NOAA OCEAN AND GREAT LAKES ACIDIFICATION RESEARCH PLAN 2020-2029

National Ocean and Great Lakes Acidification Research

Lead Authors: Emily Osborne & Libby Jewett (OAR/OAP)

MONITORING

ENVIRONMENTAL CHANGE

Expand and advance OA observing systems, technologies, and models to improve the understanding and predictive capability of OA trends and processes

Continually optimizing and expanding the configuration of observing assets (e.g. ship, mooring, autonomous instruments) is critical to understanding the variability driven by a myriad of processes and progression of acidification in the open ocean, coastal zones and Great Lakes. Maximizing usable observing data streams into model simulations is central to predicting the future of OA and informing management choices and decision makers.

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Enhance understanding and prediction of ecosystem response to OA as a factor co-occurring with multiple stressors

OA is occurring in a multi-stressor framework with other changing environmental parameters, which collectively influence the response of ecosystems to OA. Understanding the mechanisms that drive physiological responses will inform ecosystem-level predictions of future change.

Improve understanding of the biological response and adaptive capacity of ecologically and economically important species

The response of a number of economically and ecologically important marine and Great Lakes species to OA has yet to be examined. Assessing sensitivity as well as adaptation capacity is important to predicting ecosystem response and to developing mitigation and restoration plans.

Assessing the vulnerability of the U.S. Blue Economy to OA demands a transdisciplinary approach that simultaneously combines an understanding of how conditions are changing (*Environment*), how living marine resources respond to the changes (*Sensitivity*), and how such impacts affect dependent human communities (*Human Dimensions*).

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Increase research integration with vulnerable communities and stakeholders to generate useful data that supports adaptation and resilience plans

Integrating scientific knowledge into a socioeconomic framework is central to understanding the vulnerability of communities to OA. Integrated models and relevant research to develop such models should be framed and informed by the needs and concerns of stakeholders in order to create meaningful and actionable results that can be used for informed decision-making.

Open Ocean Region Acidification Research

Lead Author: Richard Feely (OAR/PMEL)

The open-ocean region refers to deep water regions that are found beyond the continental shelf break.

ENVIRONMENTAL CHANGE

Continue leadership and support for the GOA-ON

The GOA-ON provides a framework to knit together the many of ship-based hydrography, time-series moorings, floats and gliders with carbon system, pH and oxygen sensors, ecological surveys and associated biological responses. Support will assure continuation of the ongoing international observing programs, support augmentation of observation with key biological EOVs and encourage further development of novel platforms.

Separate natural and anthropogenic CO2 signal and elucidate feedbacks on seasonal to decadal scales

Quantifying the vertical and horizontal distributions, temporal variability and long-term trends of anthropogenic carbon will provide critical information for determining the biogenic responses of organisms and communities to ocean acidification.

BIOLOGICAL & ECOSYSTEM RESPONSE

Research impacts on lower trophic levels in oligotrophic waters

Biological and biogeochemical studies on hydrographic surveys can delineate biological responses to OA gradients across biogeographic province boundaries in the Open Ocean.

Research impact of OA on highly migratory species

Migratory species, including fishes, squids, and marine mammals are dependent on some OA-sensitive species as food. Analyses of species compositions and their food chains in situ and in lab experiments will help predict OA effects.

SATELLITE OBSERVATIONS FOR UNDERSTANDING OPEN OCEAN ACIDIFICATION

Derive global statistical or quasi-mechanistic algorithms to infer surface ocean carbonate dynamics and underlying biological processes to be acquired from remotely sensed data

Satellite observations can be used to determine surface ocean carbon distribution either directly or by synoptically scaling up discrete surface observations obtained from in situ observing assets.

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Alaska Region Ocean Acidification Research

Lead Author: Thomas Hurst (NMFS/AKFSC)

The Alaska Region includes the waters of the Gulf of Alaska, Eastern Bering Sea and surrounding the Aleutian Islands.

MONITORING

ENVIRONMENTAL CHANGE

Characterize seasonal cycles of OA and regional vulnerabilities

Species response studies rely on an understanding of the intensity, duration, and extent of OA exposure across organismal life cycles. Collecting the data to support the species and ecosystem sensitivity analyses requires the use of multiple observational tools that assess variability of ocean carbonate chemistry in both time and space.

