented sources, and current ethnographic interviews of Tribal members – look at historical shellfish consumption, ceremonial use, and subsistence gathering and current uses. This will permit climate model projections to be interpreted in the context of changes in access to traditional tribal resources. (OSU – Chisholm)
- Define HAB exposure patterns using two machine learning algorithms – a probabilistic self-organizing map, and a hierarchical agglomerative clustering algorithm. (OSU-Kavanaugh)

Outputs:

Stress-scape

- Used data synthesized under Objective 1 to construct functional responses of *Pseudo-nitzschia* and DA to warming across environmental gradients in the nCCE through time. This product will serve to explicitly link changes in dominant drivers of HAB risks (e.g., marine heatwaves) as resolved by climate models to future changes in HAB exposure that impact the crab fishery.

Modeling

- Evaluate the model's ability to reproduce trends in multi-stressor exposure across varying time and space scales.
- Particle tracking information to inform in-situ multi-stressor exposure for planktonic organisms.

- Forecasts of multi-stressor exposure (including HABs using information from stress-scape studies) under varying emissions scenarios

TEK

- Illustrate the patterns of use, consumption, and phenological indicators which tribal communities have relied on and where changes have been occurring.
- Understanding of the tribal communities' reliance, collection, reductions, and noted changes in shellfish, ocean patterns, or conditions that tribal members have noticed over multiple generations.

Objective 3: Construct an integrated lab to field understanding of the biological impacts of multi-stressors.

Team: Biological Experiments (OSU – Bednarsek) and in situ zooplankton observations (OSU – Cowen, Sponaugle, Schmid)

Activities:

- Conduct focused biological experiments on Dungeness crab and krill (*E. pacifica*) to identify their sensitivity to realistic scenarios of current and future multi-stressor exposure (current (control), 2050 SSP2-4.5, 2100 SSP2-4.5, and 2100 SSP5-8.5). (OSU - Bednarsek)
    - Analyze tissue from 230 individuals for Dungeness crab and *E. pacifica* each for sub-acute responses, focusing on biomarkers and exoskeleton dissolution related to the stress response.
- Compare field-collected samples to lab experiment results. (OSU - Bednarsek)
    - Analyze tissue from 75 individuals for Dungeness crab and E. pacifica each for sub-acute responses, focusing on biomarkers and exoskeleton dissolution related to the stress response for comparisons to lab responses (OSU – Bednarsek).
- Develop and apply habitat suitability indices for Dungeness crab and krill. (OSU -Bednarsek, Schmid, Cowen, and Sponaugle)
    - Use OAHT and HAB data (objectives 1 and 3) to construct HSIs that take multi-stressors into account for Dungeness crab and krill.
    - Use multistressor experiment results (objective 3) to test and validate HSIs.
    - Use HSIs with model projections (from objective 2) of ocean conditions to explore how habitat suitability might evolve under future OAHT and HAB conditions.
        - Will use 50 samples each of Dungeness crab and krill collected from the WCOA21 cruises to test for DA accumulation across the major gradients of OAHT (OSU – Bednasek).
        - Using 2016-2021, ISIIS tows to characterize Dungeness crab zoea and megalopa and krill distribution with OAHT and oxygen minimum zone overlays. Also using the observational data from past 15 years collected under Objective 1. (OSU-Cowen and Sponaugle)

Outputs:

- Documented exposure (pH/DO/T) impacts over time for Dungeness crab and *E. pacifica*
- Understand and compared stress status to OAHT of organisms collected in situ to what is found in lab experiments.
- Pinpoint zoea and megalopa as well as krill with regards to their current distribution around OAHT features.

Objective 4: Conduct a management strategy evaluation to evaluate options for multi-stressor ready fishery management.

Team: (UCSB – Free; NWFSC - Oken, Richerson; OCNMS- Waddell) – Free brings MSE on Dungeness crab fishery experience, Richerson will bring Dungeness crab fishery dynamics experience; Oken brings fish dynamics assessment modeling; Waddell will provide guidance on translating science of multi-stressor risk into marine protected area management.

- Apply new developments in multi-stressor science learned under Objectives 1-3 to evaluate the ability of management options to continue to sustain fishery performance using a management strategy evaluation (MSE).
    - Extend previous population modeling of anticipated impacts of OAH and T on Dungeness crab populations to include impacts from HABs.
    - Hold a workshop to determine management strategies to assess
    - Build a spatial, age structured and climate linked operating model that will simulate and project changing oceanographic changes to simulate (1) crab population dynamics, (2) dynamics in effort of commercial and tribal fishing fleets; and (3) fishery management.
    - Climate-linked population dynamics model – model male crabs in 1 week age classes for 80 fishing seasons (2020-2100) under two climate scenarios.
    - Fleet dynamics model – model fleet dynamics where the start of the season varies as a function of HAB risk from climate model outputs
    - Use MSE to compare the performance of alternative strategies under two potential climate futures (SSP5-8.5 and SSP2-4.5).

Outputs

- Recommended fishery management actions under different scenarios.