Characterize future OA trajectories at local to regional spatial scales

Projections and forecasts from regional models help identify the future impacts of OA for commercial and subsistence fishing in Alaska over a broad spatial scale.

Develop a distributed, community-level coastal monitoring network

Alaska communities are distributed along a vast coastline, many of which are isolated from surrounding communities, accessible only by air or sea. The impacts of OA on many of these communities will result from the local impacts on subsistence harvest fisheries and community-level industries (e.g.,, aquaculture operations). However, current oceanographic models are not sufficiently resolved to predict the OA conditions in these highly variable coastal regions. Therefore, understanding and mitigating the localized impacts of OA will require localized monitoring at multiple sites along the Alaskan coastline.

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Characterize sensitivity and adaptive potential of critical resource species to OA and other stressors

Species response research should evaluate the multi-stressor impacts of OA combined with warming, hypoxia and other environmental variables.

Examine sensitivity of critical lower trophic level "bottleneck" species to OA

Improving the fundamental understanding of lower trophic level species that are critical to Alaska ecosystems to estimate the indirect impact on commercial and subsistence value species

Identify the ecosystem-wide impacts of OA

A better understanding of the multi-faceted impacts of OA across species groups and trophic levels will improve understanding of the cumulative effects on ecosystems and fisheries. This is critical to informing protection and management of fisheries, protected species, and ecosystems and to identify risk and scope adaptation measures.

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Assess OA sensitivity of critical nutritional and cultural resource

To more comprehensively understand the societal and cultural impacts of OA on Alaska communities, assessments of OA will be expanded to include sensitivities of critical nutritional and cultural resource species.

Improve assessment of socioeconomic impacts of OA on fisheries

Developing coupled social-ecological models that are community-specific will be important to evaluating the impacts on individual ports and the fishing fleets they support.

Arctic Region Ocean Acidification Research

Lead Author: Jessica Cross (OAR/PMEL)

The Arctic Region includes the broad continental shelf areas surrounding northern Alaska, including the Northern Bering, Chukchi and Beaufort seas.

ENVIRONMENTAL CHANGE

Targeted observations and process studies to increase understanding of OA dynamics and impacts

Given the limited number of Arctic observations in the historical record, time series and process studies can help resolve key unknowns in the Arctic carbonate cycle

Build high-resolution regional models able to simulate fine-scale OA processes

Limited infrastructure and harsh conditions can make a spatially extensive carbonate monitoring system in the Arctic impractical and cost-prohibitive. High-resolution regional models will provide a broader spatial and temporal context for observations.

BIOLOGICAL & ECOSYSTEM RESPONSE

Conduct laboratory studies of OA impacts in economically and ecologically important species

In order to quantify the effects of OA on protected and managed species and the ecosystems on which they depend, it is imperative to initiate targeted, Arctic-specific laboratory and field acidification studies.

Conduct ecosystem-level studies

Characterize baseline physical and biological conditions, monitor changes in these ecosystem attributes, and perform process studies on key species in order to understand and predict ecosystem-level effects of OA.

Biological projection and forecast development

Models will be needed to integrate sensitivity studies and oceanic observations in order to predict effects of OA on Arctic species and ecosystems and to understand the impacts on, and guide the adaptation of, human communities.

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Support NOAA's contributions to U.S. Arctic fisheries management

NOAA should provide relevant OA products and data to fisheries management and conservation efforts in the Arctic. These products should be designed with managers and stakeholders in mind in order to maximize beneficial outcomes.

Assess regional adaptation strategies to OA coupled with environmental change

Many Arctic communities are already struggling with impacts to subsistence harvests. Most notably, reduced and destabilized sea ice is limiting access to large marine mammals for traditional subsistence hunting practices. Additional risks from OA could compound these stresses.

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West Coast Region Ocean Acidification Research

Lead Author: Shallin Busch (OAR/OAP, NMFS/NWFSC)

The West Coast Region includes the US coastal waters off of Washington, Oregon, and California including the continental shelf and inland seas.

MONITORING

ENVIRONMENTAL CHANGE

Improve characterization of OA parameters in subsurface environments that are critical habitats to commercially and ecologically important species

Better characterization of surface and subsurface carbonate chemistry conditions will improve understanding of the risk of species and ecosystems to OA and parameterization of models used to hindcast, describe current, and forecast conditions.

Enhance understanding of the relationships between biological systems and chemical conditions, including effective indicators of change for various habitats

Tracking biological response to OA, other long-term secular ocean changes, unusual environmental events including temperature anomalies, HABs, and mass mortality events underlies the reason for developing integrated monitoring efforts, which can help tease out environmental drivers and identify cause and effect of unusual events.

Advance analytical tools that can better describe ocean conditions in the past, present, and future

Model development is critical to providing skillful estimates of environmental conditions at daily to decadal time scales and beyond. Development of past-to-future, high-resolution West Coast ocean models should continue in order to provide decision support at relevant time scales for managers of West Coast sanctuaries, Essential Fish Habitat, deep-sea coral and sponge habitats, and shellfish and finfish species.

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Understand species sensitivity to OA and characterize underlying mechanisms

Species sensitivity studies yield information that underpins our understanding of the potential impacts of OA on human and natural systems.

Investigate the potential for species to acclimate and/or adapt to ocean acidification

Studies that target information on species acclimation and acclimatization (i.e.,, recovery of function by individuals with prolonged exposure) or adaptation (i.e.,, genetic and epigenetic changes within a population or across populations) make possible long-term predictions for key ecologically and socio-economically important species.

Enable the detection of direct and indirect impacts of OA on managed species and ecosystems

While evidence from laboratory experiments indicates that many marine species are sensitive to OA conditions, limited understanding of how this sensitivity will influence populations or their distributions in the wild or alter food webs and ecosystems creates a critical gap in current research efforts and for sound resource management under changing ocean conditions.

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Improve understanding of the risks to sociocultural and economic well-being of fishing and coastal communities that are dependent on OA-sensitive species, and the associated social-economic drivers of OA vulnerability

Human vulnerability to OA can be direct or indirect through impacts to important species and ecosystems, and compounded by other (non-OA) social-ecological stressors that human communities may face. Communities and decision-makers require better information about social-ecological relationships and mechanisms of impact in order to anticipate and understand OA risks to people.

Improve understanding of adaptation strategies of fishing and coastal communities

Improved knowledge of how communities can reduce vulnerability, including the barriers and capacities for coping with and adapting to OA and cumulative stressors, is critical to developing policies, tools and strategies for mitigating socioeconomic risks (as outlined in Objective 5.7) and identifying management actions that may result in more resilient communities.

U.S. Pacific Islands Region Ocean Acidification Research

Lead Author: Hannah Barkley (NMFS/PIFSC)

The U.S. Pacific Islands region includes Hawaiʻi, Territories of American Samoa and Guam, Commonwealth of the Northern Marianas Islands, and U.S. Pacific Remote Island Areas and the pelagic waters that surround them.

MONITORING

ENVIRONMENTAL CHANGE

Continue monitoring and assessment of OA in coral reef ecosystems

Nearshore OA monitoring is essential for tracking temporal and spatial variability in carbonate chemistry and the progression of OA in highly sensitive coral reefs. When co-located with biological assessments and ecological surveys, long-term monitoring can offer an integrated ecosystem perspective of OA impacts on reef ecosystems and provide important baseline data for science-based management strategy.

Expand regional OA observing system to include pelagic and deep-sea environments

Establishing comprehensive OA monitoring programs in Pacific pelagic waters and insular mesophotic, subphotic, and deep sea environments will improve understanding of spatial and temporal carbonate chemistry variability and enable predictions of OA effects on pelagic and deep sea ecosystems.

Create real-time and forecast OA spatial products

Regional OA maps that leverage available physical and biogeochemical data sets and model output can provide predictive and actionable spatial products. These products can be used to assess OA risk, identify vulnerable species and communities, and advise decision making at spatial scales and time frames relevant to management planning and policy decisions.

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Assess direct OA impacts on key Pacific coral reef and pelagic species

Maintaining and expanding ecological monitoring, conducting laboratory perturbation experiments on understudied taxa, and synthesizing existing data to constrain the OA sensitivity of key species will improve our understanding of OA impacts on coral reef, pelagic, mesophotic, and deep-sea ecosystems.

Evaluate indirect effects of OA on fisheries and protected species

Pelagic and coastal fisheries and protected species (monk seals, sea turtles, and cetaceans) are regional research and management foci. However, robust OA impact evaluations do not currently exist for these species and populations. Determining the impacts of changes in carbonate chemistry on trophic interactions, essential habitats, and behavior will help project their vulnerability to OA and aid in the effective management of these resources.

Determine ecosystem-scale OA impacts

An ecosystem-scale integration of physical, chemical, biological, ecological, and socioeconomic data is required to determine the effects of OA and other stressors on coral reef and pelagic ecosystems, fisheries, and protected species and evaluate management strategies.

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Assess direct and indirect impacts of OA on Pacific communities

Coupling environmental and ecological dynamics (Research Objective 6.4) with human-use sectors and non-use values in ecosystem models will support assessment of OA impacts on marine resource-reliant industries and communities, including impacts to human well-being and ecosystem services.

Characterize community awareness and resilience to ocean acidification

Integrated assessments of trends in biological conditions, social perceptions, and community vulnerabilities are necessary to develop effective management strategies in Pacific Island communities.

Develop innovative OA science communication products for diverse stakeholders

Investments in OA adaptation and management strategies will require effective dissemination of the potential changes, threats, and impacts from future OA scenarios on environmental, biological, economic, and social systems.

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SE Atlantic and Gulf Region Ocean Acidification Research

Lead Author: Leticia Barbero (OAR/AOML)

The SE Atlantic and Gulf Region encompasses continental shelf waters extending from the North Carolina to Florida coasts on the Atlantic seaboard and the marginal sea bounded by the US Gulf Coast.

MONITORING

ENVIRONMENTAL CHANGE

Improve characterization of OA in important economic, cultural, and recreational regions

The GoM and Southeast Atlantic are particularly data poor in the near-shore region where most commercial and recreational fishing and tourist industry activities take place. These regions are also home to mangroves, marshes, and estuaries, which are essential habitats within the region's marine ecosystems, play an important role in local carbon balances, and provide a wealth of ecosystems services.

Improve the characterization of OA in the Open Ocean

Coastal OA can be studied by considering a conservative mixing line with a two end-member system: open-ocean and freshwater. Currently, Open Ocean monitoring is only done as part of the OA synoptic cruises, once every four years. Autonomous sensors provide a platform for increasing data availability in deep and shelf waters.

Improve fundamental understanding of regional processes and seasonal trends

Coastal areas in the region show different seasonal surface and sub-surface patterns, but there is little data available to validate model estimates of spatial patterns and seasonal trends.

Improve scaling and predictive capabilities

Models are a critical tool for extrapolating current observations to larger regions and to improve our mechanistic understanding of linkages between the physics, chemistry and biology of OA. The findings can be used to inform best management practices. Both continued use of existing and development of new models for the region are needed.

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Increase understanding of the impacts of OA on ecosystem productivity and food webs

Plankton communities are the base of marine food webs and shifts in response to OA impact energy flow and ecosystem function. As the quantity and quality of plankton prey are altered, managed and commercially important species are affected.

Identify indicator species for OA in the region

An indicator species that is sensitive to changes in pH specific for the GoM and for the Southeast Atlantic region can be used for early detection of OA impacts to the system and investigate ecosystem impacts that may result from changes in the food web.

Characterize sensitivity and adaptive potential of critical resource species to OA and other stressors and improve the understanding of OA impacts to HAB event frequency and duration

Most species of economic interest in the region (e.g., bluefin tuna, shrimp, blue crab) lack specific studies about potential OA impacts. The SEFSC vulnerability analysis mentioned above and Omics tools can be used as a screening tool to identify species of economic importance that are likely sensitive to OA. In addition to this, a growing body of research is addressing whether OA may have species-specific impacts on the frequency, duration and degree of HAB blooms or their toxicity in other regions of the U.S. Despite the prevalence of HABs, research focused on GoM and Southeast Atlantic environments and species with regards to OA is scarce.

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Improve assessment of socioeconomic impacts of OA on local tourism, recreational fishing, commercial fishing, and aquaculture (shellfish, fisheries) industries

To date, no socioeconomic studies have been conducted to quantify the impact OA might have on commercially relevant fisheries, aquaculture, tourism or recreational fishing in the region.

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FL Keys and Caribbean Ocean Acidification Research

Lead Author: Ian Enochs (OAR/AOML)

This region encompasses the FL Keys, coastal waters of south Florida, Puerto Rico, the US Virgin Islands and surrounding areas between the Gulf and Atlantic Ocean.

MONITORING

ENVIRONMENTAL CHANGE

Characterize spatial carbonate chemistry patterns

Considerable seawater CO_2 variability has been measured throughout the region and current monitoring efforts are likely limited in their ability to detect ecologically important patterns across spatial and temporal scales.

Characterize temporal carbonate chemistry patterns

Spatial gradients in carbonate chemistry can be dramatic, but are often linked to temporal variability driven by processes such as seasonally-enhanced seagrass productivity. Infrequent sampling may not detect these patterns.

Better understand ecosystems response to OA through paired monitoring of carbonate (and ancillary) chemistry and biological/community-scale metrics

Establishing causation between stressors and responses can be difficult and is complicated by the high variability of coastal CO2, diverse ecological interactions, as well as the subtle but steady progression of global OA. Regardless, real-world biological responses to OA are central to understanding how ecosystem services are presently and will be impacted.

Ecosystem modeling that integrates multiple functional groups

There is an urgent need to develop modeling tools to gauge present day reef state and forecast persistence in future OA conditions.

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Improve understanding of the responses of bioeroding communities

Understanding the responses of bioeroders to OA and co-occurring stressors is critically important for determining reef persistence, yet the relationship is poorly understood in the Caribbean.

Evaluate the influence of carbonate chemistry variability on ecosystem engineering taxa such as bioeroding and calcifying species

Further work is necessary to understand how real-world diel and seasonal fluctuations in carbonate chemistry influence ecological and economically important species.

Evaluate differences in OA-sensitivity within coral species and molecular mechanisms associated with OA resilience

An understanding of different genotypic responses to OA will lead to science-based restoration practices that incorporate the threat of OA.

Investigate the direct response of understudied ecosystems, as well as iconic, invasive, endangered, and commercially important species to OA

Ecosystems are chemically and biologically interconnected, and their persistence is therefore interdependent. The OA sensitivities of many ecologically, economically, and culturally important species remain relatively unknown.

Identification and investigation of natural high-CO_2 analogs

Naturally high CO_2 systems provide a means of investigating complex ecosystem-level responses to OA, where long-term exposure (decades to centuries) can reveal the implications of subtle responses, as well as acclimatization.

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Economic assessment of the impact of OA in region

To date, no socioeconomic studies have been conducted to quantify the impact OA might have on commercially relevant fisheries, aquaculture, tourism or recreational fishing in the region. By coupling ecosystem forecasts with economic valuations, OA impacts can be assessed, providing important information and projections to decision makes and lawmakers.

Interdisciplinary and integrated socio-ecological approaches

Spatially-explicit economic indicators and visual mapping tools are an effective means to clearly communicate risk.

Mid-Atlantic Region Ocean Acidification Research

Lead Author: Chris Kinkade (NOS/OCM)

The Mid-Atlantic Bight Region geographically includes the eastern U.S. continental shelf area extending from Cape Hatteras, NC to Cape Cod, MA.

MONITORING

ENVIRONMENTAL CHANGE

Expand regional ocean observing system to characterize seasonal to decadal OA variability in concert with other environmental parameters

The existing portfolio of OA capable observing assets in the region are sparse and/or are measured too infrequently to reliably describe all the dominant modes of variability needed to constrain and validate regional BGC models. Processes within the MAB Region (i.e.,, eutrophication, cold pools, upwelling) have implications for OA that are not well understood.

Simulate full-water column carbonate chemistry dynamics of shelf and primary estuarine systems

With the notable exception of periodic large-scale geochemical surveys most biogeochemical observations have been taken at the surface along the MAB. However, since most potentially impacted commercial species reside at depth or even at the benthos, it's important that modeling efforts seek to fully describe the system in 4-D and that such models include all major drivers of carbonate dynamics (e.g., OA, changes in currents, exchange with off shelf waters, etc.).

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Determine how OA and other multi-stressors impact ecologically and/or economically important marine species

OA in combination with eutrophication, increased temperature, and declining oxygen concentrations may be altering the habitat suitability for ecologically and/or economically important marine species at different times in their life histories.

Use experimental results to parameterize dynamic process models to evaluate within- and among-generation consequences of OA-impaired biological outcomes in populations

Develop more realistic, biologically informed models to capture population, community, and ecosystem responses to OA and environmental co-stressors thereby enabling population projections and servicing ecosystem based management strategies.

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Understand how OA will impact fish harvest, aquaculture and communities

Enhanced modeling and predictive capability of OA impacts to shellfish and fish populations can be linked to economic models that project outcomes for fishery sectors and communities. This information will be central to improving planning and management measures in the face of progressing OA.

Evaluate benefits and costs of mitigation and adaptation strategies

Understanding the costs and benefits of adaptation and mitigation strategies under different projected OA conditions will be vital to ensuring coastal community sustainability. Adaptation and mitigation practices should be tailored to the stakeholder (fishermen, shellfishermen, aquaculturists, recreational).

Integrate OA understanding into regional planning and management

Rapid changes in OA conditions will require management to react quickly to changes in harvestable species and consider OA in future planning.

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New England Region Ocean Acidification Research

Lead Author: Shannon Meseck (NMFS/NEFSC)

The New England Region geographically includes the Gulf of Maine, Georges Bank, and Scotian Shelf.

MONITORING

ENVIRONMENTAL CHANGE

Improve biogeochemical characterization of marine habitats most relevant to economically and/or ecologically important species inclusive of full life cycle (pelagic and benthic)

Leveraging existing datasets and supplementing the current Northeast observing system with additional subsurface capabilities through various activities will be critical to characterizing the less understood benthic and near bottom environment.

Better understand the trends, dynamics, and changes in Scotian Shelf, Gulf Stream, and major riverine source waters to the Region and their influence on OA conditions

Processes including advection, nutrient loading and riverine discharge have implications for OA in the New England Region carbonate chemistry conditions that are currently not well characterized. Recent changes in the relative supply of Gulf Stream waters have increased Gulf of Maine water temperature and altered the DIC supply to the system thereby altering its buffer capacity. Climate induced changes to the precipitation have altered the timing of the spring freshet each of which alters the timing and extent of corrosive river plumes extending out from river mouths into the Gulf.

Produce forecasts of changes in OA conditions in dynamic environments on daily, monthly, seasonal, and yearly time periods

As identified through numerous regional stakeholder and industry engagement forums including those initiated via the Northeast Coastal Acidification Network, there remains a need for predictive capability at time-scales not currently well addressed through existing models. These include forecasts of OA conditions for the region that align with the time frames of industry, management and business planning and decision making.

BIOLOGICAL RESPONSE

BIOLOGICAL & ECOSYSTEM RESPONSE

Identify critical (sensitive, predictive, and consequential) responses of selected keystone species to OA and multi-stressor conditions

OA progression will happen in concert with other environmental changes including warming ocean temperature, declining oxygen concentration, and nutrient loading. In order to fully appreciate the impact to marine organisms, a multi-stressor framework that evaluates multiple life stages is needed.

Characterize the adaptive capacity of species to OA & investigate potential mitigation patterns

Field and laboratory experiments focusing on species-specific responses to future warming and acidification are central to predicting ecosystem response. Such predictions are necessary for developing viable management strategies under changing ocean conditions.

Incorporate OA and other marine stressors into single species and ecosystem models to improve ecosystem management

Incorporating knowledge from multi-stressor and adaptive capacity research into existing regional ecosystem models will improve predictions of ecosystem responses for the New England Region.

HUMAN CONNECTIONS

SOCIO-ECONOMIC IMPACTS & ADAPTATION

Understand how OA will impact fish harvest, aquaculture and communities

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